W O R L D   M E T E O R O L O G I C A L   O R G A N I Z A T I O N
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EXECUTIVE COUNCIL PANEL OF EXPERTS
ON SATELLITES

GENEVA, 9-10 MARCH 1993

FINAL REPORT

1. FINAL REPORT

1.1 The EC Panel of Experts on Satellites (ECSAT) last met as a Panel on 16-20 March 1992 and recorded its findings and recommendations in the report of the Tenth Session of the Panel. In reporting to the Forty-third Executive Council in June, 1992, the Chairman of the Panel noted that most of the tasks assigned to the Panel had been completed and that those remaining would be completed during the following year and reported to the Forty-fourth Executive Council. A drafting committee meeting was held in Geneva, 9-10 March 1993 to compile the results of the efforts by the Panel during the last year in completing its work. This final report records the results of the Panel as compiled by the drafting committee. The final report has been approved by all Panel members via correspondence.

1.2 The Panel noted that there were three outstanding tasks: a Consolidated Report by the EC Panel of Experts on Satellites; a Strategy Document for Education and Training in Satellite Meteorology; and a Report by the Rapporteur on the Use of Satellite Data in WMO Programmes.

2. A CONSOLIDATED REPORT BY THE EC PANEL OF EXPERTS ON SATELLITES

2.1 The Consolidated Report of the EC Panel of Experts on Satellites summarizes the major findings and recommendations including top-level principles and new definitions proposed by the EC Panel during its time of existence (1974-1993) in which it conducted ten sessions. The Consolidated Report should act as a transition phase between the present satellites now operational and those expected to fly by the end of this decade. It would also carry the heritage of ECSAT to the new CBS Working Group on Satellites. It is anticipated that the primary user of this document will be satellite operators and other organizations outside the WMO structure who have a need to know the requirements of the WMO.

2.2 Although the ten sessions of the EC Panel of Experts on Satellites had discussed many and varied topics related to satellite matters, not all items considered by the Panel are included in the Consolidated Report. The main emphasis is on the **space segment** for which ECSAT had a major role and had considerable competence. For instance, education and training, data processing, assessment of the level of data use, publications, etc., also were extensively considered within ECSAT, and gave rise to specific initiatives, some still ongoing; but the resulting recommendations can be found in the various session reports from ECSAT. Education and Training has been dealt with separately and its recommendations can be found in section 3 of this Final Report.

2.3 The Consolidated Report of the EC Panel of Experts on Satellites can be found in Annex I.

2.4 Several open issues remain to be addressed by the CBS Working Group on Satellites including:

- The list of definitions found in the Consolidated Report require further refinement to more clearly distinguish the various operational and research components of the space-based sub-system of the GOS.

- The overall satellite system requirements implied in the top-level principles require further definition.

- There is a need to identify and further develop data management requirements for satellite data.

- Based on actions taken at EC-XLIV, the satellite operators represented at the Co-ordination Group for Meteorological Satellites (CGMS) have commenced serious discussion that should lead to global contingency planning for the space-base sub-system of the GOS. The discussions were partly in response to the WMO Requirements for Continuity of the space-based sub-system of the GOS adopted by EC-XLIV. Those discussions will continue and their results should also be incorporated into updates to the Consolidated Report.

- The WMO satellite data requirements are of necessity in a constantly evolving process due to the user/provider dialogue that has been established with the satellite operators represented by CEOS and CGMS. The dialogue will continue and consequently the WMO satellite data requirements will require updating.

- There is a need to develop requirements for satellite derived products as well as observations.

3. A STRATEGY FOR EDUCATION AND TRAINING IN SATELLITE MATTERS

3.1 At its tenth session, ECSAT studied ways and means to improve the use of satellite data through more effective education and training. ECSAT recommended to the forty-third session of EC that to improve education and training in satellite meteorology the concept of training of instructors at the RMTCs in order to provide "on-the-spot training" should be adopted. It further noted that if EC agreed with the concept, then ECSAT would develop a proposed strategy to implement the concept. EC supported the concept and requested ECSAT to develop an appropriate strategy document. ECSAT has developed a proposed Strategy for Education and Training in Satellite Meteorology that is intended for the use by both the various WMO mechanisms involved with developing, funding and implementing the Education and Training Programme and the satellite operators.

3.2 Annex II contains the proposed Strategy for Education and Training in Satellite Meteorology. The strategic goal contained in Annex II is to:

to systematically improve the use of satellite data for meteorological and hydrological applications over the next 10 years in all Member countries, with a focus on meeting the needs of the developing countries.

To achieve this goal, the three major strategic objectives are:

(i) To build on the existing infrastructure in a way which ensures that the time scale and manner in which initiatives for improving satellite data utilisation are introduced, are consistent with the capabilities of the users to absorb and sustain them independently in their own operational environment. Four key strategies for this objective are:

(a) integrate with the Education and Training Programme Long-term Plan 1992-2001;

(b) use the whole infrastructure;

(c) tailor training material to suit the infrastructure; and

(d) minimise costs and maximise cost-effectiveness.

(ii) To focus on the developing countries, directing particular attention to systematically improving the level of expertise of instructors at all RMTCs in the utilisation of satellite data. Eight key strategies for this objective are:

(a) establish specialized satellite training centres at six RMTCs. This will provide a minimum network, within the WMO's RMTC framework, of specialized satellite applications training centres ("centres of excellence") strategically located around the globe. This is the pivotal strategy for the entire strategic plan and the activities required to support it should have the **highest overall priority**. It provides a focal point for all the other strategies in the plan and a focal point for directing funding, co-operative programmes and other scarce resources to obtain maximum overall cost-effectiveness.

(b) improve the satellite application training capability of RMTC instructors;

(c) develop standard low cost satellite applications facilities for RMTCs;

(d) improve co-ordination between RMTCs and the training institutions of national meteorological and hydrological services;

(e) use satellite experts as consultants;

(f) implement a rolling programme of satellite training seminars;

(g) upgrade the satellite education and training curriculum; and

(h) that each satellite operator participating in the space-based sub-system of the GOS co-operate with at least one of the six specialized RMTCs with regard to the satellite training programme, facilities and expertise required.

(iii) To anticipate future trends in satellite data applications and in education and training techniques, so that new developments can flow through to operational users quickly and efficiently. Four key strategies for this objective are:

(a) Co-ordination with CEOS and CGMS on future satellite activities;

(b) Ensure training modules are developed for all new satellite programmes;

(c) Maintain an awareness of advances in communications and computer-aided learning techniques; and

(d) Focus on applications for atmospheric chemistry, the oceans and climate change.

3.3 Two crucial points to implement the proposed strategy are: the establishment of specialized satellite training centres at six RMTCs; and that each satellite operator participating in the space-based sub-system of the GOS co-operate with at least one of the six specialized RMTCs with regard to the satellite training programme, facilities and expertise required. These two factors would help provide a minimum network, within the WMO's RMTC framework, of specialized satellite applications training centres ("centres of excellence") strategically located around the globe and address the difficult task of improving the available resources through direct participation by satellite operators.

4. REPORT FROM THE RAPPORTEUR ON USE OF SATELLITE DATA IN WMO PROGRAMMES

4.1 The Rapporteur on the Use of Satellite Data in WMO Programmes prepared the report contained in Annex III. The purpose of his report is to provide EC with an assessment on the completeness of satellite data exploitation, to be used as an input for decision and interaction within relevant WMO mechanisms. His report contains sections describing; the use of imagery in operational meteorology; the use of imagery in operational hydrology, agriculture and coastal waters; the use of sounding data; the use of cloud-motion winds; the use of new satellite data types; the use of satellites in climate and environmental research; and recommended areas for further improvement in the use of satellite data within WMO Programmes. Each section identifies the current uses, its impact and deficiencies and problem areas.

4.2 Amongst the Rapporteur's major findings, he noted that:

- extensive use of satellite data was made within the WWW programme in operational meteorology. The limiting factors generally associated with the performance of the space segment were: gaps in the satellite coverage; that winds were only available from cloud motion; that there was poor resolution of present soundings, etc. It is expected that these deficiencies will disappear with the advent of the next generation of geostationary and near-polar-orbiting environmental satellites (near the year 2000);

- in other WMO programmes the level of achievement was variable, the best being in hydro-agrometeorology and global climatology, while the worst was in environment where requirements for satellite data are at an early stage of definition. One common denominator was the fact that many applications of satellite data ended when a published paper was published or with the report of a successful pilot project. However, the application never arrives for the "end user" to utilize operationally. Most published "users" of satellite data have been in the R & D community which handle the information and transform it into value-added products, whilst the "end-users" are generally not really involved and therefore do not benefit.

4.3 In order to improve the use of satellite data in WMO programmes (other than the WWW Programme), particularly in developing countries, it is recommended that:

- well designed pilot projects be promoted, involving the end-user from the onset since they will have to ensure the continuation of the

  activity if the pilot project is successful. Further awareness of pilot project results should be made to different communities involved in applications of the same data type;

- improved information services be developed to allow users, particularly from developing countries, to be able to assess existing information, know where it is located and how to access it. This is critical for most environmental applications. Data from different sensors or from more than one satellite can be combined with data from many ground-based systems with a Geographical Information System (GIS) to produce new products and applications.

- education and training should reach the true end-users instead of stopping atan intermediate level (often limited by the ability to speak foreign languages). Such training does not always propagate downwards. Databases of training events (to be made known through improved information sources), distribution of computerized training packages and assimilation of satellite-focused education and training within the framework of the current local education and training organization, should be considered.

4.4 With regard to education and training, the Rapporteur fully supported the concept and strategy described in Annex II with the expectation that such a strategy would greatly enhance the WMO's use of satellite data.

ANNEX I

W O R L D   M E T E O R O L O G I C A L   O R G A N I Z A T I O N
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EXECUTIVE COUNCIL PANEL OF EXPERTS
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CONSOLIDATED REPORT

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1. INTRODUCTION

This introductory chapter includes the following items:

- a historical background on the EC Panel of Experts on Satellites including its initial terms of reference and some achievements to date;

- a description of the purpose of this Consolidated Report;

- definitions relevant to environmental satellites;

- the reference scenario, both present and planned, of the space-based sub-system of the Global Observing System (GOS).

1.1 Historical background on the EC Panel of Experts on Satellites

The EC Panel of Experts on Satellites (ECSAT) was first established by the WMO Executive Committee at its 25th Session in 1973. The assigned terms of reference were (EC-XXV Res. 4):

- to maintain on a current basis a record of the plans of Members for satellite developments and operations, and to assist the Secretary-General in making this information available to Members;

- to analyze satellite plans with respect to all WMO programmes, making appropriate recommendations to the Executive Committee and the Secretary-General; co-ordinating as appropriate with relevant WMO constituent bodies;

- to act as a focus in WMO for the co-ordination of activities with relation to satellite matters, assisting other WMO bodies in identifying opportunities or problem areas presented by the development and application of satellite technology;

- to provide for programme co-ordination among satellite system managers, especially with respect to World Weather Watch, GARP, and other WMO programmes;

- to consider data requirements of Members, making this information available to managers of satellite systems in terms of satellite data output, standards, etc.;

- to consider the unique aspects of processing and dissemination of meteorological satellite data to meet the needs of Members.

During the existence of the Panel, it conducted 10 sessions, initially at yearly intervals, then less frequently due to financial reasons. The early sessions, in 1974 an 1975, focused on the objective of the growing awareness of WMO Member States on the existence of operationally oriented satellite programmes and the potential of space technology in all fields of WMO interest. Major achievements where the publications of loose-leaf fundamental documents, such as:

- WMO Publication No. 411 "Information on Meteorological and other Environmental Satellites" which is still being used and regularly up-dated;

- Information papers on application of data from meteorological satellites;

- Information on the application of meteorological satellite data in routine operations and research: abstracts, annual summaries and bibliographies which have become the present:

- "Application of satellite technology: annual progress report", issued annually with 1991 being the last one published to date.

Technical notes on:

- "Guide on meteorological direct broadcast system",

- "Quantitative meteorological data from satellites",

- "The use of satellite imagery in tropical cyclone analysis"

and the conceptual document:

- "The role of satellites in WMO programmes in the 1980's"

All of the above can be considered as major achievements that greatly contributed to the distribution of necessary information throughout the international meteorological community and promoted applications and knowledge transfer concerning applications.

The 3rd (1977) and 4th sessions of the Panel (1978) were dominated by the need to appropriately prepare for the best possible exploitation of the global satellite observing system being implemented for the First GARP Global Experiment (FGGE). ECSAT continued to monitor the progress in implementing basic satellite-related documentation and increased the focus on the education and training aspects by promoting a large number of seminars and symposia in each WMO Region. The Panel helped establish requirements for satellite data under the various WMO programmes and referred them for further refinement to the various Technical Commissions.

The 5th (1980), 6th (1983) and 7th (1985) sessions of the Panel, whilst continuing to up-date and expand the satellite-related documentation and to monitor and promote education and training events, were dominated by the remaining problems after FGGE, i.e. to co-ordinate the various systems which entered into operation on the occasion of FGGE (1979), to grow the overall system capability by adding new elements, preferably in a co-ordinated way and, as a first priority to ensure the continuity of a basic satellite global observing system, derived from FGGE as an essential component of GOS. The work of assessing satellite data requirements as stated by the various WMO constituent bodies was continued, and the emerging requirements from the newly-established World Climate Programme were considered. Following an ECSAT-6 recommendation, an Expert Meeting was convened in March 1985 aimed at consolidating the satellite data requirements for WMO programmes. The very difficult task of prioritizing requirements and identifying operational needs and perspective or research needs was undertaken by ECSAT-7.

The long time gap between the 7th and the 8th Sessions was such that the subsequent series of sessions (8th in 1989, and 9th in 1991) almost had to start anew on a number of agenda items. The most urgent need was to allow WMO to have a strong voice which could impact the planning of new space systems to be flown starting at the end of the decade to replace and possibly upgrade the present systems. Strong competition for resources had to be faced between the requirement to maintain at the present level of services, and accommodate increasing requirements for the global change issue. A major achievement of ECSAT-8 was to establish a top-level statement on satellite requirements for operational meteorology which without any ambiguity states the priority of continuing the present system, the desire of improving it by certain developments of proved feasibility, and the indications of interest for a number of technological developments for the long-term future. ECSAT-8 recommended changing the terminology "meteorological satellite" to "environmental observation satellite", and a number of revised or new definitions were proposed for the GOS Manual. The problem of improving cost-effectiveness of environmental observation satellites had become extremely stringent because of increasing financial restrictions. It was decided to critically monitor and assess the level of use of satellite data in meteorology and other environmental applications, and also review the achievements and possibly promote new approaches in the field of education and training. Finally, the degree of awareness in satellite matters was found now so mature that the proposal was put forward to transfer responsibility for satellite matters to the Commission for Basic Systems.

The 10th, and last, session of ECSAT (1992) was in fact a joint meeting with the incoming CBS Working Group on Satellites. The aim was to conclude the previous ECSAT activities and pass to CBS as many consolidated findings as possible. Besides confirming and complementing previous findings, a special effort was made in the field of defining WMO contingency planning for use by satellite operators. Also, a top-level statement on satellite data requirements was developed. The concept of this Consolidated Report was adopted as a document to summarize the main results of ECSAT's work during the last 20 years and to constitute a background for the future work of the CBS Working Group on Satellites.

1.2 Purpose of the Consolidated Report

This document attempts to summarize the major findings achieved by ECSAT during its time of existence (1974-1992). Although the ten sessions of the EC Panel of Experts on Satellites had discussed many and varied topics related to satellite matters, not all items considered by the Panel are included in the Consolidated Report. The main emphasis is on the **space segment** for which ECSAT had a major role and had considerable competence. For instance, education and training, data processing, assessment of level of data use, publications, etc., also were extensively considered within ECSAT, and gave rise to specific initiatives, some still running; but their results can be found in other sections of the final report. This Consolidated Report includes top-level principles which need, of necessity, to be periodically reviewed but are unlikely to change frequently. In Section 1.4 of this chapter, a reference scenario of the space-based sub-system of GOS is presented.

It should be mentioned that this Consolidated Report incorporates relevant findings that were originally developed in other fora (particularly the International Polar Orbiting Meteorological Satellites (IPOMS), and the Co-ordination Group for Meteorological Satellites (CGMS) and thereafter endorsed and assimilated by ECSAT. Additional technical information on the space segment was also derived from the Committee for Earth Observations Satellites (CEOS).

It is felt that, with the exception of Section 1.4, which may need more frequent up-dating, this Consolidated Report should remain a useful reference for the rest of this decade

1.3 Definitions relevant to environmental observation satellites

In responding to the synergism amongst various space instruments, the cost-effectiveness of multi-mission platforms and of the multi-disciplinary approaches, as well as the increasing interest of WMO in operational meteorology and climate and environment, ECSAT recommended new definitions and revisions to parts of the GOS Manual which referred to satellites. These new or reviewed definition are:

- Environmental observation satellites: an artificial Earth satellite providing data on the Earth system which are of benefit to WMO programmes.[1]

- Operational satellite: one of a series of environmental observation satellites with the primary purpose to routinely provide observations and services to a consistent standard over a long period. Resources are committed to ensure continuity of services thus permitting the establishment of a reliable satellite replacement policy.
- Experimental satellite: an environmental observation satellite with the primary purpose of acquiring a defined set of research data; testing new instrumentation and/or improving existing sensors and satellite systems; and/or it may provide information for operational use, but has limitations due to a lack of a commitment to ensure continuity of service or a reliable satellite replacement policy; and also due to non-consistent modes of operations.

- Geostationary satellite: a type of environmental observation satellite orbiting in the Earth's equatorial plane at the altitude of approximately 36,000 km and with the angular velocity of the Earth, thus providing nearly continuous environmental information in an area within a range of about 65 degrees from the sub-satellite point at the Equator.

- Near-polar-orbiting satellite: a type of environmental observation satellite with nearly circular, nearly polar orbit. The combination of satellite motion and the Earth's rotation beneath the orbit enables the collection of overlapping strips of satellite data (swaths up to 3,000 km wide) from pole to pole. The satellite's altitude or inclination defining the orbit may be selected in such a way to be sun-synchronous and provide global coverage. Sun-synchronous implies that the satellite will pass over a given geographic position at the same local sun-time each day.

- Global Observing System: the co-ordinated system of methods and facilities for making meteorological and other environmental observations on a global scale in support of all WMO programmes, particularly the World Weather Watch and the World Climate Programme; the system is comprised of operationally reliable surface-based and space-based sub-systems. The objective is to assure continuity of service.

- Space-based sub-system: a major component of the Global Observing System composed primarily of environmental observation satellites in near-polar and geostationary orbits.

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[1] These data support a variety of disciplines including but not limited to meteorology, hydrology, climatology, oceanography, climate and global change related disciplines.

- Satellite operator: an entity (Member of WMO or international organization) that manages, and/or operates environmental observation satellites which are of benefit to WMO programmes.

- Direct-broadcast service: a broadcast service, provided by some operational environmental observation satellites, that transmits satellite sensor data and products in real-time for reception by ground stations within radio range of the satellite.

- Satellite data requirements: those data specified as performance goals for an operational environmental observation satellite system. At a minimum, environmental observation satellite data requirements are defined in terms of spatial, spectral and temporal resolution, geographic extent, timeliness, and measurement and location accuracy [2].

- Satellite communication services requirements: requirements for services using environmental observation satellites including, but not limited to, direct broadcast of data, radio relay of environmental data collected by automatic sensor platforms, and search and rescue transmissions.

1.4 Reference space-based sub-system of the Global Observing System

The space-based sub-system of the Global Observing System is a constellation of environmental observation satellites provided by a variety of satellite operators and driven by different requirements, some operational, some scientific or technological. Any space platform equipped with proper instruments and providing reasonable data access may be of interest to WMO. However, a distinction must be made between those satellite operators contributing to the system, which comply with all or most of the conditions as specified in chapter 2 of this report and those satellite operators contributing only partly to it (e.g. a commitment to long-term continuity).

This distinction might appear arbitrary and therefore updates are expected to this section due to the natural evolution of objectives of programmes.

1.4.1 *Geostationary satellites*

The overall WMO requirement is for five satellites that cover the equatorial belt at a roughly spaced interval of 72 degrees.

With this, the baseline service is provided by the following systems, which are committed for long-term continuity:

- 0E : METEOSAT is presently operated by ESA on behalf of EUMETSAT. The system is committed up to the year 2000, and will be directly operated by EUMETSAT by the end of 1995. The prototype of METEOSAT 2nd Generation (MSG) will be developed jointly by ESA and EUMETSAT, launched in the year 2000 and be flown

[2] These data requirements are routinely reviewed to identify common needs in order to consolidate the design of the satellite's instrument payload, and to identify requirements that could be met more effectively either by surface- or space-based observing systems.

by EUMETSAT up to the year 2012.

- 75E W and 135E W: GOES is operated by NOAA. A new series, GOES-Next, will start operations in 1994 and be used up to the year 2005.

- 140E E: GMS is operated by Japan. The next flight model will be improved, and there is a long-term commitment by Japan to continue and improve the system.

- 74E E: INSAT is operated by India. The system has recently been up-graded and is planned to be continued through the decade. Real-time data availability outside India is not allowed because of the communication features of this system mainly devoted to domestic telecommunications.

To provide for optimal services for operational meteorology, a dedicated satellite, GOMS, is near ready for launch by the Russian Federation and will be placed at 76E E. Another meteorological satellite, FY-2, is being developed by China for a launch in the mid-1990's and placed near 105E E.

1.4.2 *Near-polar-orbiting satellites*

The WMO requirements for observations from near-polar-orbiting satellites are different depending on the prevailing objective (meteorology, hydrology, climate, etc.). At system level, the most stringent requirements are those for operational meteorology, as they cannot tolerate interruptions of continuity, and require more frequent observations. Operational meteorology requires at least four coverages per day, which can be achieved with two platforms at an appropriate altitude, one in the morning/evening orbit (called a.m.), the other in the afternoon/night one (called p.m.). The required and minimum missions are: multi-purpose visible and infrared imagery, atmospheric sounding, and direct read-out.

Given this understanding, the baseline service is provided by the following systems.

- In the p.m. orbit, the NOAA series operated by NOAA. The system will be upgraded, particularly with regard to the sounding mission, in 1995, and will be totally updated in 2001 with NOAA O, P, Q to be flown out to the year 2010.

- In the a.m. orbit, NOAA will continue to provide the service up to the year 2000. At that time it will be replaced by the European series METOP, developed jointly by ESA and EUMETSAT and exploited up to the year 2010.

- The METEOR series in both a.m. and p.m. orbits is operated by the Russian Federation and upgraded on a step-by-step basis. The next up-grading is foreseen before the middle end of the decade where full high resolution direct read-out service (HRPT) is anticipated.

This baseline system is complemented by many other systems which are extremely valuable, particularly for applications other than operational meteorology, for all WMO programmes. The following list includes those satellite programmes which are characterized by a certain degree of continuity, even if confirmed on a step-by-step basis.

- The ERS series of ESA satellites is mainly devoted to pre-operational demonstration of advanced technologies, particularly for ocean, ice and land observation. The next upgrading will focus on ozone and atmospheric chemistry. The continuation of the system after 1998 is entrusted to a new series named

ENVISAT, a multi-mission concept oriented towards climate and environment process study.

- The present USA/NASA programme is based on a number of single missions (UARS for upper atmosphere research; TOPEX/POSEIDON, in co-operation with France, for ocean altimetry; LAGEOS, in co-operation with Italy, for Solid Earth; TRMM, in co-operation with Japan, for tropical rainfall from a low-inclination orbit; SeaStar for ocean colour; TOMS/Earth Probe for ozone). The EOS programme will start in 1998 and is planned to continue up to the year 2010 with a number of missions oriented toward climate and environment monitoring and study while also developing advanced instrumentation to be handed to NOAA for operational continuation.

- MOS and JERS are a Japanese series of satellites oriented towards ocean monitoring, and also for land observation. The ADEOS system (first flight in 1996), will complement the ESA and NASA efforts (ENVISAT and EOS) in climate and environment monitoring and study.

- Though originally developed for commercial purposes in the field of earth resources exploration and management, the LANDSAT and SPOT systems, managed by the USA and France respectively, have become increasingly important for a number of WMO programmes, particularly in their hydrological and agricultural aspects. The value of high resolution land observation for the International Geosphere and Biosphere Programme (IGBP) is emerging. India also has started an earth resources programme (IRS) that is intended to have a follow-on through the decade.

Other initiatives to be mentioned, but not yet mature enough to be included in the list of long-term committed programmes, are the Chinese FY-1 for meteorology, the Brazilian MECB for data collection, the Canadian RADARSAT for multi-purpose SAR imagery, and the Russian Federation OKEAN for ocean and RESURS for land observations.

1.4.3 *References for further information*

Information on the systems mentioned in the previous sections is spread across a number of documents. Perhaps the most comprehensive are the following:

- WMO Publication No. 411, mainly focused on the system more relevant to operational meteorology, and generally reporting current or near-term-planned activities;

- CEOS Dossier of Satellite Missions and Global Environmental Programmes, Volume I, reporting information on satellites for many different environmental disciplines and including plans up to year 2010.

However, more details on the above-mentioned systems (Sections 1.4.1 and 1.4.2) can be found in the Annex.

2. OVERALL SYSTEM REQUIREMENTS

This chapter consolidates the ECSAT findings concerning the overall system requirements for the space-based sub-system of the GOS. It is important to note that most of the statements reported in the chapter refer mainly to the baseline system and more generally to the other systems of WMO interest. The chapter includes:

- system requirements for near-polar-orbiting satellites;
- system requirements for geostationary satellites;
- contingency planning.

2.1 System requirements for near-polar orbiting satellites

Requirements are stated for the general configuration, the expected observations, the orbital parameters, the data circulation and the data management of the baseline system.

2.1.1 *System configuration principles*

The baseline system in near-polar orbit must comply with the following general principles:

- The number of satellites in orbit must be sufficient to provide four global coverages per day for instruments with horizon-to-horizon scanning. This should typically require one satellite in ante- meridian (a.m.) orbit and one in post-meridian (p.m.) orbit.

- Continuity of observation is required. The availability figure of having at least one satellite in orbit, either a.m. or p.m., must be 99%. This converts to a figure of 90% for each of the satellites. Redundancy of instruments, satellites, launch schedules and rapid call-up for replacement launches should be matched to achieve this objective.

- The missions for determination of the availability figures are the imagery and sounding missions, including sub-systems necessary to collect and process their data on the ground.

- The capacity of the future satellite platforms should be substantially enhanced in comparison with the present, in order to accommodate prototype-operational instruments. This would allow easier transition from experimental to operational use of the instruments.
- Direct broadcast should be ensured for the benefit of local processing, when required (e.g. nowcasting), and other real-time applications.

- Provision of global data acquisition must be ensured without gaps (blind orbits) in the global coverage and that the data must reach the users in a timely manner.

- Primary mission instruments on each satellite should be as similar as possible if not identical, and other instruments used for operational meteorology should be compatible.

- If satellites are supplied by different agencies, they must have: (1) compatible payload interfaces, and (2) compatible data transmission standards for direct broadcasting of common or compatible formats.

2.1.2 *Required capabilities from near-polar-orbiting satellites*

Near-polar-orbiting satellites are expected to provide the following capabilities (1) information useful to derive parameters, and (2) telecommunication services, as specified below:

A On the surface and the Planetary Boundary Layer (PBL):

- Air pressure
- Winds in the PBL
- Atmospheric instability
- Height of the PBL
- Sea-surface temperature
- Sea state: wave height and spectrum
- Sea level, currents, fronts, eddies
- Sea salinity
- Land temperature
- Large scale soil moisture
- Large scale vegetation index
- Ice and snow characteristics
- Precipitation rate and accumulated rainfall.

A Observations in the free atmosphere:

- Temperature profile
- Wind profile
- Humidity profile
- Liquid water, total and profile
- Height of the tropopause
- Aerosol load and profile
- Ozone and other trace gases, total and profile
- Clouds: coverage, brightness, top height, ice/liquid.

A Climate related information:

- Most of the parameters listed above
- Radiation budget
- Relevant sun/earth interactions.

A Telecommunication functions:

- Global acquisition of the total volume of data
- Broadcasting of data to local users in real-time
- Data collection and location
- Support to the Search and Rescue mission.

2.1.3 *Orbital requirements*

The optimal altitude is determined by the need to ensure global coverage for the sounding mission under acceptable viewing conditions. This results in a minimum altitude of at least 900 km. Because of technical and cost constrains, lower altitudes could be considered, but not to the limit of drastically reducing the number of acquisitions at local read-out stations in low latitudes. Therefore, orbital heights should not be lower than 820 km.

A fixed repeat cycle of the orbit, though having some operational advantage, might create biases or gaps in the coverage from instruments with limited swaths. Having regard to the instruments so far proposed, it is required that there be no cycles or sub-cycles shorter than 5 days.

The orbital height and inclination must be such as to ensure sun-synchronous observation. The local solar time (LST) at the equatorial crossing in ascending mode must be selected in such a way as to ensure good observation of convection in the early morning and early afternoon (5 and 15 LST), and to approach the main synoptic hours (00 and 12 UT) when viewing the Eastern Atlantic and the Eastern Pacific oceans for better use in NWP for Europe and America. This corresponds to 10 LST for Europe and 13 LST for America. The optimal compromise is 09 to 10 hours LST for the a.m. orbit and 13 to 14 hours LST for the p.m. orbit. As a further condition, a minimum time difference of 4 hours between a.m. and p.m. orbits must be allowed to prevent simultaneous presence of the two satellites in the acquisition range of a single station.

2.1.4 *Data circulation requirements*

Global data coverage must be provided for the benefit of the WMO World Meteorological Centres and a number of other centres engaged in NWP. Availability of global data is required without gaps in coverage or time. For NWP applications, data are required no later than 2 hours after the observation has been made by the instrument. This may well be achieved by on-board storage and successive transmission when in view of Command and Data Acquisition stations, or by using Data Relay Satellites, or by a combination of the two systems which ensures bypassing the restrictions inherent in each of these systems. For practical or financial reasons, a selection of data to be acquired globally could be necessary. This should include at least all data needed for NWP in full resolution, and all the others needed for climate and environmental applications if possible in full resolution or at least in some compressed form.

Direct broadcast should be for the benefit of local processing, when required (e.g. nowcasting), and other real-time applications. Frequencies, modulations, formats and orbital de-phasing between the a.m. and p.m. satellites must be as such to allow a particular user to acquire data from either satellite by a single antenna and signal processing hardware. Continued use of existing equipment, as much as possible, is highly desirable. This implies the continued use of the frequency bands (S-band and VHF) presently assigned to space-to-ground transmission of meteorological data. If a particular instrument of interest for meteorology and operational hydrology is flown on a platform not equipped with S-band or VHF transmitters for direct broadcast, then its data should be available in real-time at least in X-band.

Direct broadcast must be provided in two types of data streams to serve the different needs of the various user groups as follows:

- a high-data-rate stream such as the present HRPT and its planned evolution to provide large and medium-size meteorological centres with all data needed for nowcasting and regional-scale NWP models, when required, and other real-time applications;

- a low-data-rate stream such as the present APT and its planned evolution towards digital techniques to convey an essential volume of data for nowcasting to local low-cost stations.

Onboard processing is not a requirement per se, except for the preparation of the data streams to be transmitted through the data communication channels and of all ancillary data which are needed for local processing of instrument outputs. It is recommended that satellite operators provide for on-board processing for those instruments which otherwise could not be given access to in real-time because of limits of the capability of the communication channels.

2.1.5 *Data management requirements*

Due to the two-fold requirement of direct broadcast capability and global data acquisition (thus centralization), the data management concept will involve a sharing of responsibilities between satellite operators and users. For the purpose of this document, it is important to establish to what extent the satellite operators should be involved (and thus the required structure and size of the satellite operator's ground segment) and the interface specifications for the data to be distributed to the users.

2.2 System requirements for geostationary satellites

System requirements for the geostationary component of the space-based sub-system of the GOS are simpler to be formulated, as there is one dominant application to be considered, i.e. operational meteorology. The main difficulty arises from the fact that, in the case of the geostationary orbit, WMO global requirements have to be traded-off against regional requirements of the individual satellite operators.

2.2.1 *System configuration principles*

The baseline system in geostationary orbit should comply with the following general principles.

- The number of satellites in orbit must be sufficient to cover all latitudes between 50ES and 50EN with frequent observations, typically at half-hour intervals. This implies the availability of five satellites, near-equally spaced around the equator (average spacing: 72 degrees).

- Continuity of observations is required. The availability figure of having the total system working must be 90% and the availability figure of having at least 4 satellites working (with positions re-arranged according to a contingency plan) must be 99%. In-orbit stand-by flight spare models, launch schedules and rapid call-up capability for replacement satellites should be considered to achieve this objective.

- The mission for determination of the availability figures is imagery, including sub-systems necessary to collect and process the data on the ground.

- The capacity of future systems should be substantially enhanced in comparison to the present particularly aiming at monitoring thermal and water vapour atmospheric vertical structures for nowcasting purposes.

- Near-real-time broadcast of frequent observations sufficiently pre-processed to be of immediate use for nowcasting should be ensured.

- Global data sets from all of the geostationary satellites in the system must be acquired and processed for the benefit of NWP.

- All satellites contributing to the space-based sub-system of the GOS must provide an agreed subset of the total volume of observations in a standard form (e.g. WEFAX) to provide for contingency measures, relay of observations from neighboring satellites and mobile acquisition stations (e.g. ships).

2.2.2 *Required capabilities from geostationary orbit*

Due to the orbital height which allows less energy to reach the satellite, only a subset of the observations possible from near-polar orbit are possible from the geostationary and often with less accuracy. The frequency of observation however makes possible applications unfeasible from near-polar orbiters. Using the different criterium from the one adopted in Section 2.1.2, the required capabilities can be listed as follows:

A Observations from geostationary orbit (primary):

- Early detection of cyclone-genesis
- Convection development monitoring
- Winds as derived from motion of clouds or other tracers
- Atmospheric instability (temperature/moisture variation)
- Sea-surface temperature variations in coastal waters
- Diurnal variations of land temperature
- Bi-directional reflectance properties of clouds and land
- Diurnal variation of Earth radiation budget.

A Observations complementing those from near-polar orbit:

- Oceanic sea-surface temperature
- Continental land temperature
- Large scale vegetation index
- Precipitation index
- Temperature profile
- Humidity profile
- Total ozone
- Clouds: coverage, brightness, top height
- Radiation budget.

A Telecommunication functions:

- Broadcasting of data to local users in near-real-time
- Data collection available all time (for alert service)
- Meteorological data distribution
- Continuous support to Search and Rescue mission.

2.2.3 *Orbital requirements*

The orbital height of geostationary satellites is nominally 35,800 km, the orbital plan equatorial, and the velocity vector from West to East. The only flexible requirement is the longitude locations. For equal spacing of approximately 72 degrees and optimal distribution to serve regional purposes, the locations should be:

144E W , 72E W , 0E, 72E E , 144E E

which are the approximate positions of the satellites operating at the present.

2.2.4 *Data circulation requirements*

Real-time services are an essential feature of geostationary satellites, which are primarily used for nowcasting. As regards image dissemination, two modes must be provided:

- a high-data-rate mode to provide large and medium-size meteorological centres with all the data needed for nowcasting and meso-scale NWP models;

- a low-data-rate mode, as the present WEFAX and its planned evolution towards digital techniques, to convey an essential volume of data for nowcasting to low-cost stations. This mode is required to be fully compatible amongst each satellite of the system.

The portions of image for regional use must be available within a few minutes from the observation (5 min for high-data-rate stations, 15 min for low-data-rate).

Geostationary satellites must provide a relay service for data collection from ground-based data platforms (DCP). A number of channels must be identical on all satellites to allow movement of mobile platforms across areas covered by different satellites (international DCP's). Messages from regional DCP's must be available within a few minutes from emission by the DCP; messages from other DCP's should be handled in a way compatible with WWW and GTS procedures.

Geostationary satellites could be used for telecommunications, such as EUMETSAT's Meteorological Data Distribution (MDD) in support of the GTS particularly to cover areas of known deficiency. When doing this, care should be taken of the rules governing access to the GTS. As a telecommunication facility, a geostationary satellite could be used to transfer image data from other geostationary satellites and near-polar-orbiting satellites out of the acquisition range for local direct read-out.

2.2.5 *Data management requirements*

ECSAT did not discuss these to such an extent to be mentioned in this Consolidated Report. The incoming CBS Working Group will have to consider this matter.

2.3 Contingency planning

The purpose of this section is to provide guidance to the satellite operators who support the space-based sub-system of the GOS in the preparation of their contingency plans.

WMO's Eleventh Congress "urged Members concerned to maintain the polar-orbiting and geostationary satellite systems to ensure the continuity of operation, and the data dissemination and distribution services of those satellite systems ...".

Ensuring continuity in this context refers to minimizing any interruption in WMO required environmental satellite missions services due to a failure in the space-based portion of the GOS. The GOS space segment operators have developed internal contingency plans to provide substitute products and services in the event of a service outage. Many of these internal plans draw upon the data and products of other space segment operators. In addition, the satellite operators of the space-based sub-system of the GOS have through a policy of "help your neighbour" worked together to help each other in the event of such a failure. The most recent example of this being the willingness of EUMETSAT to make available a METEOSAT spacecraft for coverage over the Atlantic and North American continent. This event highlights the importance of co-operation contingency planning amongst the operators.

CGMS has long served as a forum for addressing the WMO Executive Council Panel of Experts concern regarding ensuring continuity of the meteorological satellite services and will continue to be the focus for continuity planning.

2.3.1 *Definition of the basic missions*

The WMO general requirements for the space-based sub-system of the Global Observing System have been stated at the ninth session of the EC Panel of Experts on Satellites (see ECSAT-IX report, annex IV). All of the current operational mission requirements of WMO should be addressed in the contingency plans of the satellite operators. The most urgent attention of the operators should be directed to the key missions listed below.

(a) for geostationary satellites:

- the imagery mission
- the capability to produce winds
- the capability to broadcast data to local users
- the capability to collect and relay in situ data

(b) for polar satellites:

- the sounding mission
- the imagery mission
- the capability to broadcast data to local users
- the capability to collect and relay in situ data

The importance of the continuity of direct services such as APT, WEFAX and DCS must be considered.

2.3.2 *Definition of contingency*

In the case of geostationary satellites, contingency actions should be taken if the number of operating satellites and/or their location are not suitable to ensure that the primary missions listed below are met.

(a) Images taken under a zenith angle not higher than 70 degrees are available over all latitudes lower than 50 degrees (for higher latitudes, the polar satellites provide frequent images);

(b) The image quality is such that winds can be produced up to a zenith angle of 60 degrees over all latitudes lower than 40 degrees ;

(c) The capability to distribute data and possibly perform other telecommunication functions (e.g. data collection) must be exploited up to the latitude of at least 70 degrees;

In the case of polar satellites, contingency actions should be taken if the number of operating satellites and/or their orbital parameters and/or the instrument swaths are not suitable to ensure that the primary missions listed below are met.

(a) The sounding observations under a zenith angle not higher than 60 degrees are available four times per day over all latitudes higher than 30 degrees;

(b) Global coverage from images is available four times per day, any site being observed under a zenith angle not higher than 70 degrees;

(c) Any direct readout station is able to acquire direct read-out data with a coverage area of at least 6,000 km (W-E) by 3,000 km (N-S).

2.3.3 *Guiding principles*

Contingency plans prepared by the satellite operators should take into account the duration of the possible interruption of data and services and the requirements of the user community.

For short-term interruption of service, the internal contingency plans of satellite operators will usually be sufficient to address this problem. In this case, the loss of a critical sub-system may result in loss of the associated critical mission service for a short time, assuming a replacement satellite is available.

For a longer-term interruption, the matter can be considered one of a major programme continuity. It is considered that in an operational programme, the operator has in principle the capacity to integrate and launch a new satellite.

In the event of an extended satellite outage where no standby satellite is available, co-operative contingency plans developed by the operators would be essential. The satellite operator should explore a wide range of contingency strategies involving for example spacecraft, ground systems, alternative products, etc. The satellite operators should also explore measures to improve the commonalities amongst their various systems.

Sections 2.3.1 and 2.3.2 outline the mission requirements that are considered critical by WMO. The contingency plans of satellite operators should ensure coverage of those regions of the world where severe weather conditions (eg. cyclones, tornadoes, etc.) develop. The importance of direct broadcast services such as APT, WEFAX, HRPT continuity should also be considered. To ensure the continued availability of high resolution data, standardization of transmission links and formats should be considered.

Contingency planning of this nature must be a continuing dialogue between the satellite operators and their user representatives in order to develop practical cost-effective contingency alternatives which respond to the needs of the user communities.

3. MISSION REQUIREMENTS

This chapter records the mission requirements for the space-based sub-system of the GOS as assessed by ECSAT as of its Tenth Session (1992). ECSAT was aware that major work was still necessary and should be co-ordinated within WMO circles before a number of aspects, particularly on data quality, can be finally agreed upon. The chapter includes:

- a discussion on data and data quality requirements;
- an analysis of what is presently achieved and what can be expected in the near-term future from satellites;

- a top-level statement of mission requirements and recommended strategy for near-term and long-term planning.

3.1 Data and data quality requirements

Lists of parameters to be observed and quality of observations have been compiled by many WMO Technical Commissions and many committees in charge of international programmes. These lists can be found in the documentation provided to ECSAT and discussed in a number of sessions, as reported under Section 1.1 of this Consolidated Report. Whilst making reference to the original list for details, ECSAT made an attempt to consolidate a "short list" which, for the purpose of being handed to satellite planners (for instance, those space agencies represented at CEOS), might be much more useful than the voluminous original information, which does not clearly discriminate what could be expected from satellites versus what is more appropriate for ground-based global observing system.

The requirements as expressed by ECSAT are expressed in terms of geophysical parameters, which are what the end user needs. For this reason, the requirements are different from the capabilities in Sections 2.1.2 and 2.2.2 which is much closer to the original measurement.

Data quality has to be specified at the same time as data requirement, in order to prevent misunderstandings on feasibility assessment (a data requirement cannot be considered fulfilled if the quality is insufficient for the data to have a real impact on the application). Data quality has been specified in terms of horizontal resolution, vertical resolution (if applicable), frequency of the observation, and accuracy. As quality requirements are different for the different scales of application, two figures are generally quoted, for global scale and limited areas respectively.

The ECSAT list of satellite data requirements is shown in Table I (for upper-air) and Table II (for surface) where R indicates regional and G indicates global. For traceability reasons, the Tables also mention the Use Categories of the requirement where:

User Category codes:

A = operational meteorology
B = climate and environmental monitoring and change
C = hydrology/hydrometeorology/agrometeorology

TABLE I

WMO Satellite Data Requirements - Upper Air

Requirement		Horizontal Resolution	Vertical Resolution	Frequency	Accuracy	Use
Wind profile	R G	25 km 100 km	50 Ly 15 Ly	6 hr 12 hr	1 m/s 1 m/s	A A
Temperature profile	R G	25 km 25 km	50 Ly 15 Ly	6 hr 6 hr	1.0 K 1.0 K	A A,B
Humidity profile	R G	25 km 50 km	10 Ly 10 Ly	6 hr 6 hr	5 % 5 %	A A,B

Requirement		Horizontal Resolution	Vertical Resolution	Frequency	Accuracy	Use
Precipitation rate	R G	5 km 25km		30 min 6 hr	1 mm/d 3 mm/d	A,B,C A,B,C
Liquid water, total	G	25 km 25 km	5 Ly	6 hr	0.1 (<100nm) 2 (>100nm)	A,B
Cloud top height	R G	5 km 10 km		1 hr 3 hr	2 km 2 km	A A
Cloud top temperature	R G	5 km 5 km		1 hr 3 hr	1 K 1 K	A A
Cloud type and amount	R G	5 km 5 km	10 Ly 10 Ly	1 hr 6 hr	10 % 10 %	A,B A,B
Height of tropopause Ozone total and profile	R G	25 km 50 km		6 hr 6 hr	1 km 5 %	A B
Radiation, net	R G	50 km 10 km		12 hr 12 hr	5 w/m^2 2.5 w/m^2	A,B,C A,B,C
Aerosol	G	.5km	1 km	6 hr	10 %	B

Table II

WMO Satellite Data Requirements - Surface

Requirement		Horizontal Resolution	Frequency	Accuracy	Use
Multi-purpose imagery	R G	10 m .4 km	12 hr 6 hr		A,B,C A,B,C
Pressure, sea surface	R G	20 km 25 km	1 hr 6 hr	.5 mb .5 mb	A A
Temperature, sea surface	R G	1 km 1 km	6 hr 6 hr	.1 K .1 K	A A,B
Temperature, surface	R G	.5 km 1 km	12 hr 12 hr	.1 K .5 K	A,B,C A,B,C
Sea surface wind	R G	10 km 25 km	6 hr 6 hr	3 kts 10 deg 2 kts 10deg	A A
Soil moisture	R	20 km	24 hr	6 mm	A,B,C

Requirement		Horizontal Resolution	Frequency	Accuracy	Use
	G	25 km	24 hr	6 mm	A,B,C
Albedo, visible	R G	1 km 5km	6 hr 24 hr	1 % 1 %	B,C B,C
Albedo, near IR	G	2x2 deg	1 month	3 %	B,C
Ocean wave height	G	10 km	1 hr	.3 m	A
Wave spectrum	G	10 km	1 hr	10 deg (dir) .5 s (period)	A
Ice coverage	R	10 km	1 d	2 %	A,B,C
Ice edge	R	10 km	1 d	2 %	A,B
Ice thickness	R	25 km	1 d	10 %	B,C
Snow coverage	R G	1 km 1 km	1 d 1 d	2 % 10 %	A,B,C A,B,C
Snow edge	R	1 km	1 d	2 %	A,B,C
Snow depth	R G	1 km 1 km	1 d 12 hr	5 mm 5 mm	A,B,C A,B,C
Snow water equivalent	R	1 km	12 hr	2 mm	C

3.2 Expected contribution from satellites

Although the approach which led to the ECSAT list of satellite data requirements is more constructive than recording the original detailed data requirements, it is also necessary to indicate to satellite-system planners what WMO reasonably expects from satellites in the near- and medium-term. For this purpose, this section attempts to convert data requirements, as expressed in terms of geophysical parameters, into mission requirements, as expressed in terms of observing techniques. In fact, it would be unfair on the user side to expect satellite operators to take the responsibility of ensuring that a certain parameter will be derived from certain observations with the required quality, as this correspondence generally requires the application of processing algorithms and models which are under user control.

This section will therefore specify user requirements in terms easier to be accepted by space technologists, i.e. in terms of observing missions. These will be grouped as:

- multi-purpose imagery
- atmospheric sounding
- sea-surface observation
- radiation budget and atmospheric chemistry
- high-resolution imagery
- telecommunication functions.

For each mission, objectives and requirements will be specified, as well as typical instrumentation either operational at present or proposed. As far as near-polar-orbiters are concerned, for practical reasons only instruments flying or planned for flight on the baseline system as defined in Section 1.4.2 (i.e. NOAA, METEOR and, in the future, METOP), the nearly-operational LANDSAT and SPOT and the major future undertakings (ADEOS-1, ENVISAT-1 and EOS up to year 2000) have been mentioned. With regard to the geostationary satellites, all major programmes have been mentioned. Additional details on these near-polar and the geostationary satellites, as well as on their instrumentation, are reported in the Annex.

3.2.1 *The multi-purpose imagery mission*

The objectives of this mission are (the term "inference" indicates that additional processing is needed to get the information):

- direct observation of cloud patterns
- inference of cloud properties
- inference of precipitation rate and indexes
- inference of land and sea surface temperatures
- inference of vegetation index and soil moisture
- direct observation of ice and snow cover
- inference of ice and snow parameters
- inference of cloud-motion winds
- inference of atmospheric instability

and others, also in support of other missions, particularly the sounding and the Earth radiation budget missions.

The observation requirements to allow for these applications to be implemented, are as follows:

- spectral bands: atmospheric windows and specific absorption bands (particularly for water-vapour) in the visible (vis), infrared (IR) and microwave;

- geometrical resolution: 0.5 to 5 km (meteorology, oceanography, ice), 10 to 50 km (climatology);

- radiometric accuracy: S/N = 10 at 1% albedo (short-waves) NEDT = 0.1 K at 300 K (long-waves);

- spectral channels: 3-5 channels in vis/NIR, 3-10 channels in IR, 4-8 channels in microwave;

- repeat cycle: 10-30 min (geostationary), 6 hours (polar).

Typical existing or proposed instruments to fulfil the mission are (see Annex for acronyms and a short description):

- AVHRR, MODIS, for medium-resolution VIS/IR
- MIMR, for microwave imagery
- Imagers from all geostationary satellites.

3.2.2 *The atmospheric sounding mission*

The objectives of this mission are mainly driven by operational meteorology. They are:

- vertical temperature profile
- vertical humidity profile
- vertical wind profile
- liquid water (total and possibly profile)
- atmospheric discontinuities (height of PBL and tropopause). It is understood that all of these parameters need intensive processing for extraction and require support from the imagery mission and other-than-satellite information.

The observation requirements to allow for these applications to be implemented, are as follows:

- spectral bands: absorption bands of CO2, O2, water vapour and nearby atmospheric windows in IR and microwave; selected vis/NIR and IR lines exploited in an active mode (lidar)

- horizontal resolution: 50 km global, 25 km local

- vertical resolution: for profiles 1 km low-medium troposphere, 2 km medium-high troposphere, 3 km above the troposphere; for discontinuities 100m PBL, 1 km tropopause

- spectral channels: 20 to 1000's channels in IR, 10 to 20 channels in microwave, 2-3 channel lidar in vis/NIR, 1 channel doppler lidar in IR

- repeat cycle: 6 hours.

Typical existing or proposed instruments to fulfil the mission are:

- HIRS, MODIS for coarse vertical resolution in IR
- IASI, AIRS for high vertical resolution in IR
- AMSU-A and AMSU-B for all-weather sounding in microwave.

Space lidars for wind profile and atmospheric discontinuities are not planned to be flown before 2000.

3.2.3 *Sea-surface observations*

The objectives of this mission account for meteorological, oceanographic and climate applications. They are:

- accurate sea-surface temperature
- wind stress and vector
- wave height and spectrum, sea state
- sea level, currents, fronts, eddies
- chlorophyll concentration and suspended sediments
- air pressure
- accurate precipitation rate.

The sea-surface measurement requirements for these applications to be implemented are:

- spectral bands: atmospheric windows in vis/NIR, in thermal IR and in microwave; selected microwave channels exploited in active mode (radar)

- geometrical resolution: 25 km (global), 5 km (local)

- spectral channels: 5-10 in vis/NIR, 3-5 in thermal IR, 5-8 in passive microwave; 2-3 in active microwave

- repeat cycle: 6 hours.

Typical existing or proposed instruments to fulfil the mission are:

- ATSR, MODIS, for vis/NIR and IR
- MIMR, for passive microwave
- MERIS, SeaWIFS, OCTS, for high-spectral resolution vis/NIR
- ASCATT, NSCAT, for scatterometry in active microwave
- RA-2, for altimetry in active microwave
- ASAR, for active microwave imagery.

There are no plans to fly instruments for air pressure or accurate precipitation rate observations on the operational or near-operational satellites. Therefore, they have not been considered in this review.

3.2.4 *Radiation budget and atmospheric chemistry*

The objectives of this mission are driven by climatological and environmental monitoring and study. For the purpose of climate and environment, they are complementary to all objectives which have been listed in the previous sections 3.2.1, 3.2.2 and 3.2.3. They are:

- short-wave components of the Earth radiation budget
- long-wave components of the Earth radiation budget
- aerosol load and profile
- accurate water vapour profile in high troposphere
- green-house trace gases (total and rough profile)
- ozone total and profile
- stratospheric trace gases active on the ozone life cycle
- tropospheric trace gases hazardous to humans and bio-masses
- solar-terrestrial interactions.

The observation requirements to allow for these applications to be implemented, are as follows:

- broad-band radiometry, accurately calibrated, of all significant bands for energy budget: ultraviolet (UV), vis, near, thermal and far IR;

- scanning modes allowing multi-viewing angles to account for bi-directional reflectance properties and polarization;

- high-resolution spectroscopy across all fields of UV, vis, IR and sub-millimetre waves;

- nadir-scanning for total-column observation and tropospheric profiling, and limb-scanning for high vertical resolution in the upper atmosphere, also exploiting sun and star occultation;

- multi-platform observation (including geostationary satellites) to account for diurnal variations;

- monitoring of solar particles and space environment.;

Typical existing or proposed instruments to fulfil the mission are:

- ERBE, SCARAB, CERES, for broad-band UV/VIS/IR
- MERIS, POLDER, MISR, for reflectance properties
- SBUV, GOME, TOMS, SCIAMACHY, for nadir-viewing UV/VIS/NIR
- GOMOS, SAGE, SCIAMACHY, ILAS, for limb-viewing UV/VIS/NIR
- IASI, AIRS, IMG, MOPITT, for nadir-viewing IR spectroscopy
- MIPAS, ILAS, for limb-viewing IR spectroscopy
- SEM, for space environment monitoring.

3.2.5 *High-resolution imagery*

The objective of this mission, limited to certain fields of WMO interest, is, in general, to complement the multi-purpose imagery mission by more accurate observation of surface details on specific sites critical for global climate monitoring and study. Some of these observations are:

- de-forestation in tropical areas, desertification
- land water, run-off, floods, coastal erosion
- ice edge, thickness and type in the polar caps
- snow edge, depth and water equivalent in strategic basins
- coastal-zone water dynamics (eddies, currents, ...).

The observation requirements to allow for these applications are generally met by systems which have been designed primarily for commercial applications (resources discovery, monitoring and management). For WMO purposes, they are:

- spectral bands: vis and NIR atmospheric windows, microwave in active mode (Synthetic Aperture Radar)

- horizontal resolution: 10 to 100 m

- spectral channels: 3-10 in vis and NIR, 1-3 in thermal IR (TIR), 1-3 in active microwave (SAR) with two polarizations

- repeat cycle: one week to one month

The typical existing or proposed instruments to fulfil the mission are:

- LANDSAT TM, in vis, NIR and TIR
- SPOT HRV, in VIS and NIR with stereo capability
- ADEOS-1 VNIR, in VIS and NIR
- EOS ASTER, in VIS, NIR and TIR with stereo capability
- ENVISAT-1 ASAR, in C-band, with dual polarization.

3.2.6 *Telecommunication functions*

The objectives of this mission are:

- global data acquisition from all geostationary and near-polar-orbiting environmental satellites of interest for WMO programmes;

- direct broadcast to local read-out stations of all data useful for operational meteorology;

- data collection from "in situ" automatic station and location of the platform if mobile;

- meteorological data distribution through geostationary satellites in support of the GTS;

- support to Search and Rescue.

The requirements for this mission have been discussed in some detail in the paragraphs "Telecommunication functions" of sections 2.1.2 and 2.2.2, and in sections 2.1.4 and 2.2.4 "Data circulation requirements".

Most of the existing and planned systems either provide or will provide these services. The operational instrument for data collection and location from NOAA satellites is called ARGOS. The Search and Rescue support is being provided by NOAA and METEOR satellites by a system called SARSAT within the framework of an international programme called COSPAS.

3.2.7 *Summary Table of Section 3.2*

Table III summarizes the content of this section highlighting the relationships amongst the required parameters, observing technologies and candidate instruments.

3.3 Top-level statement on mission requirements and strategy

In the previous chapters and sections of this chapter, overall system requirements and mission requirements have been discussed in general terms in an attempt to reflect in a balanced way WMO requirements developed since the last two sessions of Congress. The consequence of this approach has been an extremely wide range of requirements, which can only be met by a great number of satellites and instruments, and that indicates a need for new technological developments. This result could be not very helpful to satellite system planners, if resources are limited. ECSAT has therefore developed a "top-level statement" which attempts to indicate WMO priorities and suggested a strategy.

To this end, ECSAT accounted for the statement from the Eleventh Congress and EC Sessions that "the World Weather Watch programme has the highest priority as the basic WMO Programme on which nearly all other programmes of the Organization depend" by recommending that:

- absolute priority must be given to the continuation of the present operational mission, including those improvements which are under way;

- observations which have been proven sufficiently mature for transition to an operational status should be added to the baseline at the earliest occasion, without however undermining the achievement of the first priority objective (continuity);

- a number of important data requirements for WMO cannot be met with present operational or demonstrated instruments and therefore technological developments should be undertaken in a focused manner on the outstanding items.

The following sections specify the contents of the three prioritized requirements listed above.

3.3.1 *Continuity of the current core operational mission*

The core mission for the space-based sub-system of the GOS is based primarily on imagery and sounding plus related sub-systems for data transmission to the ground together with the ancillary information needed for data processing. Also the core mission includes instruments for public safety which, though not of meteorological interest, have been hosted by meteorological satellites on the basis of long-standing co-operation agreements which should continue to be honoured.

TABLE III
WMO SATELLITE DATA REQUIREMENTS

Measurement	Instrument type	Candidate sensor
Wind	Geostationary imaging radiometer	VISSR, MVIRI
Wind profile	(undetermined)	(undetermined)
Temperature profile	Atmospheric sounder (IR, microwave)	HIRS,AIRS,IASI,MSU
Humidity profile	Atmospheric sounder (IR, microwave)	HIRS, AIRS, IASI, MSU, MHS
Liquid water, total, and precipitation rate	Imaging multi-spectral (microwave)	SSMI, TMI, MIMR
Cloud top temperature	Imaging multi-spectral (vis, IR) radiometer Atmospheric sounder (IR)	AVHRR, MODIS, MERIS HIRS, AIRS, IASI
Cloud type and amount	Imaging multi-spectral (vis, IR) radiometer	AVHRR, VISSR, MVIRI, SEVIRI, MODIS, MERIS
Ozone total and profile	Atmospheric chemistry spectrometer	TOMS, GOME, GOMOS, SCIAMACHY, MOPITT, IMG, ILAS, HIRDLS, TES
Radiation, net	Earth radiation radiometer	CERES, ScaRaB
Aerosol	Imaging multi-spectral (vis, IR) radiometer	AVHRR, MODIS, MERIS
Multi-purpose imagery	Imaging multi-spectral (vis, IR) radiometer	AVHRR,SEVIRI,MODIS, MERIS
Pressure, sea surface	(undetermined)	(undetermined)
Sea surface temperature (SST)	Imaging multi-spectral (IR) radiometer Atmospheric sounder (IR) Multi-directional radiometer (IR)	AVHRR, OCTS, MODIS, MERIS AIRS, IASI, HIRS ATSR
Temperature, surface	Imaging multi-spectral (vis, IR) radiometer Multi-directional radiometer (IR)	AVHRR, MODIS, MERIS ATSR
Ocean surface wind vector	Wind (microwave) scatterometer	AMI, NSCATT, STIKSCAT
Soil moisture	(undetermined)	(undetermined)
Earth surface albedo	Imaging multi-spectral (vis, IR) radiometer	MODIS, MERIS, AVHRR, AVNIR
Ocean wave height	Radar altimeter	ALT, RA
Wave spectrum	Mapping radar (SAR)	AMI
Ice coverage, edge	Imaging multi-spectral (vis, IR, microwave) radiometer	AVHRR, MODIS, MERIS, SSMI, MIMR
Ice thickness	(undetermined)	(undetermined)
Snow coverage, edge	Imaging multi-spectral (vis, microwave) radiometer	AVHRR, MODIS, MERIS, SSM/I, MIMR
Snow depth, snow water equivalent	(undetermined)	(undetermined)

The geostationary satellite component of the space-base sub-system of the GOS should be continued with an array of five spacecrafts on the approximate longitudes:

144EW, 72EW, 0E, 72EE, 144EE.

The recommended core mission shall be continued and improved as practicable with at least the following instruments:

- vis/IR imagers for measuring the development and motion of clouds, possibly including channels for atmospheric thermal and moisture structures observation

- data collection systems to relay from in situ platforms in support of environmental missions

- communication facilities to transmit the instrument output to the ground and distribute pre-processed images and other information to the users

- space environment monitors for space flight safety and diagnosis of instrument behaviour in orbit

- supporting Search and Rescue systems.

The near-polar-orbiting satellite component of the space-base sub-system of the GOS should continue to provide global coverage of the Earth and its atmosphere. There should be at least two satellites, one in the morning and one in the afternoon orbits, of sufficient altitude to ensure four global coverage per day of at least imagery and sounding.

The recommended core mission is expected to be continued and improved as practicable by the following instruments:

- IR and microwave sounders for global temperature and moisture profiles

- vis and IR radiometers primarily for cloud imagery but also for sea-surface temperatures, etc.

- data collection systems to relay data from in-situ platforms in support of environmental missions and to locate them if mobile

- direct broadcast communications for real-time data transmission and global data acquisition from the core mission instruments

- space environment monitors for space flight safety and diagnosis of instrument behaviour in orbit

- supporting Search and Rescue systems.

Operational Earth resources satellites such as LANDSAT and SPOT are not part of the baseline space-base sub-system of the WMO Global Observing System, but there is a WMO interest that high-resolution data continue to be available in support of hydrological, climatic and environmental monitoring.

The following list of requirements includes those that should be added to the present operational system to improve its performance, to satisfy the requirements of the year after 2000 and to achieve a more comprehensive set of measurements by adding oceanographic, climatological and environmental observations to the current operational mission. This list only includes observations for which instrumentation has been flown in the past, although only in an experimental environment (Nimbus, Seasat, etc.).

From geostationary orbit, the most stringent requirement is to improve monitoring and understanding of atmospheric convection, and accuracy of cloud-motion winds. To this end, more imaging channels are needed, to simultaneously observe the cloud pattern, the surface temperature and the atmospheric instability (i.e. temperature and water vapour). More frequent imagery, e.g. every 15 min, is required to improve wind accuracy and yield.

Extension of the use of geostationary satellites to climate monitoring, particularly by exploiting their ability to account for diurnal variations, requires the addition of suitable channels (e.g. for total ozone) and careful radiometric design to allow for accurate and stable calibration.

From near-polar orbits, the most stringent requirement for operational meteorology as well as for climate and environmental monitoring is to improve the performance of atmospheric sounding in terms of vertical resolution (goal: 1 km), accuracy of temperature (goal: 1 K) and humidity (goal: 10 %) and total-column content of key trace gases. It has been demonstrated that high-spectral resolution IR spectroscopy could fulfil this requirement.

A second requirement is to extend the multi-purpose imagery mission into the spectral domain of microwaves in order to improve the observation of hydrological parameters such as precipitation, snow/ice coverage and soil moisture, as well as oceanographic (sea-surface wind stress and temperature) and atmospheric (vapour, liquid and solid water). It has been demonstrated that passive multi-frequency microwave radiometers could to a large extent meet the requirements, provided that the horizontal resolution is improved to a few kilometres. There is also an interest to have access to high-resolution active microwave images (from SAR), for which, however, other user community have a leading role.

The observation of sea-surface state is very important to describe the momentum and water/energy fluxes from the ocean into the atmosphere across the PBL and also is important for input to coupled ocean/atmosphere numerical models. Active microwave instruments such as radar scatterometers and altimeters have already been demonstrated the potential to meet such requirements, in association with the multi-purpose imagery mission, particularly if extended into the microwave domain.

The accuracy of sea-surface temperature measurements needs to be improved to 0.2 K in order to monitor climate change. It is unclear whether the calibration mechanisms of the operational multi-purpose imagers is sufficient to this end. A dedicated specially calibrated IR instrument could be necessary.

Observation of the Earth radiation budget and its components is mandatory to monitor climate change. There is a requirement to improve the present short-wave and long-wave instrumentation by exploiting more spectral intervals and more viewing conditions.

The chemical processes in the troposphere and stratosphere need to be monitored and studied in relation to the problem of climate change and environment degradation. There is a very stringent need to at least monitor the total ozone content and vertical profile, and the total-column content of some chemically active trace gases. There is also a need, perhaps within relaxed operational requirements of continuity, to fly sophisticated instrument complexes to improve the understanding of physio-chemical processes in the atmosphere, following the heritage of instruments presently flown on operational meteorological satellites and on one-shot missions such as UARS.

In order to evaluate the removal rate of greenhouse gases, such as CO2, from the atmosphere by the ocean, we need knowledge of the status of the ocean surface, i.e. its productivity and salinity. Whilst salinity measurement requires technological developments still to come (low frequency microwave implying very large antennae), productivity can be deduced by ocean colour observation. There is therefore an interest to access data from high-spectral-resolution short-wave radiometers.

It is important to note that the list above is in rough order of priority, having operational meteorology as the driving application. However, there is a strong gap of priority between the first item on the list (improved IR sounding, which is an outmost requirement) and the others.

3.3.3 *High priority longer-term requirements*

There is a class of measurements which are urgently required for a number of WMO programmes, for which a technical solution seems feasible but has not yet been demonstrated. This represents the next challenge for new experimental developments which could serve as a basis for later operations, beyond the year 2000.

For geostationary satellites the highest priority is for high-vertical resolution frequent soundings which could be achieved by IR spectrometry as it is planned for the near-polar orbit. The addition of a microwave sounder also is considered important.

For near-polar-orbiting satellites, the highest priority is by far wind profiling, to replace the present cloud-motion tracing from geostationary satellite, which only is applicable where clouds exist and only provides wind at two levels (high and low). Technological studies have indicated that wind profiles in clear-air troposphere can measure wind by tracking the eddies of the atmospheric turbulence by means of doppler lidars. As wind data are more important in the low latitudes, demonstration of such instrument could be conveniently performed from a low-inclination orbit.

Atmospheric discontinuities are the next priority. Knowledge of the heights of the PBL, of the tropopause and of cloud tops are important observations per se, and also would drastically improve the accuracy of soundings, which tend to be less accurate where discontinuties occur. A backscatter lidar-based imager appears to be an instrument potentially able to meet the requirement.

Precipitation rate over the ocean as observed by passive microwave radiometers could be sufficient for operational meteorology, but fails to be accurate enough for atmospheric energetics study, dominated by latent heat release over the ocean, particularly in the intertropical regions. Active microwave (rain-radar) have been proposed for this purpose. The limited swath possible for such an instrument could be sufficient to calibrate the wide-coverage passive microwave observations. Since more than two-thirds of global precipitation falls in the tropics and convective clouds are strongly affected by diurnal variations, a low-inclination orbit would be more suitable for this mission. An experiment in this direction, the TRMM mission, is being planned by the USA and Japan for 1997, by using i.a. a prototype rain-radar.

Air surface pressure remains a problem over a large part of the globe, particularly intertropical and Southern Hemisphere oceans where ships and buoys are very infrequent. Air-surface pressure is not only important per se, but also affects the accuracy of geopotential sounding retrieval from temperature/humidity sounding. DIAL lidar and very-high-resolution spectroscopy in the O2 A-band in vis have been proposed for this observation.

3.3.4 *Summary Table of Section 3.3*

Table IV summarizes the ECSAT top-level statement on general requirements for the space-based sub-system of the Global Observing System.

TABLE IV

Summary of the General Requirements for the Space-Based Sub-System of the Global Observing System

CURRENT OPERATIONAL MISSION REQUIREMENTS

OBJECTIVES: Basic Sounding, Imagery, Related Sub-Systems, Hosted Missions for Public Safety

From sun-synchronous orbit: (at least two satellites, one in the AM and one in the PM)

- Microwave and infra-red temperature and humidity sounder
- Visual and infra-red multi-purpose imagery
- Data collection systems and platform location
- Direct broadcast communications and global data acquisition
- Space Environment Monitoring
- Search and Rescue support

From geostationary orbit: (at least five satellites)

- Visual and infra-red multi-purpose imagery (plus soundings from GOES)
- Data collection systems
- Communication facilities, relay of pre-processed images and information
- Space Environment Monitoring

From Earth Resource Satellites:

- continuity of observations for long-term research purposes and improvements in data.

EXTENDED OPERATIONAL MISSION REQUIREMENTS

OBJECTIVES: Improvement of sounding and imagery missions; Achieve more comprehensive ocean, climate and environmental observations

From sun-synchronous orbit:

- improved temperature and humidity sounding
- extend multi-purpose imagery in the microwave domain

- sea-surface momentum and fluxes
- improved sea-surface temperature
- earth radiation budget
- ozone and other trace gases
- ocean colour

From geostationary orbit:

- atmospheric convection/instability
- expanded use in climate monitoring

HIGH PRIORITY LONGER-TERM REQUIREMENTS

OBJECTIVES: New observations not possible at present

From low-inclination orbit

- Three-dimensional wind measurements
- Precipitation over the ocean

From sun-synchronous orbit

- Atmospheric discontinuities and cloud top height
- Surface pressure

From geostationary orbit

- improved high quality and high resolution sounding data

SUMMARY INFORMATION ON SATELLITES AND INSTRUMENTS

INTRODUCTION

This Annex is a short report on the satellites and instruments referred to in the Consolidated Report, particularly in Sections 1.4 and 3.2. For practical reasons, reference is made only to those programmes which have a long-term continuity approach, such as:

- all of the geostationary satellites listed in Section 1.4.1, i.e. Meteosat, GOES, GMS, INSAT, GOMS, FY-2;
- the near-polar-orbiting satellites providing the baseline service (NOAA, METEOR, METOP), the main programmes for climate and environment observation being prepared for launch in the last part of the century (ENVISAT-1, ADEOS-1 and the EOS platforms committed up to the year 2000) and the land observation programmes with a tradition of long-term continuity (LANDSAT and SPOT).

The main sources of information for this short note are:

- WMO Publication no. 411 (revised edition to be distributed in 1993);
- CEOS Dossier of Satellite Missions and Global Environmental Programmes, Vol. 1 (Draft, June 1992).

1. GEOSTATIONARY SATELLITES

1.1 METEOSAT (position: 0E degrees)

Programme overview

Five models launched so far (last: METEOSAT 5, March 1991). Two more models are committed (METEOSAT 6 and MTP, Meteosat Transition Programme, to be used up to the year 2000-2002). METEOSAT Second Generation (MSG) to be launched in the year 2000 and followed by two more models up to the year 2012. The authority in charge of the programme: EUMETSAT. The development of MSG will be a joint programme with ESA.

Missions:

Present series (including MTP):

- imagery in three channels, VIS (2.5 km), IR and WV (5 km)
- image cycle: 30 min
- dissemination of pre-processed images (including WEFAX)
- data collection system
- meteorological data distribution (MDD)
- meteorological data extraction including cloud-motion wind
- archive and retrieval service.

Meteosat Second Generation:

- imagery in 12 channels (3 in VIS, 1 in NIR, 8 in IR)
- resolution in one VIS channel 1 km, in all others 3 km
- image cycle: 15 min
- same missions as in MOP/MTP, plus:

  - atmospheric instability monitoring
  - ozone monitoring
  - improved contribution to Earth radiation budget
  - Search & Rescue.

1.2 **GOES** (positions: 75EW and 135EW)

Programme overview

Seven models launched so far (last: GOES 7, February 1987). GOES-next to start in 1994 with GOES I, followed by GOES J, K, L and M to be used up to the year 2005. Authority in charge of the programme: USA/NOAA.

Missions:

Present series:

- imagery in two channels, VIS (1 km) and IR (8 km)
- image cycle: 30 min or less for partial scanning
- sounding (VAS) in 12 IR channels (8-14 km), alternative to imagery, flexible cycle (global in 13.5 h)
- dissemination of pre-processed images (including WEFAX)
- data collection system
- Space Environment Monitor (SEM)
- cloud-motion wind extraction
- archive and retrieval service

GOES-next:

- imagery in five channels, 1 VIS (1 km), 4 IR (4 km)
- sounding in 1 VIS and 18 IR channels, 8 km, 7.5 h cycle
- same missions as in present GOES, plus Search & Rescue.

1.3 **GMS** (position: 140EE)

Programme overview

Four models launched so far (last: GMS-4, September 1989). GMS-5 to be improved. Launch in 1994. Long-term continuation planned, with occasional up-gradings. Authority in charge of the programme: Japan Meteorological Agency (JMA).

Missions:

Present series:

- imagery in two channels, VIS (1.25 km), IR (5 km)
- image cycle: 30 min
- dissemination of pre-processed images (including WEFAX)
- data collection system
- meteorological data extraction including cloud-motion wind
- Space Environment Monitor (SEM)
- archive and retrieval service.

GMS-5 and following:

- imagery in four channels, 1 VIS (1.25 km), 3 IR (5 km)
- same missions as GMS-4 except for SEM.

1.4 **INSAT** (alternative positions: 74E or 83EE)

Programme overview

Four models launched so far (last: INSAT-ID, June 1990). Improved models of the series INSAT-II to be launched soon. Authority in charge of the programme: Indian Space Research Organization (ISRO).

Missions:

Present series (INSAT-I):

- imagery in two channels, VIS (2.75 km) and IR (11 km)
- image cycle: 3 hours (less over limited areas)
- image dissemination limited to India, WEFAX not provided

- data collection system
- cloud-motion winds extracted once per day on limited areas
- archive and retrieval service.

INSAT-II:

- imagery in two channels, VIS (2 km) and IR (8 km)
- image cycle: 30 min
- same missions as INSAT-I.

1.5 **GOMS** (position: 76EE)

Programme overview

Prototype planned for launch in 1993. Authority in charge of the programme: Russian Federation Committee for Hydrometeorology and Monitoring of Environment (ROSCOMGIDROMET).

Missions:

- imagery in two channels, VIS (1.5 km) and IR (8 km)
- image cycle: 30 min
- dissemination of pre-processed images (including WEFAX)
- data collection system
- meteorological data extraction including cloud-motion wind
- space environment monitoring
- archive and retrieval service.

1.6 **FY-2** (position: 105EE)

Programme overview

Prototype planned for launch in 1995-96. Authorities in charge of the programme: National Space Committee, Ministry of Aerospace and State Meteorological Administration.

Missions:

- imagery in three channels, VIS (1.25 km), IR and WV (5 km)
- image cycle: 30 min
- dissemination of pre-processed images (including WEFAX)
- data collection system

- meteorological data extraction including cloud-motion wind
- space environment monitoring
- archive and retrieval service.

2. NEAR-POLAR-ORBITING SATELLITES

2.1 **NOAA** (a.m. and p.m.)

Programme overview

Twelve models launched so far (last: NOAA 12, May 1991), alternatively in the a.m. and p.m. orbits. Two more models of the same series are available, to cover up to the year 1994. NOAA K,L,M,N will improve the system in the interval 1994-2002, continuing to cover both a.m. and p.m. orbits. With NOAA O,P,Q only the p.m. orbit will be covered. Authority in charge of the programme: US NOAA.

Orbits: Heights around 850 km, equatorial crossing time 7.30 and 14.

Communications:

- HRPT: direct read-out of full information in S-band
- APT: direct read-out of reduced-resolution images in VHF
- DRB: direct read-out of sounding data in digital VHF
- GAC: global data acquisition at reduced image resolution
- LAC: local data acquisition at full image resolution.

Payload instrumentation

Present series (up to NOAA J = NOAA 14):

- AVHRR/2 (Advanced Very High Resolution Radiometer), multi-purpose medium-resolution 5-channel VIS/NIR/IR radiometer
- HIRS/2 (High Resolution Infrared Sounder), 20-channel IR radiometer for temperature/humidity sounding
- SSU (Stratospheric Sounding Unit), 3-channel IR radiometer for stratospheric temperature sounding
- MSU (Microwave Sounding Unit), 4-channel MW radiometer for all-weather temperature sounding
- SBUV (Solar Backscatter Ultra Violet radiometer), ozone sounder with 12 UV channels, nadir-viewing
- ERBE (Earth Radiation Budget Experiment), multi-angle viewing, narrow and

broad band UV/VIS/IR radiometer

- ARGOS (Data Collection and Location System), to collect data from in-situ platforms and locate them if mobile

- SARSAT (Search and Rescue Satellite-Aided Tracking) to relay emergency signals and locate the source

- SEM (Space Environment Monitor), a group of counters to measure charged particle fluxes at platform level.

NOAA K,L,M,N series:

- AVHRR/3, as AVHRR/2 plus one NIR channel

- HIRS/3, up-graded from HIRS/2

- AMSU-A (Advanced Microwave Sounding Unit-A), 15-channel MW radiometer for all-weather temperature sounding

- AMSU-B (Advanced Microwave Sounding Unit-B), 5-channel MW radiometer for all-weather humidity sounding

- SBUV, ARGOS, SARSAT and SEM as in previous NOAA's.

NOAA O,P,Q series:

- VIRSR (Visible and Infrared Scanning Radiometer), up-graded from AVHRR to 7 channels (3 VIS/NIR, 4 IR)

- IRTS (Infra-Red Temperature Sounder), upgraded from HIRS

- MTS (Microwave Temperature Sounder), upgraded from AMSU-A to 21 channels

- MHS (Microwave Humidity Sounder), upgraded from AMSU-B

- TOMS (Total Ozone Mapping Spectrometer), cross-track scanning spectrometer in six UV spectral bands

- LEFI (Local Electric Field Instrument), for ambient vector electric field

- SBUV, ARGOS, SARSAT and SEM upgraded from previous NOAA's.

2.2 **METOP** (a.m.)

Programme overview

Prototype to be launched in year 2000 to ensure continuity in the a.m. orbit after the NOAA K,L,M,N series. Two models are foreseen, to be used up to year 2010. Authority in charge of the programme: ESA and EUMETSAT (role of ESA dominant in the development of the prototype).

Orbit: Height around 850 km, equatorial crossing time around 9.

Communications

- MCP: direct read-out in S-band and VHF plus global acquisition in X-band after on-board recording

- DRS: demonstration of Data Relay Satellite under study.

Payload instrumentation

- AVHRR/3 (METOP-1)and VIRSR (METOP-2), as in NOAA

- HIRS/3 (METOP-1) and IRTS (METOP-2), as in NOAA

- AMSU-A (METOP-1) and MTS (METOP-2), as in NOAA

- MHS, ARGOS, SARSAT and SEM, as in NOAA O,P,Q

- IASI (Infrared Atmospheric Sounding Interferometer), an IR spectrometer for improved temperature/humidity sounding and total-column trace gases

- MIMR (Multi-frequency Imaging Microwave Radiometer), a 6-channel dual-polarization multi-purpose MW imager

- ASCAT (Advanced Scatterometer), a C-band dual swath scatterometer for sea-surface wind

- AATSR (Advanced Along-Track Scanning Radiometer), a VIS/IR radiometer for improved sea-surface temperatures

- GOME (Global Ozone Monitoring Experiment), a UV/VIS spectrometer for ozone and trace gases, nadir scanning

- SCARAB (Scanner for Radiation Budget), a 4-channel, broad and narrow bands, UV/VIS/IR radiometer.

2.3 **METEOR** (a.m. and p.m.)

Programme overview

26 models launched so far (20 of the METEOR-2 series, 6 of the METEOR-3 series; last launch: METEOR-3/6, January 1991). The METEOR-3M series is in preparation for flight in 1995. Authority in charge of the programme: ROSCOMGIDROMET.

Orbits: Heights around 950 km (METEOR-2) and 1200 km (METEOR-3).

Communications

- APT: direct read-out of VIS and IR images

- Global data acquisition in UHF

- HRPT-type direct read-out planned for METEOR-3M series.

Payload instrumentation (METEOR-3)

- Scanning radiometer for 2 km VIS imagery (APT)
- Television system for 1 km VIS imagery
- Scanning radiometer for 3 km IR imagery (APT)
- 10-channel IR radiometer for atmospheric sounding
- space environment monitoring
- experimental UV/VIS/NIR spectrometers for ozone
- TOMS (see NOAA O,P,Q), provided by NASA
- SCARAB (see METOP), provided by France and Germany for METEOR-3/7 and follow-on.

2.4 **LANDSAT** (a.m.)

Programme overview

Five models launched so far (last: LANDSAT 5, March 1984). LANDSAT 6 and 7 approved, to cover up to year 2000. Authority in charge of the programme: USA/NOAA (to be handed over to NASA and Department of Defence before LANDSAT-7).

Orbit: height 705 km, repeat cycle 16 days.

Communications

- Direct read-out in X-band to appointed stations
- On-board recording of selected images
- Near-global acquisition through data relay satellites

Payload instrumentation (LANDSAT 4 and 5)

- MSS (Multispectral Scanner System), a 4-channel VIS/NIR radiometer with 80 m resolution, 185 km swath
- TM (Thematic Mapper), a 7-channel VIS/NIR/IR radiometer (1 in IR) with 30 m resolution (120 in IR), 185 km swath.

2.5 **SPOT** (a.m.)

Programme overview

Two models launched so far (last: SPOT-2, January 1990). One more model available. SPOT-4 (1997) will be upgraded. Authority in charge of the programme: CNES (France).

Orbit: height 822 km, repeat cycle 26 days.

Communications

- Direct read-out in X-band to appointed stations

- On-board recording of selected images.

Payload instrumentation (SPOT 1-3)

- HRV (High Resolution Visible), a 3-channel VIS/NIR radiometer with 20 m resolution (10 m panchromatic), 120 km swath (60+60 with two cameras) and stereo capability.

2.6 **ADEOS** (a.m.)

Programme overview

One model being prepared for launch in 1996 (ADEOS-1). A second model is planned for 1999, but the payload is not yet fixed. Authority in charge of the programme: NASDA (Japan)
Orbit: height 797 km, repeat cycle 41 days.

Communications

- Direct read-out in X-band to appointed stations

- On-board recording of selected data

- Experimental acquisition through data relay satellites.

Payload instrumentation (ADEOS-1)

- OCTS (Ocean Colour Temperature Scanner), a 12-channel medium-resolution radiometer (8 VIS/NIR, 4 IR)

- AVNIR (Advanced Visible and Near-Infrared Radiometer), 5 channels, 16 m resolution (8 m panchromatic), 80 km swath

- NSCAT (NASA Scatterometer), an X-band dual swath scatterometer for sea-surface wind

- TOMS, as in NOAA O,P,Q and METEOR-3

- POLDER (Polarization and Directionality of Reflectances), with 3 VIS/NIR channels in 3 polarization directions and 5 VIS/NIR unpolarized channels

- ILAS (Improved Limb Atmospheric Spectrometer), in three spectral bands (1 in NIR, 2 in IR), by solar occultation

- IMG (Interferometric Monitor for Greenhouse Gases), very high spectral resolution in IR, focused on CO2, CH4 and N2O; nadir-viewing

- RIS (Retroreflector in Space), a 50 cm corner-cube for VIS/NIR laser beam reflectance to derive total-column trace gases by absorption techniques.

2.7 **ENVISAT** (a.m.)

Programme overview

One model being prepared for launch in 1998 (ENVISAT-1). Second model planned for 2003, payload not yet fixed. Authority in charge of the programme: ESA.

Orbit: height around 800 km, repeat cycle around 30 days.

Communications

- Direct read-out in X-band to appointed stations

- On-board recording of selected data

- Near-global acquisition through data relay satellites.

Payload instrumentation

- ASAR (Advanced Synthetic Aperture Radar), a C-band SAR with flexible polarization, viewing angle and swath
- RA-2 (Radar Altimeter 2), dual-frequency (X and S bands), supported by a MW radiometer and a positioning system

- MERIS (Medium Resolution Imaging Spectrometer), in the VIS/NIR range, with tilt capability to offset sunglint

- MIPAS (Michelson Interferometer Passive Atmospheric Sounder), for limb sounding in the IR range

- GOMOS (Global Ozone Monitoring by Occultation of Stars), for limb sounding in three spectral bands of UV/VIS/NIR

- SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Cartography), nadir and limb sounding in UV/VIS/NIR

- AATSR and SCARAB as mentioned under METOP.

2.8 **EOS** (a.m. and p.m.)

Programme overview

Series of satellites to be launched starting from 1998. Only missions planned for launch within 2000 are mentioned. Authority in charge of the programme: USA/NASA.

Orbit: height 705 km, repeat cycle 16 days.

Communications

- Near-global acquisition through data relay satellites

- Direct read-out in X-band to appointed stations.

Payload instrumentation

EOS-AM 1 (a.m., 1998):

- ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), with 9 VIS/NIR and 5 IR channels, resolutions 15 m, 30 m and 90 m (IR), swath 60 km, stereo capability

- CERES (Clouds and the Earth's Radiant Energy System), two broad-band 3-channel UV/VIS/IR radiometers

- MISR (Multi-angle Imaging Spectro-Radiometer), 4-channel VIS/NIR radiometer viewing under 9 different angles

- MODIS-N (Moderate Resolution Imaging Spectrometer, Nadir viewing), a 36-channel VIS/IR imager and sounder

- MOPITT (Measurements Of Pollutants In The Troposphere), a 4-band correlation NIR/IR spectrometer, nadir scanning.

EOS-Color (a.m., 1998)

- SEAWIFS (Sea-viewing Wide Field Sensor), an 8-channel VIS/NIR radiometer with tilt capability for ocean colour

EOS-AERO (57E inclined orbit, 2000)

- SAGE III (Stratospheric Aerosol and Gas Experiment - III), UV/VIS/NIR limb sounder for solar and lunar occultation

EOS-PM 1 (p.m., 2000)

- AIRS (Atmospheric Infra-Red Sounder), an IR spectrometer for improved temperature/humidity sounding and trace gases

- MODIS-N and CERES, as on EOS-AM 1

- MIMR, AMSU-A and MHS, as in METOP-1 and/or NOAA O,P,Q.

ANNEX II

W O R L D   M E T E O R O L O G I C A L   O R G A N I Z A T I O N
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EXECUTIVE COUNCIL PANEL OF EXPERTSON SATELLITES

A STRATEGY FOR EDUCATION AND TRAINING
IN SATELLITE MATTERS

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WMO EXECUTIVE COUNCIL
PANEL OF EXPERTS ON SATELLITES

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EXECUTIVE SUMMARY

1. The strategic plan to improve the use of satellite data for meteorology and operational hydrology over the next 10 years is summarised in Tables 1 and 2. These identify the strategic goal, objectives, strategies, plans, and implementation timetables. The plan utilises the whole of the existing infrastructure and strongly focuses on meeting the needs of developing countries via significantly improved training of RMTC instructors, who in turn will conduct "on the spot" training of local personnel within their region.

2. While the strategy aims to serve the full spectrum of needs, from the least developed to the most developed countries, it is intended to be applied in such a way that the focus is always on the needs of the developing countries. Thus, while all WMO Members continue to benefit as time goes by, some (the least developed) will benefit more than others. In this way the gap in satellite data utilisation capability between the least developed and the more developed countries should become continually narrower.

3. The major recommendation is to upgrade and standardise the satellite training facilities and capabilities at six RMTCs. This improves cost-effectiveness because major funding will be shared among 6 RMTCs instead of all 17 and also provides a buffer against the impact of continuing shrinkage in the total funds available for satellite activities. The other 11 RMTCs will continue to provide some basic satellite education and training in their core programmes, but may be equipped to specialise in training in some other field.

4. It is recognised that funding limitations will act as a strong brake on the rate of implementation of the plan. The proposed overall funding strategy is based on a cost minimisation strategy and a co-operative funding mechanism which strives for more efficient use of the existing funded projects and funding sources by focusing them all on a few clearly identified high priority satellite education and training activities. The first priority should be to focus as much funding as possible on upgrading the satellite education and training facilities and capabilities of six RMTCs.

5. It is proposed to implement the plan over the next 10 years in two separate phases:

- Phase 1 (1993-96) will build on, strengthen, and more sharply focus existing activities and plans to improve the use of satellite data in the developing countries, while, at the same time, further develop, prepare, and arrange funding for a broader, longer term education and training plan for implementation from 1997. A major goal in this phase will be to strengthen the satellite education and training capabilities of six RMTCs.

- Phase 2 (1997-2001) will see the progressive implementation of the broader based education and training strategy. By 1997, the necessary strengthening of the infrastructure should have been largely completed, an effective funding mechanism should have been developed, the plan should have been trimmed as necessary to fit the available funds, and enough funding should have been secured to begin the first half of the revised implementation phase. A solid, scientifically based programme of education and training in satellite applications should be ready for implementation, together with an effective monitoring and review mechanism.

6. Critical success factors for this strategic plan are:

(a) The achievement of the necessary funds to implement and maintain the overall plan. This depends on the effectiveness of the cost minimisation and co-operative funding mechanisms proposed. This is the most critical element for the overall success of the plan;

(b) The full integration and overall management of this plan within the Education and Training Programme's Long-term Plan 1992-2001;

(c) The establishment of a clear and effective administrative framework within WMO for the co-ordination and management of the various implementation tasks;

(d) The co-operation of national meteorological services (particularly their training institutions) in supporting the plan to upgrade the satellite training facilities and capabilities of at least one RMTC in each Region;

(e) The co-operation of the international satellite operators in ensuring that the development of appropriate user education and training modules and programmes become an integral part of their plans and operations.

(f) The implementation of recommendations from the Operational World Weather Watch System Evaluation for Africa (OWSE-AF) for an improved satellite communications system for meteorological data dissemination, and the future development of similar systems in other Regions.

7. The EC panel of Experts on Satellites recommends that the Executive Council:

(a) approves the Strategy for Education and Training in Satellite Meteorolgy as contained in the Final Report from the EC Panel of Experts on Satellites.

The strategic goal is:

to systematically improve the use of satellite data for meteorological and hydrological applications over the next 10 years in all Member countries, with a focus on meeting the needs of the developing countries.

Three major strategic objectives to achieve the goal are:

(i) To build on the existing infrastructure in a way which ensures that the time scale and manner in which initiatives for improving satellite data utilisation are introduced, are consistent with the capabilities of the users to absorb and sustain them independently in their own operational environment. Four key strategies for this objective are:

(a) integrate with the Education and Training Programme Long-term Plan 1992-2001;

(b) use the whole infrastructure;

(c) tailor training material to suit the infrastructure; and

(d) minimise costs and maximise cost-effectiveness.

(ii) To focus on the developing countries, directing particular attention to systematically improving the level of expertise of instructors at all RMTCs in the utilisation of satellite data. Eight key strategies for this objective are:

(a) establish special satellite training centres at six RMTCs. This will provide a minimum network, within the WMO's RMTC framework, of specialized satellite applications training centres ("centres of excellence") strategically located around the globe. This is the pivotal strategy for the entire strategic plan and the activities required to support it should have the **highest overall priority**. It provides a focal point for all the other strategies in the plan and a focal point for directing funding, co-operative programmes and other scarce resources to obtain maximum overall cost-effectiveness;

(b) improve the satellite application training capability of RMTC instructors;

(c) develop standard low cost satellite applications facilities for RMTCs;

(d) improve co-ordination between RMTCs and the training institutions of national meteorological and hydrological services;

(e) use satellite experts as consultants;

(f) implement a rolling programme of satellite training seminars;

(g) upgrade the satellite education and training curriculum; and

(h) that each satellite operator participating in the space-based sub-system of the GOS co-operate with at least one of the six specialized RMTCs with regard to the satellite training programme, facilities and expertise required.

(iii) To anticipate future trends in satellite data applications and in education and training techniques, so that new developments can flow through to operational users quickly and efficiently. Four key strategies for this objective are:

(a) Co-ordination with CEOS and CGMS on future satellite activities;

(b) Ensure training modules are developed for all new satellite programmes;

(c) Maintain an awareness of advances in communications and computer-aided learning techniques; and

(d) Focus on applications for atmospheric chemistry, the oceans and climate change.

(b) Considers the provision of one additional full time staff member to the Education and Training Programme to administer and co-ordinate further overall development and implementation of the plan.

(c) Requests the President of the Commission for Basic Systems to assign the CBS

Working Group on Satellites, in co-operation with the EC Panel on Education and Training, the tasks: to further refine and tune the strategies; to provide expert advice on the further development of the strategy; to more clearly identify six candidates as specialized satellite training centres and to make available for the next Congress's consideration in 1995 a firm and fully costed plan for implementation in the 1996-2000 Programme and Budget.

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1. INTRODUCTION

1.1 The Executive Council requested the EC Panel of Experts on Satellites to develop education and training strategies for improving the use of satellite data with particular emphasis on meeting the needs of the developing countries. This task has been worked on for several years and was completed in the first half of 1993 by the EC Panel of Experts on Satellites during the transition mode prior to the formal disbandment of the EC Panel and its replacement by the CBS Working Group on Satellites.

1.2 In preparing its report and recommendations, the EC Panel of Experts on Satellites has been guided by the Executive Council and the strategic directions given in the WMO's Third Long-term Plan 1992-2001. The Panel/CBS WG has consulted various WMO Commissions, Programmes, Panels, Working Groups and associated rapporteurs, as well as key units in national meteorological services and relevant external agencies. Particular note has been taken of the recent comments and recommendations by the EC Panel of Experts on Education and Training (XIV Session, November 1991), the Co-ordinating Committee of the Standing Conference of Heads of Training Institutions of National Meteorological Services (CO-COM for SCHOTI) (Second Meeting, October 1992), the Commission for Basic Systems (CBS-X, November 1992) and the Commission for Hydrology (CHy-IX, January 1993).

1.3 The following major activities have been undertaken by the EC Panel:

∀ an analysis of the existing infrastructure which is supporting, or could support, education and training in the application of satellite data for meteorology and operational hydrology in all Member countries;

∀ an assessment of what could be done to improve the application of satellite data in the developing countries, with particular emphasis on how the effectiveness of RMTCs could be improved;

∀ a review of current and planned satellite education and training publications, training methods (including the emerging computer-based training), and training curricula;

∀ a survey of the various information services and systems suitable for disseminating information on satellite education and training matters;

∀ a list of topics which require specialised education and training in the field of satellite applications for meteorology and operational hydrology, and a corresponding list of suitably qualified experts who could either assist in the training of instructors, or who could deliver special training courses on these subjects;

1.4 The strategies and plans which emerged from all this work are described in this document together with the recommendations, for the Executive Council's consideration, on implementation action. The basic information which forms the foundation for this strategy is consolidated in Appendices I to XVI.

2. STRATEGIC GOALS AND OBJECTIVES

2.1 The inter-related set of strategic goals, objectives, strategies and plans are summarised in Table 1.

2.2 The strategic goal is:

to systematically improve the use of satellite data for meteorological and hydrological applications over the next 10 years in all Member countries, with a focus on meeting the needs of the developing countries.

2.3 In support of the strategic goal there are three major strategic objectives:

(a) To build on the existing infrastructure in such a way which ensures that the time scale and manner in which initiatives for improving satellite data utilisation are introduced, are consistent with the capabilities of the users to absorb and sustain them independently in their own operational environment;

(b) To focus on the developing countries, directing particular attention to systematically improving the level of expertise of instructors at all RMTCs in the utilisation of satellite data;

(c) To anticipate future trends in satellite data applications and in education and training techniques, so that new developments can flow through to operational users quickly and efficiently.

3. MAJOR STRATEGIES AND PLANS FOR BUILDING ON THE EXISTING INFRASTRUCTURE

3.1 The existing infrastructure has to provide the starting point for the implementation of any strategy to improve the utilisation of satellite data over the next 10 years, but it would be wise to build slowly and steadily upon it, focusing the very limited resources on key priority areas and consolidating progress on the way.

3.2 Planned scientific and technological revolutions are often achieved more effectively if they are programmed to occur incrementally over an extended period, thus allowing people the time they really require to accept the need for change, to fully absorb the changes, and to actively participate in implementing changes in work practices so that the benefits ultimately flow through to the end customer.

3.3 While people are being trained in new systems and application techniques, they must be taught about the supporting infrastructure for their working environment, which itself will need to change. This point was made by the WMO Secretary-General in summarising the initial OWSE-AF experience with training in the use of information transmitted through MDD. He advised the EC Panel of Experts on Education and Training in October 1991 that:

∀ three main areas require training when new technology is implemented in developing countries: (1) the operation and maintenance of the facilities; (2) the use of the information; and (3) the infrastructure supporting the facilities. (This infrastructure includes functional responsibilities, organisational structure, management principles and data quality control).

Table 1.

GOAL	OBJECTIVES	STRATEGIES	PLANS
SYSTEMATICALLY IMPROVE THE USE OF SATELLITE DATA FOR METEOROLOGY AND OPERATIONAL HYDROLOGY	BUILD ON THE EXISTING INFRASTRUCTURE	INTEGRATE WITH ETRP LONG TERM PLAN 1992-2001 USE THE WHOLE INFRASTRUCTURE TAILOR TRAINING MATERIAL TO SUIT THE INFRASTRUCTURE MINIMISE COSTS AND MAXIMISE COST-EFFECTIVENESS	DEVELOP ADMINISTRATIVE AND CO-ORDINATION MACHINERY INTEGRATE SATELLITE TRAINING TIMETABLE WITH ETRP ACTIVITIES LINKS TO NATIONAL TRAINING INSTITUTES, UNIVERSITIES, ETC CO-ORDINATED PREPARTION OF SATELLITE TRAINING MODULES IDENTIFY EXPERTS IN SATELLITE TRAINING TOPICS UPGRADE INVENTORY OF TRAINING MATERIAL UPGRADE OF SATELLITE TRAINING LIBRARY LANGUAGE TRANSLATION OF SUITABLE TRAINING MODULES STREAMLINE ACCESS TO SATELLITE TRAINING INFORMATION SYSTEMS INCORPORATE GEOGRAPHIC INFORMATION SYSTEMS IDENTIFY "BASIC CORE""ADVANCED" AND "VERY ADVANCED" TOPICS FOCUS FUNDS AND SPONSORSHIP ON FEWER ACTIVITIES COMBINE SOME RESEARCH AND TRAINING FELLOWSHIPS MAKE MORE USE OF BARTER SYSTEM TO OFFSET COSTS DEVELOP STANDARD LOW-COST EQUIPMENT SPECIFICATIONS INVESTIGATE BULK PURCHASE ARRANGEMENTS UNDERTAKE FULL COST ANALYSIS AND RE-EVALUATE PLAN

Table 1 (continued)

GOAL	OBJECTIVES	STRATEGIES	PLANS
SYSTEMATICALLY IMPROVE THE USE OF SATELLITE DATA FOR METEOROLOGY AND OPERATIONAL HYDROLOGY (CONT)	FOCUS ON THE DEVELOPING COUNTRIES	DESIGNATE SIX RMTCs AS SPECIAL SATELLITE TRAINING CENTRES IMPROVE SATELLITE TRAINING FOR ALL RMTC INSTRUCTORS STANDARDISE SATELLITE TRAINING FACILITIES AT RMTCs IMPROVED NATIONAL TRAINING INSTITUTION SUPPORT FOR RMTCs SATELLITE EXPERTS AS CONSULTANTS IN TRAINING AT RMTCs ROLLING PROGRAMME OF SATELLITE TRAINING SEMINARS	DEVELOP DETAILED MANAGEMENT PLAN FOR SPECIALIST RMTCs DEVELOP AT LEAST ONE SATELLITE SPECIALIST INSTRUCTOR PER RMTC RMTC LINKS TO SATELLITE OPERATOR SPONSORED ACTIVITIES CO-ORDINATE WITH SCHOTI FOR RMTC SUPPORT LINK RMTCs TO THE UPGRADED SATELLITE INFORMATION NETWORK UPGRADE RMTC SATELLITE TRAINING CURRICULUM HOLD ALL SATELLITE TRAINING EVENTS AT SPECIALIST RMTCs ATTACH EXPERTS TO SPECIALIST RMTCs AS CONSULTANT TRAINERS TRAINING FELLOWSHIP ASSIGNMENTS AT RMTCs BULK PURCHASE OF STANDARD EQUIPMENT FOR RMTCs RMTC INSTRUCTORS TO IMPLEMENT "ON THE SPOT" TRAINING IMPROVED ROLLING TRAINING SEMINARS FOR RMTCs INSTAL AND UTILISE MDD SYSTEM AT RMTCs

	ANTICIPATE FUTURE TRENDS	CO-ORDINATION WITH CEOS AND CGMS BETTER PLANNED TRAINING FOR NEW SATELLITE SYSTEMS BETTER AWARENESS OF NEW TRAINING TECHNIQUES & SYSTEMS FOCUS ON ATMOSPHERIC CHEMISTRY, OCEAN AND CLIMATE	CO-ORDINATION WITH CEOS & CGMS ON FUTURE SATELLITE ACTIVITIES TRAINING MODULES TO BE PLANNED FOR ALL NEW SATELLITES FURTHER STREAMLINE ELECTRONIC BULLETIN BOARD SYSTEM MONITOR AND TEST CAL AND OTHER NEW TRAINING TECHNOLOGY OPTIMISE OWSE-AF OUTCOME AND MAYBE EXTEND TO OTHER REGIONS DEVELOP TRAINING FOR ADVANCED SYSTEMS (SOUNDERS, DERIVED WINDS)| MONITOR ATMOS. CHEMISTRY OCEAN & CLIMATE APPLICATIONS

- ∀ the implementation of new technologies is placing a major set of new stresses on the training required. It is not sufficient just to provide training in the normal operation of the facility or the application of the data. Training must also be provided on the overall system in which the technologies are embedded, the use of the new information which is becoming available, and on self-reliance.

3.4 The EC Panel proposes four key strategies for building on the existing infrastructure: (a) integrate with the ETRP Long-term Plan 1992-2001; (b) use the whole infrastructure; (c) tailor training material to suit the infrastructure; and (d) minimise costs and maximise cost-effectiveness.

Integrate with the ETRP Long-term Plan 1992-2001

3.5 This strategy is designed to ensure that plans to specifically improve satellite data utilisation are injected systematically into the basic WMO education and training framework, are properly co-ordinated, are implemented in compliance with professional education and training standards, and can be properly evaluated over time. The major tasks (some of which have been partially completed by the EC Panel of Experts/CBS WG on Satellites) required under this strategy are:

(a) Develop the necessary administrative machinery for overall co-ordination, funding and implementation of the plan;

(b) Further develop the overall budgetary and human resource requirements for the strategy and then re-evaluate the viability of the plan;

(c) Further develop the list of satellite training topics and related experts on satellite data utilisation, from as many countries as possible, who have teaching competency and could assist in various training activities. Use this as a basis for refining the draft programme of training activities and its integration with the ETRP core training programme;

(d) Progressively upgrade the WMO training library's selection of publications on satellite applications;

(e) Significantly improve the ETRP's existing inventory of texts, workbooks, audio tapes, slides, videotapes and other forms of training modules on satellite applications. Expand this to incorporate advanced technologies such as CD-ROM and IVD (Interactive Video Disc) when these are sufficiently proven and in more general use.

(f) Develop a systematic programme of translation of key satellite education and training material into the official and working languages of the WMO;

(g) Upgrade, and streamline international access to, the existing information service on education and training in the use of satellite data. Improve the data base and classification system, streamline the data dissemination process and work towards the establishment of an electronic bulletin board (EBB) system linked to the ETRP;

(h) Develop a strategy for the integration of Geographic Information Systems (GIS) with satellite data application techniques. This is particularly important for agricultural, hydrological and climate applications;

(i) Develop a system for monitoring and reviewing the effectiveness of the overall strategy.

3.6 The EC Panel's consolidated status reports relevant to the above strategy and tasks are contained in the Appendices to this document as follows:

Appendix I:	Action plan for the co-ordination of activities to improve the use of satellite data with the activities of the Education and Training Programme (ETRP) Long-term Plan 1992-2001.
Appendix II:	A list of experts in the use of satellite data for meteorology and operational hydrology.
Appendix III:	Status report on training modules and publications on satellite data utilisation.
Appendix IV:	Status report on information and computer-assisted learning systems for satellite education and training activities.

Use the whole infrastructure

3.7 This strategy is designed to maximise benefits by making integrated use of the whole infrastructure, rather than just a particular part of it. This should also enable funding, which is fragmented across the whole infrastructure, to be focused more effectively on the common goal.

3.8 The use of the whole infrastructure is both complementary and supplementary to all the other strategies in the plan. It is the cement that bonds everything together. This strategy is intended to serve the full spectrum of needs, from the least developed to the most developed countries, but should be applied in such a way that the focus is always on the needs of the developing countries. Thus, while all WMO Members continue to benefit as time goes by, some (the least developed) will benefit more than others. In this way the gap in satellite data utilisation capability between the least developed and more developed countries should become continually narrower.

3.9 A matrix showing the inter-relationship between various parts of the infrastructure and the various activities needed to improve the use of satellite data, is given in Table 2. Note that all elements of the existing infrastructure are shown as focusing on the needs of the developing countries.

3.10 There is a lot of overlap between the tasks required to implement this strategy and the tasks required for the other strategies in the plan. The major task is to develop effective two-way connectors between the key satellite education and training activities in the developing countries (especially in the RMTCs) and the various components of the infrastructure listed in the left hand column of Table 2.

3.11 The EC Panel's status report on the existing infrastructure for education and training in satellite data utilisation in WMO Member countries is given in Appendix V.

Tailor training material to suit the infrastructure

3.12 To complement the above two strategies, the third strategy is to tailor the design and content of new education and training material on satellites to best suit the part of the infrastructure into which it is being injected. The strategic concept is to classify all education and training material as "basic", "advanced" and "fully advanced" and to inject it at the appropriate level of user capability, taking into account the status of satellite data reception and processing systems to which the target user has access.

3.13 It is proposed that the Education and Training Programme (ETRP) should look after the "basic" or "core" training in satellite data utilisation and its integration into overall training programmes. The CBS WG on Satellites should concentrate on identifying the "advanced" and "very advanced" topics, the experts in those topics and co-ordination of the development of suitable training material and schedules. These would be delivered in the way of special seminars, training courses or remote learning modules designed for "on the spot" application. The CBS WG on Satellites would advise the WMO Secretariat responsible for the ETRP on these aspects and the Secretariat would co-ordinate the implementation of the training.

3.14 Core topics for education and training on the use of satellite data should be regarded as suitable for incorporation into any general training course on meteorology and operational hydrology. The EC Panel/CBS WG's status report on general reference works on basic training in meteorology and operational hydrology has previously been circulated. The Panel/WG's guidelines on the incorporation of satellite applications topics into existing course curricula for WMO Class I-IV personnel is given in Appendix VI.

3.15 The following major tasks are required to improve the effectiveness of education and training in "basic" satellite applications within the existing infrastructure. It is proposed that these tasks should be undertaken co-operatively by the EC Panel/CBS WG on Satellites and the WMO Secretariat responsible for the ETRP:

(a) Translation of training material and special training modules (e.g. audio-visual and computerise modules) into other languages for local use. The EC Panel/CBS WG's evaluation of the suitability of some training publications on satellite imagery for translation into languages other than English or French has previously been circulated. Further work is needed along these lines, with audio-visual material also being considered. It will also be necessary to ensure that language requirements are addressed in the initial stages of the development of all new training material on satellites.

(b) Development of basic training material and courses on the maintenance and ongoing system support of satellite reception and processing facilities. This should be aimed specifically at personnel in the developing countries.

(c) Development of low cost workstations and software systems for satellite data utilisation. There are several such systems available, or under development in various parts of the world suitable for reception and utilisation of APT, HRPT, and geostationary satellite WEFAX transmissions. The Satellite Meteorology Center of the People's Republic of China has also developed a low cost PC-286 and -386 based system for the reception and use of Stretched-VISSR geostationary satellite data. This is described in Appendix VIII.

Minimise costs and maximise cost-effectiveness

3.16 A workable strategy for achieving adequate funding for satellite education and training activities is the critical element for success of the overall strategic goal. It is also the most difficult to achieve. Funding is potentially available from a number of sources (e.g. WMO Programmes, VCP, FAO, ICAO, national foreign aid programmes, satellite operators, private and commercial sponsors) but resources will continue to be tight and there will be a lot of competition for the small amount of funds that are available.

3.17 In essence, funding limitations will act as a strong brake on the rate of implementation of satellite training programmes, so it is important to adopt a strategy that minimises costs. This strategy applies particularly to all the activities aimed at improving the use of satellite data in the developing countries, which is discussed in the next section of this document.

3.18 Experience has shown that cost sharing models which rely on assessed (in contrast to voluntary) contributions and long-term commitments have little chance of success. Therefore, it is proposed to adopt a co-operative funding mechanism which strives for more efficient use of the existing funded projects and funding sources by focusing them all on a few clearly identified high priority satellite education and training activities. The first priority should be to focus (to the maximum extent possible) all the currently funded activities and all new funding on upgrading the satellite education and training facilities and capabilities of one RMTC in each Region.

3.19 The major plans proposed for minimising costs and maximising cost-effectiveness are:

(a) Focus the use of the WMO's funding pool and as much as possible of the activities funded from elsewhere, on upgrading satellite education and training facilities in just one RMTC in each Region. This is more cost-effective because funds will be shared among 6 instead of 17 RMTCs. It also provides a buffer against the impact of continuing shrinkage in the total funds available for satellite activities;

(b) Develop specifications and standards for low-cost design satellite data receiving equipment, systems, workstations and related training facilities for the RMTCs specialising in satellite applications, and request tenders for the bulk supply of equipment and spares. A list of the cheapest suitable contractors could then be compiled and equipment and spares would be purchased from these firms. This should reduce unit costs and improve overall efficiency, particularly if the specifications include the Open Systems Interconnectivity arrangements designed to ensure compatibility of different hardware and software.

(c) Persuade the satellite operators, via the WMO's co-ordination with CEOS and CGMS, to make basic education and training programmes an integral part of their forward planning. The costs could then be identified up front and carefully factored into the very large funding envelope required to launch and operate a satellite. At present some operators are perceived to introduce education and training post-launch, as something as an afterthought or perhaps as a rather expensive marketing ploy. Additionally, each satellite operator participating in the space-based sub-system of the GOS should be requested to sponsor at least one of the six specialized RMTCs with regard to the satellite training programme, facilities and expertise required

(d) Hold satellite training courses and seminars exclusively in the satellite specialising RMTCs instead of in a host country where costs could be higher.

(e) Wherever possible, ensure that fellowship assignments for training in satellite applications are made within the candidate's home region, taking advantage of the RMTC that specialises in satellite applications. This would reverse the current, more costly, situation in which the majority of fellowships are assigned outside the home region. The success of this plan depends on the success and rate of implementation of the plans to upgrade the satellite training facilities and capabilities of key RMTCs;

(f) Convert some of the "research" fellowships in satellite applications into "research and training" fellowships which require a specific training outcome. This would involve a longer stay but would be an incremental benefit to the Fellow, the host RMTC and possibly also a host meteorological or hydrological agency;

(g) Make greater use of the barter system, whereby goods and services are traded and value added, instead of the levying of financial contributions for the value adding process or the delivery of the service. For example, agencies may be prepared to offer satellite applications training material in return for translation of that material, or for some other service of roughly equivalent value.

3.20 A full costing and cash flow analysis of the overall plan has not been done and remains one of the key tasks to be undertaken. Cost estimates for some of the key activities (eg: RMTC 5-year training programme) are contained in Appendix VIII.

Table 2: Matrix showing the inter-relationship between various parts of the existing infrastructure and the various activities needed to improve the use of satellite data.

COMPONENT OF THE EXISTING INFRASTRUCTURE	COORDINATION AND PLANNING	FUNDING SUPPORT	PROVIDE/ARRANGE SATELLITE EXPERTS	PROVIDE TRAINING MODULES	DO THE TRAINING	FOCUS ON DEVELOPING COUNTRIES	FOCUS ON ADVANCED APPLICATIONS	FOCUS ON NEEDS OF HYDROLOGY	TRAINING MATERIALS INVENTORY	TRAINING INFORMATION SERVICE
WMO EDUCATION AND TRAINING PROGRAMME	x	x		x		x		x	x	x
WMO TECHNICAL COOPERATION PROGRAMME		x	x	x	x	x				
WMO CBS WG ON SATELLITES	x		x			x	x	x	x	x
OTHER WMO COMMISSIONS, PROGRAMMES, WORKING GROUPS AND RAPPORTEURS	x	x	x	x		x		x		x
OPERATIONAL WWW SYSTEMS EVALUATIONS (OWSE)	x		x	x		x				
SCHOTI COORDINATING COMMITTEE	x		x	x		x	x	x	x	x
CEOS AND CGMS ACTIVITIES	x		x			x	x		x	x
GCOS AND GOOS ACTIVITIES	x	x	x			x	x			x
RMTC ACTIVITIES				x	x	x		x	x	x
TRAINING INSTITUTIONS OF NATIONAL METEOROLOGICAL AND HYDROLOGICAL SERVICES	x	x	x	x	x	x	x	x	x	x
UNIVERSITIES/RESEARCH INSTITUTES			x	x	x	x	x	x	x	x
ESA & EUMETSAT TRAINING PROGRAMME			x	x	x	x	x	x	x	x
NOAA/NESDIS SATELLITE APPLICATIONS TRAINING PROGRAMMES			x	x	x	x	x	x	x	x
COOPERATIVE PROGRAMME FOR OPERATIONAL METEOROLOGY EDUCATION & TRAINING (COMET)			x	x	x	x	x	x	x	x
NATIONAL FOREIGN AID PROGRAMMES		x	x	x	x	x				
UN EDUCATION & TRAINING FELLOWSHIP OPPORTUNITIES		x		x		x		x		
ETRP REGIONAL SEMINARS AND FELLOWSHIPS		x		x	x	x		x		
OTHER		x	x	x	x	x	x	x		x

4. MAJOR STRATEGIES AND PLANS FOR FOCUSING ON DEVELOPING COUNTRIES

4.1 The Executive Council endorsed two key strategies for focusing on the needs of developing countries: (a) upgrading the training of RMTC instructors; and (b) provision of "on the spot" training, which is interpreted to mean that training for RMTC instructors and the subsequent training of operational personnel should take place at the RMTCs. The EC Panel believes that the strategic concept of "on the spot" training could be extended in the future to embrace the idea that training of operational personnel could occur not only at the appropriate RMTC, but also in the countries where operational personnel are located and even in local operational centres. This could be achieved via the use of remote learning systems and training modules.

4.2 The EC Panel has done a comprehensive analysis of the status of, and future needs for, satellite applications training in the RMTCs and has devised a number of strategies and plans in addition to the above strategies endorsed by the Executive Council. These plans have emerged from the information contained in some of the Appendices referenced earlier in this document and from the more specific analyses of RMTC needs which are contained in additional Appendices referenced below:

Appendix II	(List of experts in the use of satellite data for meteorology and operational hydrology);
Appendix III	(Status report on training modules and publications on satellite data utilisation);
Appendix IV	(Status report on information systems on satellite education and training material);
Appendix VI	(Guidelines on the incorporation of satellite application topics into existing course curricula for WMO Class I-IV personnel);
Appendix IX	(List of WMO RMTCs);
Appendix X	(Status report on RMTC teaching staff, student enrolment, training programmes and short-term fellowships);
Appendix XI	(Status report on RMTC satellite applications education and training activities);
Appendix XII	(Guidelines on designating RMTCs as Centres of Excellence)
Appendix XIII	(Status report on the availability of training assistance for RMTC instructors);
Appendix XIV	(Proposals by NOAA/NESDIS for satellite technology and applications training programmes);
Appendix XV	(Status report on satellite ground stations and their status in the developing countries);
Appendix XVI	(Status report on the satellite education and training requirements for hydrology).

4.3 The EC Panel proposes eight key strategies for focusing on the developing countries: (a) establish special satellite training centres at six RMTCs; (b) improve the satellite application training capability of RMTC instructors; (c) develop standard low cost satellite applications facilities for RMTCs; (d) improve co-ordination between RMTCs and the training institutions of national meteorological and hydrological services; (e) use satellite experts as consultants; (f) implement a rolling programme of satellite training seminars; (g) upgrade the satellite education and training curriculum; and (h) that each satellite operator participating in the space-based sub-system of the GOS volunteer to sponsor at least one of the six specialized RMTCs with regard to the satellite training programme, facilities and expertise required.

4.4 All these strategies are supported to varying degrees by the strategies and plans proposed in Section 3 above (Building on the existing infrastructure) and in Section 5 below (Anticipating future trends).

Establish special training centres at six RMTCs

4.5 This strategy is designed to provide a minimum network, within the WMO's RMTC framework, of specialized satellite applications training centres ("centres of excellence") strategically located around the globe. This is the major strategy of the entire strategic plan and the activities required to support it should have the highest overall priority. It provides a focal point for all the other strategies in the plan and a focal point for directing funding, co-operative programmes and other scarce resources to obtain maximum overall cost-effectiveness.

4.6 It is proposed that each specialized RMTC would be:

∀ equipped with standard facilities for education and training in satellite data utilisation for meteorology and operational hydrology;

∀ provided with standard satellite applications training modules in the principal languages of the WMO Regional Association in which the RMTC is located;

∀ staffed with at least one instructor who is specially trained in satellite data utilisation;

∀ designated as the principal location for the training of instructors from all RMTC's in satellite data application techniques;

∀ designated as the principal location for the proposed rolling programme of special training seminars in satellite data utilisation, the attachment of international experts in special fields of satellite data applications for meteorology and operational hydrology, and the development of specially tailored satellite education and training modules to suit the WMO Regional Association in which the RMTC is located;

∀ supported by the training institutions of the national meteorological and hydrological services in the WMO Regional Association in which the RMTC is located; and

∀ linked to a satellite education and training information network to be developed within WMO with connections to the electronic bulletin boards and information services of the satellite operators and major relevant education and training agencies.

- ∀ sponsored by one satellite operator that participates in the space-based sub-system of the GOS with regard to the satellite training programme, facilities and expertise required.

4.7 The selection of 6 out of the 17 RMTCs is an arbitrary judgement based on the factors such as geographical location, capability to service the needs of the entire WMO Region, the need to strengthen satellite data utilisation and training in particular locations, and the more efficient overall use of scarce (and probably shrinking) resources. The other 11 RMTCs would still implement satellite data utilisation training programmes via their standard curricula but would not specialise in it. They could be designated as specialized training centres in other fields as appropriate. Some guidelines for this are given in Appendix XII.

4.8 The involvement of RMTCs in providing regular training in satellite meteorology in most cases would entail substantial investments and development of human resources. Only a few RMTCs now offer regular international courses in satellite meteorology, and, while most RMTCs may serve well as a host for relevant training courses, it would be neither cost-effective nor practical for many of them to maintain the required special facilities for satellite training on a more or less permanent basis. It would be better to try to set up one RMTC per region with the appropriate satellite training facilities and courses, on the condition that the national meteorological services and satellite operators in the region provide adequate scientific and technical support.

4.9 After a very preliminary evaluation, the EC Panel suggests that the following six RMTCs be further considered as specialized centres for training in satellite data utilisation: Kenya (Nairobi) in RA I; Iraq (Baghdad) and India (Pune) in RA II; Brazil (Belem) in RA III; Barbados (Barbados) in RA IV; and the Philippines (Quezon City) in RA V. It is not considered necessary to have a specialized satellite training centre at the RMTC in RA VI.

4.10 The major tasks required to implement this strategy are:

(a) Develop the necessary administrative machinery overall management, co-ordination, funding and implementation;

(b) Develop a detailed plan within the approved strategic framework;

(c) Develop the necessary specialized training programmes for RMTC instructors, the special training modules, the rolling programme of special satellite training seminars, the linked information network, etc. (Tasks for each of these are discussed under other strategies, below);

(d) Establish the necessary links with training institutions of the national meteorological and hydrological services. A mechanism for doing this is emerging via the activities of CO-COM SCHOTI (the Co-ordinating Committee of the WMO Standing Conference of Heads of Training Institutions of National Meteorological Services) and the ETRP Secretariat; and

(e) Directly involve the satellite operators by requesting that each operator participating in the space-based sub-system of the GOS sponsor at least one of the six specialized RMTCs with regard to the satellite training programme, facilities and expertise required.

4.11 The EC Panel's assessments of the status of RMTC training activities is given in Appendices XII and XIII. These contain summaries of RMTC teaching staff, student enrolment, satellite applications training programmes, Fellowship programmes, and the major problems currently being experienced by RMTCs.

Improve the satellite applications training capability of RMTC instructors

4.12 This strategy is designed to systematically upgrade the training of RMTC instructors as a major vehicle for achieving long-term, progressive improvements in satellite applications in the developing countries. The strategy is aimed at all RMTC instructors but also aims to develop at least one instructor in each RMTC who is a designated specialist in satellite applications training.

4.13 The new satellite applications skills acquired by the RMTC instructors will be used to provide a solid foundation for training successive generations of indigenous Regional Association personnel "on the spot" in their own environment with training matched to suit the particular state of scientific and technological development that exists locally at the time. This process will also be applied progressively to the local development of regional distance learning modules as a logical extension of the "on the spot" concept for ongoing training.

4.14 The EC Panel/CBS WG's status report on the availability of training assistance to RMTC instructors is given in Appendix XIII. Training assistance is available from a number of sources, such as those indicated below. Use could be made of all these sources in an integrated programme.

(a) ETRP Regional Training Seminars and Fellowships. Under the WMO regular budget the ETRP has arranged regional training seminars for RMTC instructors in RA III/IV in 1992, RA II/V in 1993 and RA I/VI in 1994. Each seminar will include a topic on remote sensing (satellite) applications. Training Fellowships are also available.

(b) NOAA/NESDIS Satellite Applications Laboratory. NOAA/NESDIS has proposed some initiatives (described in Appendix XIV) for satellite technology and applications training programmes and seminars for RMTCs over a 5-year period. The concept is that visiting satellite experts would undertake a logical sequence of training visits starting with the basics of remote sensing and progressing to more complex applications. In addition to teaching a course to students as a demonstration, the visiting expert would provide instruction to the RMTC instructors so they could teach the same course and use the same materials provided by the expert. These proposals remain unfunded by both NESDIS and WMO at this stage.

(c) ESA Training Activities. The European Space Agency (ESA) offers a variety of satellite applications training activities which could be used by RMTC instructors. In particular ESA provides training manuals (series ESA-TM-xxx) and organises or co-sponsors training courses in various parts of the world. Some of these are aimed specifically at introducing users to the new types of data provided on ESA satellites (e.g. on ERS-1).

(d) Training Institutions of National Meteorological and Hydrological Services. The activities of training institutions of National Meteorological Services are now becoming better co-ordinated. Collectively they have a large pool of expertise which could be drawn upon and directed towards improved training of RMTC instructors. Many of these institutions have developed satellite applications training packages which could be adapted for, or transported into RMTCs.

(e) National Foreign Aid Programmes. These can be a source of assistance for RMTC instructors, provided the training activities are carefully considered and incorporated into the programme plans from the early planning stages. These types of programmes have certain weaknesses: they are often expensive and consume considerable time and personnel effort from the donor country; they have a propensity by the donor country to offer systems that are too advanced for the recipient country's basic needs; they tend to proliferate non-standard equipment, software and systems; and they often leave the donor agencies with an unmanageable problem in purchasing spares and consumables to keep the system running.

4.15 The major tasks required to implement this strategy are inherent in the list of tasks given above for establishing specially designated RMTCs.

Develop standard low cost satellite applications facilities for RMTCs

4.16 This strategy is designed primarily as a cost-effectiveness and an efficiency strategy and, in the longer term, would lead to the adoption by the WMO RMTCs of the new international standards now being developed for Open Systems Interconnectivity (OSI). The adoption of standard equipment and software systems for satellite training purposes in the RMTCs (especially in specialised satellite training centres) would have significant advantages in streamlining the development, implementation and exchange of training modules and could have significant cost savings for capital equipment and consumables via bulk purchase arrangements.

4.17 The strategy is also designed to cater for the fact that many of the more sophisticated and more expensive satellite processing and display systems require a level of supporting infrastructure (communications, computing, local supply and maintenance services, etc) that is beyond the current capacity of the developing countries to provide. Cheaper, simpler systems should be quite adequate for the time being.

4.18 There are several reasonably cheap systems available, or under development in various parts of the world suitable for reception and utilisation of APT, HRPT, and geostationary satellite WEFAX transmissions. The Satellite Meteorology Center of the People's Republic of China has also developed a low cost PC-286 and -386 based system (described in Appendix VII) for the reception and use of Stretched-VISSR geostationary satellite data. This is quite a sophisticated facility at quite a low cost.

4.19 The preliminary results of OWSE-AF on the use of the MDD system in Africa have been very encouraging. This system provides at a reasonable cost, high quality capability for developing countries to receive basic meteorological data, including charts and satellite imagery. The consolidation of this system and its extension to other WMO regions in the future will provide a very important facility for improving the cost-effectiveness of training in the RMTCs.

4.20 The major tasks needed to implement this strategy are:

(a) Consult with the CBS WG on Data Processing, the CBS WG on Telecommunications, the OWSE-AF project, the WMO Standing Committee of Heads of Training Institutions of National Meteorological Services (SCHOTI), and other similar groups or projects on the most appropriate standards and facilities for RMTC satellite training facilities;

(b) Develop a set of standards and a system design suitable for putting to open international tender;

(c) Call tenders for the bulk supply of equipment and spares. A list of the cheapest suitable contractors could then be compiled and equipment and spares would be purchased from these firms;

(d) Investigate the dedicated use of one of the MDDs' extra channels for disseminating

WMO information (including satellite related activities) in its area of coverage, either from an uplink station to be established in Geneva or by identifying a time slot for such information within the current MDD operational schedule.

Improve co-ordination between RMTCs and the training institutions of national meteorological and operational hydrological services

4.21 This strategy is designed as the major connection between the development and ongoing maintenance of satellite applications training in the RMTCs, especially those designated as centres specialising in satellite applications. Collectively there is a large pool of expertise and supporting infrastructure in the national training institutions which must be drawn upon if the overall plan is to succeed.

4.22 A mechanism for implementing this strategy is already emerging via the activities of the Co-ordinating Committee (CO-COM) of SCHOTI and its links with the ETRP. These links will be further strengthened if the strategic plan for improving satellite utilisation is fully integrated within the ETRP Long-term Plan, as recommended in Section 3 of this document.

Use satellite experts as consultants

4.23 This strategy is designed to take advantage of the expertise that exists internationally and could be pooled and focused on upgrading the skills of RMTC instructors as well as on the provision of special satellite applications seminars for a broader audience. The concept is that designated experts, with teaching qualifications of proven teaching capability, would be called upon to act as consultants in the development of training modules, would undertake short-term attachments to RMTCs and would conduct special training seminars. A specific example of how this strategy would operate is contained in the NOAA/NESDIS proposal described in Appendix XIV.

4.24 The EC Panel has prepared a preliminary list of experts (suitably qualified or experienced in teaching) in various basic and advanced satellite applications techniques. This is given in Appendix II. Many of these people are lecturers at national training institutes. Their participation would help reinforce the above strategy of strengthening the links between these institutions and the RMTCs.

4.25 Further development and consolidation of this strategy is required and, in particular, a specific funding mechanism needs to be identified. This could comprise a combination of a rolling programme of one or two consultancies per year (such as proposed in Appendix XIV) funded from within the ETRP, plus some consultancies on a voluntary or on an externally sponsored basis.

Implement a rolling programme of satellite training seminars

4.26 This strategy has been referred to several times previously in this document and is included here for completeness. Traditionally, this has been the only way of providing a focus on specialised training events for developing countries that is fundable within the WMO system.

4.27 An unfunded proposal is contained in the NOAA/NESDIS initiatives described in Appendix XIV. It is proposed to draw on support from the whole infrastructure to make the seminars in this programme more effective and more frequent.

Involve the satellite operators

4.28 This strategy is designed to maximize the participation of all organizations that have a vested interest in improving the use of satellite data through a more agressive training and education programme. One such group of organizations is those satellite operators contributing to the space-based sub-system of the GOS. Many satellite operators already have an existing infrastructure dedicated to training. Fortunately, the suite of satellite operators are strategically distributed to provide a close correspondence to the WMO regions. Additionally, the satellite operators have the resources, either financially or in kind, to make a substantial contribution to WMO's satellite education and training programme. The satellite operators also have a vested interest in improving the awareness, utilization and effectiveness of the data derived from their satellites.

5. MAJOR STRATEGIES AND PLANS FOR ANTICIPATING FUTURE TRENDS

5.1 Strategies for anticipating future trends are an essential part of any 10 year strategic plan because this enables rolling plans to be formulated for the smooth and rapid transfer of new developments into operations and services.

5.2 The remote sensing instruments which will be on board the new generation of operational satellites scheduled between now and the early 2000s are already known and some are now being tested on satellites in an experimental mode. The EC Panel/CBS WG on Satellites has drafted, for approval by the Executive Council, a comprehensive set of WMO satellite observation requirements up to the year 2010. The satellite operators and the research and development community will take these requirements into account in their forward planning.

5.3 The phenomenal rate of development in technologies such as communications and computing show little immediate signs of slowing. These technologies continue to have major benefits for satellite data utilisation because they offer the capability to receive, process, disseminate and display increasingly large amounts of data faster and faster, while at the same time reducing costs and system size. Small but quite powerful and affordable desk top workstations are now in general use in the more developed countries and are penetrating into the least developed countries.

5.4 Concurrently, rapid advances are being made in education and training systems and technologies with the experimental use of Computer Aided Learning (CAL) systems and CD-ROM. In turn, this is showing up serious deficiencies in satellite data archival and data base management systems which need to be significantly improved to make these new training technologies fully effective.

5.5 The new generation of earth resources satellites, which carry active sensors such as synthetic aperture radar, open up new horizons for applications in land use, oceanography, hydrology and the general environmental impacts of climate change and offer substantial benefits monitoring in these fields in the developing countries. These satellites deliver more data (orders of magnitude) than the current generation of meteorological satellites and hence require much larger and more expensive ground stations and extremely expensive data processing, archival and data access facilities. Furthermore, they open up a whole new field of education and training much of which will require very advance knowledge such as a thorough understanding of the complexities of interpreting remotely sensed radar imagery and associated data. It will take a long time to impart such knowledge and interpretative skills to large numbers of operational meteorologists and hydrologists.

5.6 Paradoxically, the development trend for the future of the meteorological satellite programme itself has flattened considerably in the past few years and has certainly not kept pace with trends in the communications satellite programme or in the transfer of new technologies into satellite processing, applications and training systems. Programmes are being severely pruned and launch schedules significantly deferred now in almost all satellite operating countries due to economic pressure for the resources to be directed elsewhere (e.g. to social welfare programmes). The new expensive earth resources satellites, with their output focus on climate and environment, are now competing for funds from the funding pool which was once the exclusive domain of the meteorological satellites, whose output focus is essentially on day-to-day weather forecasting.

5.7 Against this background, the EC Panel of Experts on Satellites has devised four major strategies for anticipating future trends in satellite education and training:

(a) Co-ordination with CEOS and CGMS on future satellite activities;

(b) Ensure training modules are developed for all new satellite programmes;

(c) Maintain an awareness of advances in communications and computer-aided learning techniques; and

(d) Focus on applications for atmospheric chemistry, the oceans and climate change.

Co-ordination with CEOS and CGMS on future satellite activities

5.8 This strategy is designed to provide a connection between the satellite operators (represented by CEOS and CGMS), the WMO users (represented by the EC Panel of Experts on satellites and the new CBS Working Group on Satellites) and the WMO instructors (represented by the ETRP) for strategic planning purposes. The basic co-ordination mechanisms have already been established via cross-representation of members of CEOS, CGMS and the EC Panel on key planning and advisory committees and representation of the ETRP Secretariat at the EC Panel/CBS WG meetings.

5.9 Co-ordination will be strengthened by the full integration of the EC Panel's overall strategy into the ETRP Long-tTerm plan as proposed in Section 3 of this document. It will also be essential that WMO continues to be effectively represented on CEOS and CGMS after the formal disbandment of the EC Panel of Experts on Satellites. It is assumed that the Chairman of the CBS WG on Satellites will undertake this role in the future.

Ensure training modules are developed for all new satellite programmes

5.10 This strategy is designed to ensure that applications training programmes become an integral part of the satellite operators' overall planning for future satellite programmes so that users are able to fully utilise new data as soon as it becomes routinely available. Several satellite operators and related organisations (e.g. ESA, EUMETSAT, NOAA/NESDIS) are already doing this but there is a need to involve such programmes and plans more directly in the plans for improving the satellite education and training capabilities of the RMTCs.

5.11 Further work needs to be done on these aspects by the CBS WG on Satellites in consultation with the ETRP and SCHOTI. In particular, the potential impact of future commercialisation of satellite education and training activities needs to be carefully explored.

Maintain awareness of advances in communications and Computer-Aided Learning (CAL) techniques

5.12 This strategy is designed to ensure that advances in various forms of communications and training technology, such as CAL, are carefully considered and integrated into satellite education and training operations at the most appropriate time and in the most cost-effective manner. The initial enthusiasm for leading edge ideas and systems often has to be tempered as new sets of problems emerge with those systems. Extensive operational trials need to be undertaken before new systems are introduced generally.

5.13 The major tasks to be undertaken in support of this strategy are:

(a) Further investigation of information systems and electronic bulletin boards for satellite education and training purposes. The EC Panel's status report on this is given in Appendix IV.

(b) Further investigation of the suitability of CAL and other new education and training technologies for introduction into RMTCs. This should be done in close consultation with SCHOTI (who have a Working Group on CAL and Distance Learning) and ETRP. The EC Panel's status report on CAL and related techniques is also contained in Appendix IV.

(c) Optimisation, for satellite education and training purposes in the developing countries, of the outcome of the Operational World Weather Watch System Evaluation for Africa (OWSE-AF) and any extension of this concept to other Regional Associations. This involves utilisation of the MDD system which appears to be very cost effective for the developing countries.

Focus on applications for atmospheric chemistry, the oceans, and climate change

5.14 This strategy is designed to open a window for future satellite education and training in key areas where there are current deficiencies in remote sensing observation techniques and/or in general knowledge. It is intended to supplement strategies for education and training on advances satellite applications techniques and systems in current use (e.g. vertical sounding retrieval methods, cloud and water vapour drift wind techniques, new applications for hydrology) and recognises the training needs in support of the GCOS and GOOS programmes.

5.15 The selected focal points are atmospheric chemical composition (which is poorly observed by satellite at present and is a critical factor in the monitoring and understanding of climate change), the oceans (to which the above comments apply, but to a lesser extent) and the monitoring of climate change which has emerged as the major focal point for global endeavour and co-operative activities in environmental science for the remainder of the 1990s and well into the next century.

5.16 The development and implementation of training programmes to assist the understanding and application of major new remote sensing instruments such as the multi-channel sounders, the atmospheric pressure sensor and the advanced along track scanning radiometer, will need to be closely monitored. It is envisaged that these tasks would be performed by the CBS WG on Satellites as part of their ongoing activities.

6. **IMPLEMENTATION TIMETABLE**

6.1 It is proposed to implement this strategic plan over the next 10 years in two separate phases:

- Phase 1 (1993-96) will build on, strengthen, and more sharply focus existing activities and plans to improve the use of satellite data in the developing countries, while, at the same time, further develop, prepare, and arrange funding for a broader, longer-term education and training plan for implementation from 1997. A major goal in this phase will be to strengthen the satellite education and training capabilities of six RMTCs.

- ∀ Phase 2 (1997-2001) will see the progressive implementation of the broader based education and training strategy. By 1997 the necessary strengthening of the infrastructure should have been largely completed, an effective funding mechanism should have been developed, the plan should have been trimmed as necessary to fit the available funds, and enough funding should have been secured to begin the first half of the revised implementation phase. A solid, scientifically based programme of education and training in satellite applications should be ready for implementation, together with an effective monitoring and review mechanism.

6.2 The proposed implementation steps and timetables are identified in more detail below:

PHASE 1: BUILD ON AND MORE SHARPLY FOCUS CURRENTLY PROGRAMMED ACTIVITIES WHILE STRENGTHENING AND CONSOLIDATING THE STRATEGIC PLAN.

Remainder of 1993:

- ∀ Executive Council considers the proposed strategy and issues guidelines and directions for implementation.

- ∀ CBS Working Group on Satellites meets to organise the detailed implementation of the strategy. ETRP, SCHOTI, OWSE-AF, CHy, relevant CBS Working Groups and relevant external agencies start to become actively involved in the further development of the strategic planning.

- ∀ All satellite education and training events and activities currently scheduled by the Satellite Activities Office, the ETRP and other parts of the supporting infrastructure continue as planned.

1994-96:

- ∀ All satellite education and training events and activities currently scheduled by the Satellite Activities Office, the ETRP and other parts of the supporting infrastructure continue as planned, but are supplemented progressively by new activities and events emerging from the initial implementation of the strategic plan.

- ∀ Top priority is given to completion of all tasks associated with the strategy for upgrading the satellite education and training facilities and capabilities of the six designated specialized RMTCs. This includes:

  - Development of the necessary administrative machinery overall management, co-ordination, funding and implementation;

  - Development of a detailed management plan within the approved strategic framework;

  - Development of the necessary specialized training programmes for RMTC instructors, special training modules, rolling programme of special satellite training seminars, linked information network, etc.;

- Establishment of the necessary links with training institutions of the national meteorological and hydrological services via CO-COM SCHOTI (the Co-ordinating Committee of the WMO Standing Conference of Heads of Training Institutions of National Meteorological Services) and the ETRP Secretariat;

- Sponsorship by one satellite operator that participates in the space-based sub-system of the GOS with regard to the satellite training programme, facilities and expertise required.

∀ A new standard RMTC satellite training syllabus is finalised by a group of experts from the CBS WG on Satellites in collaboration with ETRP experts. This activity needs to be co-ordinated with existing plans for curriculum development and review under the ETRP calendar.

∀ The proposed costing model is reviewed and modified as necessary. The overall strategic plan is fully costed and funding sources are identified.

∀ WMO standards and specifications are developed, approved and promulgated for low cost satellite reception, processing, display and training equipment. Bulk purchase arrangements are made if possible within the newly developed funding mechanism.

∀ An effective satellite education and training information system is developed and implemented incrementally. This will incorporate existing electronic bulletin boards (EBB)and the possible development of a WMO EBB.

∀ An ongoing review is maintained by the CBS WG on Satellites on developments in education and training technology suitable for satellite applications in meteorology and operational hydrology. Promising systems are evaluated via trial arrangements in the specialized RMTCs.

∀ CBS WG on Satellites makes available for the next Congress's consideration in 1995 a firm and fully costed plan for implementation in the 1996-2000 Programme and Budget.

PHASE 2: PROGRESSIVE IMPLEMENTATION OF MAJOR PLANS

1997:

∀ WMO Congress already approved the plan for 1996-2000.

∀ All satellite education and training events and activities now proceed in accord with this plan.

∀ Implement the new satellite training curriculum at all RMTCs.

1998-2000

∀ Finalise the upgrading of facilities and capabilities of designated RMTCs for satellite education and training.

- ∀ Progressively implement new training technologies at all RMTCs as funds permit, with priority to the satellite specialized RMTCs.
- ∀ Implement all other aspects of the approved plan as funds permit.
- ∀ Monitor and review the progress and effectiveness of the plan and report annually to the Executive Council.
- ∀ Work on extending the plan to 2010 in readiness for the new generation of operational satellites.

2001

- ∀ Report to the Executive Council on the results of the 1996-2000 Plan and seek approval for the new 2001-2010 Plan.

7. MAJOR RECOMMENDATIONS

7.1 The EC panel of Experts on Satellites recommends that the Executive Council:

(a) Notes the comprehensive strategic plan prepared by the EC Panel to improve the use of satellite data in meteorology and operational hydrology over the next 10 years;

(b) Approves, in principle, the strategic directions indicated in the plan and encapsulated in the proposed implementation timetable;

(c) Specifically approves the major strategic element of the plan, which is to upgrade and standardise the satellite education and training facilities at six RMTCs who will be designated as specialized training centres for satellite;

(d) Agrees that the plan should be fully integrated with the Education and Training Programme Third Long Term Plan 1992-2001 and considers the provision of one additional full time staff member to the ETRP to administer and co-ordinate further overall development and implementation of the plan; and

(e) Requests the President of the Commission of Basic Systems to assign the CBS Working Group on Satellites, in co-operation with the EC Panel on Education and Training, the tasks of fine-tuning the strategies, providing expert advice on the further development of the strategy, more clearly identifying six candidates as specialized satellite training centres and making available for the next Congress's consideration in 1995 a firm and fully costed plan for implementation in the 1996-2000 Programme and Budget.

APPENDIX I

Action plan for the co-ordination of activities
to improve the use of satellite data and the activities of the ETRP Long-term Plan 1992-2001.

ETRP PLAN REFERENCE	ACTION ON SATELLITES	RESPONSIBILITIES
Project 61.1 (assessing and meeting training needs)	Compile a list of satellite training topics and related experts on satellite data utilization who can assist in various training activities	CBS WG on Satellites provides information to EDTP Secretariat who co-ordinates action with core training programme
Project 62.1 (training publications)	Prepare texts, tapes, videos, CD-ROM, CAL, and other forms of training modules on satellite applications	CBS WG on Satellites co-ordinates development of modules; EDTP Secretariat arranges translation, etc.
Project 62.2 (WMO training library)	Progressive upgrade of training library on satellite applications	EDTP Secretariat ensures regular upgrade and also maintains and operates library
Projects 62.3,4,5 (RMTC activities)	Plan and implement a programme of visits and secondments of satellite experts to RMTCs	CBS WG does the planning, EDTP Secretariat co-ordinates, implements and investigates funding

Preliminary list of experts in the application of satellite data for meteorology and hydrology, who could be used as consultants for developing special training modules or conducting special training courses for RMTC instructors. (These experts have formal teaching qualifications and/or proven capability in education and training) NOTE: List incomplete; input needed from many other countries.

EXPERT	CORE OR BASIC SUBJECTS	ADVANCED SUBJECTS	LANGUAGES
AUSTRALIA			
I. Bell	All normal core topics in meteorology	Advanced synoptic met applications	English
G. Crane		Tropical cyclones	English
B. Ebert		Sea temp., sea ice, rainfall est.	English
D. Griersmith		HRPT applications, volcanic ash, sea temp.	English
J. Le Marshall		TOVS, new vert sounder, cloud drift winds, NDVI, rainfall est.	English
S.West		Tropical cyclones	English
M. Williams	All normal core topics in meteorology	Advanced tropical met. topics	English
(Others could be nominated)	Systems and software installation and maintenance; systems management	Oceanography, ozone, new remote sensing instruments (eg APS, AATST, SAR)	English
AUSTRIA			
Rott		Hydrology	English, German
Zwaatz-Meise	Interpretation of Imagery		English, German
CHAD			
Ndeminga Doumo	Synoptic meteorology		French
CHINA			
Dong Chaohua		TOVS applications	English
Fan Huijun	High latitude applications		English
Fang Zhongyi	Interpretation of imagery, meso- and synoptic scale applications	Advanced synoptic meteorology applications	English
Jiang Jixi	Tropical cyclones		English

Liu Yujie	HRPT applications	Tropical cyclones	English
Sheng Yongwei	Agrometeorology and forestry	Agrometeorology and forestry	English

EXPERT	CORE OR BASIC SUBJECTS	ADVANCED SUBJECTS	LANGUAGES
	CHINA (continued)		
Wu Rongzhang	Hydrology	Hydrology	English
Xu Jianmin	Tropical meteorology	Advanced tropical meteorology	English
	EGYPT		
Ainer Nasr Eid Helmy	Agrometeorology	Advanced agrometeorology	Arabic, English
El-Hussainy Fathy	Hydrology	Advanced hydrology	Arabic, English
Youssef Kamal	Climatology, agrometeorology	Advanced climatology and agrometeorology	Arabic, English
	ETHIOPIA		
Babu Imare	Synoptic meteorology		English, Russian
	FRANCE		
Desbois	All normal core topics in meteorology	Advanced topics for RMTC instructors	French
Hoffman	All normal core topics in meteorology	Advanced topics for RMTC instructors	French
Mercier	All normal core topics in meteorology	Advanced topics for RMTC instructors	French
	GERMANY		
Benesch	Interpretation of imagery, high latitude applications, synoptic and meso- applications, aviation, hydrology, image processing		English, German
Bohm		TOVS data	English, German
Bolle		Advanced agrometeorology	English, German
Burrows		Atmospheric chemistry	English, German
Fischer		Atmospheric chemsitry	English, German
Grabl		Environment, energy, radiation, fisheries and	English, German

		oceanography	
Hasselmann		Fisheries and oceanography	English, German
Janecke	Aviation, most basic core topics		English, German

EXPERT	CORE OR BASIC SUBJECTS	ADVANCED SUBJECTS	LANGUAGES
GERMANY (continued)			
Klaes		TOVS data	English, German
Knottenburg		Image processing	English, German
Kopke		Agrometeorology, environment, energy, radiation	English, German
Kriebel		HRPT applications	English, German
Kurz	Most core topics, water vapour channel, high latitude		English, German
Lopmeier	Agrometeorology		English, German
Neumeister	Hydrology, most core topics	Image processing	English, German
Olesen		TOVS data	English, German
Ottenbacher		Cloud drift winds	English, German
Raschke		Energy, radiation, environment, high latitude applications	English German
Roth		Forestry, agrometeorology	English, German
Ruprecht		AMSU data	English, German
Schlussel		TOVS data	English, German
Schmetz		Cloud drft winds	English, German
Simmern		AMSU data	English, German
Spankuch		Atmospheric chemistry	English, German
Strubing		Fisheries and oceanography	English, German
Warneke	All basic core topics		English, German
Werner		LAWS data	English, German

GHANA			
Okutta William	Hydrology		French, English
GUINEA			
Bah.M.Lamine	Most basic core topics		French, English
Traore Ahmed	Agrometeorology		French, English
KENYA			
Anyamba Kamila	Tropical meteorology	Tropical meteorology	English, Swahili

EXPERT	CORE OR BASIC SUBJECTS	ADVANCED SUBJECTS	LANGUAGES
KENYA (continued)			
Masika S. Richard	Data processing		English
Okola E.Raphel	Tropical meteorology		English, Swahili
NETHERLANDS			
Pransma		TOVS data	English
REUNION			
G. Lakermance	Tropical cyclones		French, English
P.Y. Lemme	Tropical cyclones		French, English
F.Pangrani	Tropical cyclones		French, English
RWANDA			
Bashau Mathias		Energy	French, English
Kayiranga Theoneste	Most basic core topics		French, English
SIERRA LEONE			
Kallon R.Seneste	Communications		English, French
SUDAN			
Ahmed Youssef	Hydrology		Arabic, English
Ali M. Ahmed	Synoptic meteorology		Arabic, English
Mohammed N. Eldain	Applications for numerical weather prediction		Arabic, English, Russian
Paramena Jafferies	Hydrology		Arabic, English
SWEDEN			
Liljas		HRPT applications	English
USA			
R. Achutuni	Agrometeorology	Computer systems, agrometeorology	English
G. Ellrod	Aviation, all general core topics	Advanced applications for aviation and synoptic meteorology	English
M. Mogil	All general core topics	Applications for numerical weather analysis, many other topics	English
J. Purdom	Meso-scale applications	Meso-scale applications	English

R. Schofield	Rainfall estimation, heavy precipitation	rainfall estimation, heavy precipitation	English

EXPERT	CORE OR BASIC SUBJECTS	ADVANCED SUBJECTS	LANGUAGES
	USA (continued)		
R. Zehr	Tropical cyclones	Tropical cyclones	English
(many others could be nominated	All core subjects	sounding systems, wind estimation, global climate change, atmospheric chemistry	English
	JAPAN		
Shigenari Naito	Imagery interpretation, synoptic and meso-scale applications		English
Yoshiyuki Abe		Tropical cyclone applications, applications for the tropics	English
Hideyuki Sasaki	Applications for hydrology		English
Akira Shibata	Applications for fisheries and oceanography	SAR, AMSU and LAWS data, atmospheric pressure sounder	English
Masami Tokuno		Application of HRPT multi-channel data, application of water vapour channel data	English
Toshito Onone		Application of HRPT multi-channel data	English
Hiroyuki Uchida		Derivation of cloud drift winds	English
Tadao Aoki		Applications for atmospheric chemistry	English
Yoshiaki Takeuchi	Use of TOVS data		English
	BRAZIL		
I. Cavalcanti	Imagery interpretation	Synoptic applications	English, Portuguese
M. Ferreira	Remote sensing and digital treatment principles, quantitative applications of meteorological satellite imagery and data	Radiative transfer modelling aimed at environmental satellite applications, quantitative applications, atmospheric soundings	English, Portuguese, (Spanish but not for writing)

N. Ferreira	All normal core topics in meteorology	Synoptic applications	English, Portuguese, (Spanish but not for writing)
M. Gan	Imagery interpretation, meso and synoptic scale applications	Synoptic meteorology	Spanish, Portuguese, English
EXPERT	CORE OR BASIC SUBJECTS	ADVANCED SUBJECTS	LANGUAGES
BRAZIL (continued)			
L. Machado	Tropical meteorology	Structural properties of cloud clusters	French, Portuguese, English
A. Perrella	Imagery interpretation, tropical applications, synoptic and meso-applications, aviation and hydrology applications, image processing		English, Portuguese
J. Sakuragy	Digital imagery treatment, synoptic and meso-scale TOVS applications		Portuguese, English, (Spanish but not for writing)

Status Report on Electronic Information Systems
and Computer-Assisted Learning (CAL) Systems
for Satellite Education and Training Purposes

ELECTRONIC INFORMATION SYSTEMS AND SERVICES

Background

1. Rapid developments are occurring in global telecommunications and the related use of electronic mail, electronic bulletin boards and computer-to-computer file transfers. Major backbones for this shared network are extensive international systems such as Internet and OMNET, which link into national information networks such as the Australian AARNet (Australian Academic Research Network) and similar networks in other countries.

2. Access to electronic bulletin boards is available to individuals or organisations who have access to a personal computer, a suitable modem, and entry to a shared network such as Internet or AARNet. Large amounts of data (such as satellite imagery) can be accessed automatically and often anonymously at very high speed. A potential problem is that usage of these shared networks is virtually uncontrolled and is growing at a much faster rate than planned. Thus, there is a very real danger of network saturation and system collapse from time to time.

3. The costs of accessing and using such networks are variable according to the country of origin. Users (i.e. the host organisation) have to provide the local computers and communications interfaces to use the system, as well as pay the costs of communications links into defined access node locations for the networks. Then there is an annual access fee to the network (which varies according to line speed)and sometimes also a network usage charge or subscriber charge which can vary according to the speed of the communications link required. Once connected to the network, access is usually available to a large number of bulletin boards or other information data bases free of charge, unless the operators of these systems have some local charge or user control arrangements.

Situation in the developing countries

4. Developing nations lack efficient and reliable information systems especially in relaying satellite related activities. This has continued to be a fundamental problem which has posed major constraints on technological transfer. Vital information relating to satellite activities takes a very long time to reach the user community in most developing countries. This needs to be given high-priority attention when drawing up strategies for education and training.

5. The new concept of Meteorological Data Dissemination (MDD) systems works and it has shown great potential in dissemination weather-bulletins via the Meteosat satellite in Africa and the Middle-East where there are quite a number of MDD stations now operating, in fact over 10%. These have greatly enhanced meteorological data availability in Africa. The systems have two up-link stations in Rome and Bracknell which utilise two of the four channels existing on the MDD receivers. Most of these stations are PC-based and this offers a great advantage in that they are both cheap and easy to maintain. The trend now is towards an increase of these MDD stations in Africa and the Middle-East. This offers great potential for disseminating satellite related information via Meteosat as well as via the Global Telecommunications System (GTS). A summary of the OWSE-AF evaluation of the trial use of the MDD system in Africa is given in Attachment 1.

6. Data Collecting platforms (DCP) and Data Retransmission Systems have also shown an

improvement in the availability of data.

7. The use of Electronic Bulletin Boards (EBB) is apparently non-existent in most developing countries, but is considered to have major potential benefits provided that cheap access can be arranged and that high speed telecommunications interfaces are not required. The EUMETSAT EBB is currently considered to provide the best information on satellite related activities for the African Region (RA I) but has limited availability at present because of the requirement to hire a telephone line for access.

8. The Regional Satellite Communication system (RASCOM) for RA I could include a training programme for the future aimed at improving information systems for the Region.

Electronic Bulletin Boards (EBB)

9. A number of satellite related electronic bulletin boards have been developed already:

- ∀ Attachment 2 gives a progress report from the February 1992 CGMS Meeting on the status of the CGMS Electronic Bulletin Board;

- ∀ Attachment 3 gives information on the NOAA/NESDIS EBB to which public access has been discontinued due to budgetary constraints which operates in a complementary fashion to the NOAA/NESDIS bulletin board.

- ∀ Attachment 4 gives information on the EUMETSAT EBB.

Strategy and plans

10. It is important to recognise that the introduction of EBBs and digital information networks is beyond the capacity of many of the developing countries in the short-term. Therefore, plans for further development of such systems should be framed as medium- to long-term activities, rather than immediate high priority activities, so as not to further increase the technological gap between the developed and the least developed countries.

11. As a longer-term strategy, it is proposed that an EBB containing information on satellite applications should be established for access by WMO Member countries using the electronic mail system. This should be done as a sub-project of a broader EBB system under the auspices of the Education and Training Programme. A future role of the CBS WG on Satellites role would be to oversee the preparation of suitable information on satellite applications for inclusion on the ETRP Bulletin Board.

12. The satellite EBB information could be fully self contained, or it could contain references to complementary EBBs, such as the CGMS, the EUMETSAT and the NOAA/NESDIS EBBs, and how to access them. (This latter approach is preferred).

13. Apart from arranging for user access to the EBB, arrangements could also be developed for authorised people (e.g. the ETRP Secretariat, the Satellite Activities Secretariat, Heads of National Training Institutions, CBS Satellite WG members, Heads of RMTCs) to independently update the EBB. This would enable a much quicker transfer of information internationally than is currently available. The CBS WG on Satellites would need to regularly review the full content of the EBB to maintain a proper quality control.

COMPUTER ASSISTED LEARNING (CAL)

Current status

13. The Standing Committee of the Heads of Training Institutions of National Meteorological Services (SCHOTI) recently established a Working Group on Distance and Computer-aided Learning. This WG held its first meeting in May 1992 and developed a visionary statement (reproduced in Attachment 1) of expected CAL developments over the next five years and a summary (reproduced in Attachment 5) of some current CAL activities in meteorology, several of which involve applications of satellite data. This WG is involved in the organisation of an international conference on Distance and Computer Aided Learning in Meteorology, Oceanography and Hydrology to be held in Boulder (USA) in July 1993 and made a number of recommendations concerning the introduction of CAL into WMO training activities.

14. Independently of this, a project is being initiated (still in the draft stage, we understand, and therefore unofficial) to create an innovative CAL module in association with the introduction of Meteorological Data Distribution (MDD) through METEOSAT in Africa. The project is large and is proposed as a possible basis for meeting the changing requirements for training in developing countries.

15. A project called MOSAIC has been initiated by EUMETSAT and is being developed by the University of Oxford for training on the best use of MDD data in combination with satellite data with specific emphasis on applications in developing countries.

16. CD-ROM and video disc technology are now also being used for satellite data archival and for production of satellite application modules. These systems have the capacity to store and replay a large amount of satellite imagery at relatively low cost and they can be connected to PCs to enable interaction with local applications software. A description of the ZEAM Meteo Disc system, produced by the Freie Universitat Berlin, is given in Attachment 6. The Meteo Disc system is being used in New Zealand and will be introduced soon for training in Australia.

17. Some satellite applications for a "no frills" CD-ROM system have also recently been developed by Dr C.Duncan of the University of Edinburgh as part of a work attachment to the Bureau of Meteorology Training Centre in Melbourne, Australia.

Strategy and plans for using CAL modules to assist in improving the application of satellite data in developing countries

18. The strategy and plans for using CAL modules to help improve satellite data application in the developing countries require careful consideration. There is a need to develop generic compatibility in CAL packages so that they can be easily transposed and transported. This will probably emerge through the widespread adoption of Open Systems.

19. It would seem that with the emergence of the WG on Distance and Computer-Aided Learning there will be an excellent framework for planning and development in this field, upon which we can graft special satellite applications modules. Thus it is proposed that key strategic elements should be:

(a) Co-ordination with the ETRP strategic plans and the activities of the WG on CAL. In particular we should maintain an active interest in the outcome of the July 1993 International Conference on Distance and Computer-Aided Learning;

(b) Development of a list of topics suitable for CAL modules on satellite applications for use by RMTCs. This can be done in conjunction with the strategy proposed in the earlier sections of this document;

(c) Co-ordinate, assist with the provision of funding, and actively encourage a systematic programme of CAL satellite module development over the next 10 years. We can commence planning on five fronts: (i) following through with the US NESDIS proposal with an initial targeting of CAL module development on applications for RMTCs in Central and South America, linked to applications for the GOES and NOAA satellite systems; (ii) following through with ESA's and EUMETSAT's initiatives targeted mainly for the African area and linked to ESA satellite systems; (iii) encouraging developments targeted for countries in Asia and the South Indian Ocean linked to emerging Indian and Chinese satellite system developments; (iv) encouraging similar development targeted at the Pacific rim countries (mainly within RA V) linked mainly to the Japanese satellite systems.

Attachment 1 to APPENDIX IV

Summary of
Operational World Weather Watch System Evaluation for Africa (OWSE-AF)
Report on Evaluation of telecommunications systems using Meteosat

1. Data collection platforms and Data Retransmission Systems (DCPs and DRS).
   - DCPs provide an excellent link to National Centres.

   - GTS continues to have persistent data-loss problems.

1.1 List of countries with DCPs ,DRS and the supporting organization or country.

   a. DCP and DRS supported by WMO:
      Nigeria, Ghana, Zaire, Kenya, Sudan and Ethiopia.

   b. DCP and DRS supported by France:
      Senegal, Guinea Bissau, Guinea and Cape-Verde.

   c. DCP and DRS supported by Germany:
      Egypt and Madagascar

   d. DCP and DRS supported by UK:
      St. Helena

2. Meteorological Data Dissemination Systems (MDD)

   - MDD concept does work.

2.1 MDD locations in Africa and support by April 1992.

   - Djibouti (France)
   - Kenya (EUMETSAT and UK now)
   - Uganda (UNDP)
   - Swaziland (EEC)
   - Niger (EUMETSAT)

Implementation in progress:

   - Egypt (EUMETSAT)
   - Ethiopia (UK)
   - Madagascar (Germany)
   - Zimbabwe (UK)
   - Ghana (UK)

Types of Station:

   - Vax 3100
   - Wang 386 (with Venix)
   - IBM compatible 386.

Results:

   - Good data source
   - Excellent potential.

2.2 Recommendations of the MDD evaluation group in Africa and future trends

- Optimise in this new cost-effective communication system
- Design a Computer Based Training (CBT) programme for all levels of training through UK based computer Consultants. Work is currently underway.

- Benefits of using CBT:

  a. Augment existing training.
  b. Use MDD computers for training
  c. Modular format
  d. "Hands-on" experience with simulated stations
  e. Available to all persons

- Trends are towards a standardisation of MDD systems

- Most African countries intend to acquire MDD systems in the near future. Currently over 10% are utilising the system.

2.3 Development of communication.

- Provide an information system to enable users' to be aware of training events.

- Mode and means of dissemination of information

- Research/technology publications

The MDD system provides an ideal mode of disseminating information to Africa and the Middle-East. DCPs and DRS may also have potential for becoming information systems but the message lengths maybe a limitation.

Status Report on the Existing Infrastructure
for Education and Training in Satellite Data

The existing infrastructure for education and training in satellite data utilisation in the WMO Member countries consists of:

∀ The United Nations Development Programme (UNDP), which supports international centres in the developing countries where training programmes in satellite meteorology might be established. Examples from the African region are: DMC and IMTR in Nairobi (Kenya); AGRHYMET and ACMAD in Niamey (Niger).

∀ Other United Nations agencies, such as UN (ECA) and FAO, who, through the approval of Member states, provide financial and technical assistance to developing countries for long-term and short-term satellite training courses with an overall objective of producing local expertise (manpower) in remote-sensing for exploration, exploitation and management of their natural resources. Examples to emerge from this type of infrastructure support are the three African region operational centres for training in space science and technology applications:

- the Regional Centre for Services in Surveying, Mapping and Remote Sensing (RCSSMRS) in Nairobi (Kenya);
- the Regional Centre for Aerospace Surveys (RECTAS) in Ile-Ife (Nigeria); and
- the Regional Remote-Sensing Centre (CRTO) in Ougadougo in Chad.

∀ The WMO Education and Training Programme, whose long-term plan for 1992-2001 is described in document WMO-No.766. The Programme's main functions are:

- assessment of present and future training needs;
- provision of technical advice and support for training activities, particularly for the RMTCs;
- administration of education and training fellowships;
- co-ordination with other WMO Programmes and activities; and
- support for training events under other WMO Major Programmes.

∀ The WMO Technical Co-operation Programme, which supports the Education and Training Programme, particularly in the utilization of external resources for education and training;

∀ A network of seventeen WMO Regional Meteorological Training Centres (RMTCs), spread amongst the six WMO Regional Associations. The RMTCs specialise in the education and training of meteorological and hydrological personnel. Almost all the RMTCs are located in developing countries;

∀ A network of WMO advisory bodies and rapporteurs including, in particular:

- the EC Panel of Experts on Education and Training;

- the EC Panel of Experts/CBS Working Group on Satellites and its associated rapporteurs on education and training, use of satellite data, and satellite data retrieval methods;

- the rapporteurs on satellite applications for the eight WMO Technical Commissions;

- the World Weather Watch (WWW) Programme and, in particular, its Operational WWW Systems Evaluation (OWSE) activities.

∀ The training institutions of the national meteorological and hydrological services. There is a WMO Standing Conference of Heads of Training Institutions of National Meteorological Services (SCHOTI) whose activities are co-ordinated by a committee. SCHOTI has established a Working Group on Computer Aided Learning (CAL) which has particular relevance to education and training in the use of satellite data;

∀ Universities, research centres, schools, and national training institutions in disciplines related to meteorology and hydrology. For example, in WMO's Regional Association I (Africa) there are four universities offering meteorology courses (Kenya, Egypt, Nigeria, and Algeria) and the Niger has plans for offering post-graduate courses. However the remote-sensing component in most of these universities is deficient due to a lack of proper infrastructure and a lack of lecturers in remote-sensing. There are a number of directories available which list the various universities and research institutions which have remote-sensing education, training or research programmes.

∀ Major government or private/commercially sponsored agencies and various co-ordinating bodies specialising in meteorological satellites and related education and training programmes. Some examples are:

- ESA and EUMETSAT, which have been particularly active in supporting satellite education and training activities in the African region as well as in Europe;

- NASA and NOAA/NESDIS, which have been particularly active in supporting education and training activities in the Central and South American regions as well as other parts of the world;

- NASDA, and the Japan Meteorological Agency's Meteorological Satellite Center;

- The State Meteorological Administration of the People's Republic of China and its Satellite Meteorological Center;

- CEOS and CGMS, the co-ordinating bodies of the operators of the earth resources and geostationary meteorological satellites respectively. These organisations have working groups on various matters relating to education and training on satellite applications;

- The Co-operative Programme for Operational Meteorology, Education and Training (COMET) run by the University Corporation for Atmospheric Research (UCAR) in Boulder, USA;

∀ Foreign aid agencies of various donor governments. The foreign aid programmes of Japan, France, USA, and Australia have been among the most active in supporting satellite education and training programmes in the developing countries with a major objective of producing locally sustained expertise.

ANNEX III

WORLD METEOROLOGICAL ORGANIZATION
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EC PANEL OF EXPERTS ON SATELLITES

REPORT FROM THE RAPPORTEUR ON
THE USE OF SATELLITE DATA IN WMO PROGRAMMES

GENEVA - 9 - 10 MARCH 1993

CONTENTS

OBJECTIVE: To provide EC with an assessment on the completeness of satellite data exploitation, to be used as an input for decision and interaction with relevant counterparts

CONTENTS:

1. USE OF IMAGERY IN OPERATIONAL METEOROLOGY
1.1 Data availability and access
1.2 Availability of hardware/software handling systems
1.3 Applications and impact analysis
1.4 Deficiencies

2. USE OF IMAGERY IN OPERATIONAL HYDROLOGY, AGRICULTURE AND COASTAL WATERS
2.1 Data availability and access, processing tools
2.2 Review of applications
2.3 Problem areas

3. USE OF SOUNDING DATA
3.1 Availability of data and processing systems
3.2 Progress in data use and impact analysis
3.3 Preparation for new generation sounders

4. USE OF CLOUD-MOTION WINDS
4.1 Present availability, use and limitations
4.2 Ideas for further improvements

5. USE OF NEW OBSERVATIONS
5.1 New available observations
5.2 Problem areas

6. USE OF SATELLITES IN CLIMATE AND ENVIRONMENTAL RESEARCH
6.1 Main applications
6.2 Comments

7. SUMMARY CONCLUSIONS AND INDICATIONS OF ACTION ACTIVITIES
7.1 Overall assessment
7.2 The need for well designed pilot projects
7.3 The need for a new strategy in education and training
7.4 The need for improved information services

OBJECTIVE

This report has been prepared by the Rapporteur on the Use of Satellite Data in WMO Programmes. The aim of this report is to provide an assessment on the completeness of satellite data exploitation within the various WMO programmes. This assessment is based on the following reference material:

- The WMO "Annual Progress Report on Application of Satellite Technology" (1991)

complemented by various sources of information published EUMETSAT

- Meteosat Scientific Users Meeting, 9th session, Locarno, Switzerland, 1992) and:

- AVHRR Data User Meeting, 5th session, Tromso, Norway, 1991,

and:

- International TOVS Study Conference, 7th session, Igls, Austria, 1993,

organised by the International TOVS Working Group. There were four workshops organized during the period 1990-1992 which had a direct bearing on satellite activities:

- Wind extraction from operational meteorological satellite data, organized by EUMETSAT, NOAA and WMO in Washington DC, 1991;

- The use of satellite data in nowcasting and very short range forecasting, organized by EUMETSAT in Reading, UK, 1990;

- First ERS-1 Symposium "Space at the service of our environment", organized by ESA in Cannes, France 1992;

- A Conference on "Environment observation and climate modelling through international space projects" organized by ISY in Munich, Germany, 1992.

1. USE OF IMAGERY IN OPERATIONAL METEOROLOGY

The imagery mission exploited in operational meteorology is defined by geometrical resolutions ranging from 1 to 10 km and spectral bands in visible (VIS), infrared (IR) and microwave (MW) atmospheric windows or specific absorption bands, e.g. for water vapour (WV). The following aspects will be considered:

- data availability and access
- availability of hardware/software handling systems;
- applications and impact analysis
- deficiencies (structural, occasional).

1.1 Data availability and access

The basis for the operational imagery mission continues to be the AVHRR VIS/IR radiometer from the NOAA series of polar satellites, generally providing four coverages per day (more at higher altitudes), and the VIS/IR images from geostationary satellites, generally at half-hourly intervals for high-rate receiving stations and up to 3-hour intervals for WEFAX stations. VIS/IR images from polar METEOR satellites are largely used by a number of WMO Member states and, as complementary to AVHRR by others. MW images are available from the SAM/I radiometer onboard the polar DMSP satellites.

There is no apparent problem of local real-time availability and access to polar satellite VIS/IR images. Many users are able to acquire APT images at reduced resolution at VHF frequencies, even from mobile platforms (ships), and are able to acquire full resolution images in digital mode in the S-band. Global image coverage is generally possible only at low resolution (GAC) and then over selected areas at high resolution (LAC).

Availability of images from geostationary satellites is less satisfactory. There is a coverage problem in the Middle-Asian region and Indian Ocean, where the WEFAX service is not yet available. Also, the half-hourly frequency is generally effective only for high-rate digital acquisition stations and for WEFAX stations belonging to the satellite provider countries, but not for general WEFAX stations, particularly those in the intertropical regions where the half-hourly frequency would be extremely useful for convection monitoring. The problem will not easily be reduced by systems introduced in the near future, as physical limitations exist which prevent the transmission of frequent full-resolution information to low-cost stations under the present allocations of frequencies and bandwidths. A better organization of the ground segment (e.g. dissemination of higher level products with lower data rate, or clusterization of local users around major acquisition facilities) would be a step forward.

MW images are not generally available locally in real-time. Distribution occurs by bilateral agreements with NOAA and/or a number of acquisition stations belonging to NATO. Level 2 data (derived geophysical parameters) are more easily accessible than original images.

Data policy problems are becoming an issue which will have an impact on satellite data access in the near future. With the advent of a strong interest by the private sector to produce value-added services in the meteorological field, and the requirement of many meteorological services to cover part of their budget by providing specialized services, the need to control satellite data access is emerging and is being discussed in WMO as well as in satellite system producers. A way will have to be found to ensure that an agreed basic service continues to be provided to the world meteorological community on a non-discriminatory basis, free-of-charge and without unnecessary complications for accessing the data.

1.2 Availability of hardware/software handling systems

Impressive developments have occurred in the field of image handling systems. The traditional hardcopy-oriented approach has been replaced by software, e.g. on TV screen visualization associated to digital processing. Hardware/software systems have been developed which allow for image enhancement (contrast stretching, zooming, panning, colour-coding, etc.), multi-channel image handling for synthetic pseudo-image display and information compression, multi-temporal image sequentiality (animation), geofrequency in appropriate projections, and merging of images overlayed with other information (radar images, bulletins, maps, etc.).

After the initial development in large meteorological centres of medium-large processing facilities, many key-in-hand systems have been made available by a number of specialized factories, supported by mini-computers, workstations and PCs. Software transportability requirements across different infrastructures have been taken into account, including maintenance in different environments of the world. These systems not only work downstream of digital acquisition stations, but also on digital APT and WEFAX images, obviously with different performances.

WMO's active support to developing countries for the acquisition and maintenance of processing facilities is complemented by other national and international aid-to-development programmes. Of course, there is large room for improvement in this area.

1.3 Applications and impact analysis

The imagery mission is undoubtedly the most consolidated application of satellites in operational meteorology. The support to synoptic analysis (front detection, cyclone tracking, air mass characterization, etc.) and mesoscale monitoring (early detection or cyclogenesis, convection development, local weather conditions, etc.) are the basics for nowcasting and short-range weather prediction.

With the increasing availability of efficient hardware/software systems for rapid information processing, applications have become numerous and more objective. The main achievements derive from the capability of processing more channels (multi-spectral analysis) and frequent images (animation).

Multi-spectral analysis is applicable to AVHRR images, which include five channels. Automatic cloud classification, including fog detection and top height estimate, is now operational at more meteorological centres, and often supports the multi-spectral analysis by overlayed conventional information.

Animation of images from geostationary satellites allows early detection and growth monitoring of convection. Precipitation rate estimates may be attempted in a number of cases, particularly convective clouds, with the help of associated mesoscale models. Systems to merge radar and satellite images to extrapolate radar-infrared precipitation measurements in space and time are operational at many nowcasting centres.

Air mass analysis is still an application of imagery and is particularly valuable over large oceanic areas lacking conventional observations, e.g. the Southern Hemisphere. Pattern recognition techniques are used, associated with merging with conventional information and other satellite observations such as soundings.

After intensive processing images are also used to derive other information valuable for operational meteorology. Leaving a dedicated section to winds, sea-surface temperature (SST) is perhaps the most valuable. Global SST maps to support numerical weather prediction (NWP) are regularly produced with a large contribution from satellite observations, mainly from polar but also geostationary orbits. Local scale, high- resolution SSTs are also produced at meteorological services which have responsibilities in coastal zone activities. In aeronautical meteorology, the imagery mission is used intensively, i.e. for jet stream detection, weather conditions en route, at the terminal airports, and for detection and monitoring of volcanic ash plumes. Meteorological services having responsibility for ice monitoring also use intensively satellite images.

The use of MW imagery for operational meteorology is still poor. This is due, apart from the problem of timely access to the data, to the limited resolution offered by the present instrumentation (SAM/I). Observations of paramount importance for operational meteorology, such as precipitation and wind stress over the ocean, are only achieved with a resolution of some 20 and 80 km respectively. Experimental use of this data has been started at some meteorological centres.

1.4 Deficiencies

Although imagery is the most fully exploited mission in operational meteorology, a few deficiencies can be identified, some structural, some occasional. Occasionally, the insufficient availability of imagery, particularly in WEFAX mode, in Middle-Asia and the Indian Ocean, can be cited, the incoming GOMS geostationary satellite is expected to fill this shortfall. Also the limits in accessing SAM/I MW images can be surpassed easily if real interest grows. The limits in resolution is structural, and will only be resolved by new instrumentation, such as MIMR which is to be flown in the year 2000.

Automatic cloud classification certainly represents a great achievement for operational purposes, when large volumes of information have to be co-processed in a short time. However, the question arises whether enough information is actually carried out by present imaging radiometers. It would be desirable to have more channels in the WV bands in excess of those used in AVHRR, and of those used in geostationary satellites (with the exception of VAS on GOES, which, however, has all the necessary channels but poor resolution and operational modes). An improvement of the geometrical resolution is required, and to have it more suited to the horizontal structure of cloud cells would be desirable. The 1 km resolution of AVHRR is more than sufficient, but is only achieved around the sub-track, whilst degrades up to 6 km at the wedge of the image. For the geostationary satellites, the best resolution available at present in IR is 5 km at the equatorial sub-satellite point. We have to wait for the next generation of satellites and instruments, in the year 2000, to have more channels and improved resolution (there is evidence that AVHRR will not be substantially improved even after the year 2000).

Whilst waiting for more spectral channels, also extending to the MW field, and better resolution, it is believed that the success of some of the present applications may be due to insufficient validation of the claimed achievements, as it is extremely difficult to validate large scale fields of cloud parameters. Other applications, such as precipitation inference, in the absence of best suited information (e.g. microwave radiometry) and with the present geometrical and spectral resolution, could be successful only in a limited number of circumstances (e.g. tropical convection). Fortunately, in each meteorological service there is still staff with sufficient skill in synoptic meteorology as to appropriately filter the information provided by automatic systems.

A clear deficiency which is apparent after the discussion under Section 1.1 is that most of the advanced image applications are not possible in many areas of the world where WEFAX or APT acquisition is dominant. This problem will only be solved after the year 2000, if more efficient telecommunication systems, such as Data Relay Satellites (DRS), have been demonstrated to be cost-effective and operationally consolidated (which could well take up to the year 2010). Until then, a more efficient organization of the ground segment will be the best way to adequately serve WMO Member countries. Provision and distribution of level 2 products (geophysical parameters) or even level 3 (analysis fields) should be preferred to the dissemination of raw data.

2. USE OF IMAGERY IN OPERATIONAL HYDROLOGY, AGRICULTURE, AND COASTAL WATERS

Images used in operational hydrology, agriculture and coastal water activities are taken in the same spectral bands as for operational meteorology (atmospheric windows in VIS, IR and MW). More channels are needed in the VIS band, narrower, and an extension to the near IR, NIR is also needed. Furthermore, much better geometrical resolution (10s of metres) is required in a number of applications. In this section the following aspects will be considered:

- data availability and access, processing tools;
- review of applications and impact analysis;
- problem areas.

2.1 Data availability and access, processing tools

Images from operational meteorological satellites (AVHRR from NOAA and images from geostationary satellites) are widely used in operational hydrology, agriculture and coastal water activities. Data access is, however, more difficult, except when these applications are run at large meteorological services which have responsibilities in those fields. Digital processing is generally needed which in turn means that high-rate digital acquisition stations are required for near-real-time applications. Otherwise, data are obtained from archives, and thus only for delayed time applications.

Also required are much higher geometrical resolutions than for operational meteorology, particularly for hydrology and agriculture, which also require more spectral bands in the VIS/NIR range. These are available from satellites such as LANDSAT and SPOT, which have been operational for many years, and it is planned to continue their operation in the future. This continuity of operations is based on an individual flight basis. The technical complexity of acquisition and distribution of these images, due to the high data rate and the use of the X-band, and the data policy, which is commercially oriented, seriously limit the access to these data beyond applications such as pilot projects.

Much higher spectral resolution (more channels and narrower) in the VIS/NIR range is required for coastal water applications such as ocean colour, though the required geometrical resolution is similar to what is needed for operational meteorology. Images from the Nimbus 7 CZCS have been available for many years. The instrument has not been re-flown, but archived data bases are available for preparing the exploitation of future instruments which, however, are unlikely to provide real-time data.

Passive MW radiometry, which, in principle, could be extremely valuable in hydrology and agriculture are not available with the appropriate resolution. However, SAM/I is used within the limits of its capabilities.

Hardware/software systems for data processing are similar to those available to handle images for operational meteorology. However, satellite data can seldom be used in isolation for hydrological and agricultural purposes; geometrical image processing is generally more intensive, and Geographical Information Systems (GIS) are associated, supplying all necessary background information, including Digital Elevation Models (DEM). Modern technology provides reasonably inexpensive workstations able to support these applications.

2.2 Review of applications

In the context of this report, which is aimed WMO's fields of interest, commercial applications such as resource discovery, monitoring and management, will not be considered. Only those hydrological, agricultural and coastal water aspects which interfere with meteorology, climate and global environment will be considered.

Perhaps the most popular application of AVHRR imagery outside operational meteorology is vegetation monitoring by means of the Normalized Differential Vegetation Index (NDVI), obtained by comparing the reflected radiances in the red channel (decrease in chlorophyll reflectance from healthy vegetation). Regional scale NDVI maps processed from GAC data (reduced resolution) are produced routinely by NOAA and distributed to a number of interested organizations. NDVI maps with resolution at pixel level are produced on specific areas by using AVHRR imagery acquired in real-time and archived in a number of data centres. Applications take place on nation, as well as a regional scale (for example, monthly maps of Vegetation Index over Europe have been regularly produced for many years). In a number of countries, the national meteorological services have introduced the NDVI map production, generally at monthly intervals, as a routine application.

Although the situation with Vegetation Index map production seems satisfactory, less evidence exists about the use of the product for practical purposes. Perhaps the use on a large-scale, to monitor the seasonal regularity of vegetation development over large areas such as, Sahel, is better documented. Local/national scale pilot projects have shown the potential of NDVI as an input to models for crop forecasting. However, these type of applications heavily depend on the available background information, as well as ancillary high resolution information from LANDSAT and/or SPOT and ground truth activity. Thus it is difficult to assign NDVI with an impact figure.

Evaluation of soil moisture would be a great achievement for hydro-agro-meteorology. Whilst waiting for advanced MW radiometry, which have more potential in this field, attempts are made to evaluate soil moisture through observation of the Apparent Thermal Inertia (ATI), as derived from land temperature excursion and collected solar radiation (thermal inertia represents the response time-lag of a body's surface to increase its temperature when supplied with heat, a moist soil responds more slowly to increasing sunshine during the morning). Both AVHRR data and geostationary images are used, the second having the advantage of following better the temperature diurnal variation. Results are better over bare soil than over vegetation.

This application has been of great interest, but the accuracy of results depends very much on the use of external information (for example, air temperature and humidity) which can be only roughly parameterized. Again, the reported applications appear more as convincing pilot projects rather than something which could be handed to real users for operations.

Another way to estimate soil moisture is by relying on precipitation indexes. Operational applications have been developed, for instance by FAO, using geostationary imagery over those regions (essentially intertropical) where cloud appearance is more closely correlated with precipitation occurrence. Validation of this product is surprisingly convincing, and the product is being operationally used, for instance, for locust invasion warning (locusts are attracted by moist soil, which enables them to deposit their eggs, and thus reproduction). Of course, it only works on specific areas.

Discovery and monitoring of forest fires is another well documented application of AVHRR imagery. Of course, the ability of early detection is limited by the space and time resolution (the geostationary satellite would be much better, but the resolution in IR is too coarse). However, the monitoring of fire (or, rather, smoke plume) is useful during the intervening period, and at the end of the event, images have been useful to for showing damage assessment, also in combination with high resolution LANDSAT and SPOT images. Pilot projects have developed convincing models of the overall warning system, within the framework of the International Decade for Natural Disaster Reduction (IDNDR).

Still within the framework of IDNDR, the value of AVHRR for flood monitoring is being extensively investigated. Due to the impact of clouds on VIS and IR imagery (and, of course, to the limited resolution), detection is generally not possible, but evaluation of the flood extent is often feasible. Use of AVHRR to monitor zones exposed to geological risk (e.g. erosion) is documented in many scientific papers and reports from pilot projects. As a general rule all pilot projects for the application of environmental satellites to hydrology emphasize the need to have available at the same time coarse resolution frequent images (including those from geostationary satellites, in spite of their limits in resolution and number of spectral channels), and high resolution through infrequent images: all of which supported by powerful and well updated GIS's. An important contribution to satellite data is for continually updating knowledge of soil condition (a sort of "past-casting"), which is basic for evaluating the possible consequences of forecasting a new weather event (the effect might be totally different over soils with different accumulated water).

Well consolidated applications are reported on the use of AVHRR in ice surveillance and snow monitoring. Apart from obvious contour detection, ice and snow maps are used to estimate water reservoirs. Careful modelling of the hydrological basin is requested, as well as physical models of the relationships between snow temperature/brightness and total-column water. The success of these applications are very dependent on the particular basin, and sometimes models can be very simple, e.g. in Scandinavia), and sometimes very complex, e.g. in the Alpine region. For large-scale ice surveillance, e.g. over Canada or in the polar caps, the SAM/I resolution is sufficient to provide age and type classification.

Applications in coastal waters require image processing at pixel level, due to the need of sufficiently high resolution. Sea surface temperatures for use in coastal water activities are being routinely produced by many meteorological services, both from AVHRR, with a better resolution, and geostationary satellites, with worse resolution but more frequent updating due to the higher probability of finding cloud-free pixels during the day. These fine resolution sea-surface temperature maps are able to show thermal fronts, useful for fishery, and shows features indicative of local circulations, useful for prediction of sea-pollutants transport. As in most applications at this scale, satellite-derived sea-surface temperatures must be used in combination with local models, as they refer to only the skin temperature which is not fully representative of the bulk temperature, which is more closely associated to ocean dynamics.

Observation of water quality has been attempted with AVHRR images, supported as practicable by LANDSAT and SPOT imagery. Direct observation of sea pollution, e.g. oil spills and large algae extensions, is being reported. The results appear very occasionally, and are more suitable for scientific publications than for practical purposes. Convincing applications have been based on the CZCS data, which are now only available from archives. The ability to measure chlorophyll concentration and suspended sediments, either inorganic or of an organic nature has been well proven with CZCS. Future instruments should possibly combine the colour and temperature measuring capabilities for a more comprehensive observation of coastal waters.

2.3 Problem areas

The discussion above has highlighted applicability, but also the limiting factors of satellite imagery for hydrology, agriculture and coastal water activities.

The current performance of imaging instruments is clearly the main limiting factor. Most applications in these fields would require high geometrical resolution at the same time as many channels in VIS+IR+MW, and frequent observations. The combined use of images from geostationary, polar meteorological and polar Earth resource satellites is the way forward, but this is difficult to implement, due to processing complexity and different data policy, access modality and cost of the data. The recent Act of the US Congress which withdraws LANDSAT-7 from the commercial market will contribute to alleviating the cost problem. However, information-dense data are expensive to access and handle. A good design of the data circulation schemes and a strong organization of the ground segment will be necessary.

The need to process satellite data in connection with a substantial amount of ancillary data and making use of background information such as GIS also represents a problem. It may be difficult for many users to have access to all necessary information, and even to have knowledge of which information exists and where it is located. Strengthening of user-oriented information systems, particularly addressing their services to newcomers in satellite data use is essential.

One major preoccupation which arises when reviewing application of satellite data in other than meteorological fields is that most of the applications, even those well demonstrated, are actually carried out in establishments which do not really belong to the true user community. Many applications are carried out by institutes whose mandate is of a research and development nature, more interested in transforming the raw information into value-added products rather than making use of those products for the final disciplinary application. This has two major consequences. First, a true, long-term validation and impact assessment of the product never occurs, because the final operational customer is not involved. Second, the economic benefit of stretching the use of satellite data over a larger community is fictitious, in that in many cases, the provider of the application is himself supported by space agencies or other research and development financial sources, whilst the final end user, who should in principle pay for the production chain, is lacking.

In order to face this problem, a strong promotion activity is still needed. There is a strong need for the pilot projects to be planned in such a way as to closely involve the end-user from the beginning, and to be transferred for operational continuation to the end-user after a definite time. Co-ordination of pilot projects, transfer of knowledge and care of transportation of results to areas of similar characteristics should be pursued. There is also a need to renew the methodologies adopted for education and training, taking advantage of advanced techniques now available, PC-supported, and addressing directly the end-users.

3. USE OF SOUNDING DATA

The sounding mission exploited in operational meteorology is supported by radiometers operating in absorption bands of CO2 and H2O in IR, with supporting nearby atmospheric windows (including some in VIS), and 02 in WV, with supporting window and WV channels. Geometrical resolution of instruments ranges from 20 to 200 km, depending on spectral bands. The following aspects will be considered in this section:

- availability of data and processing systems;
- progress in data use and impact analysis;
- preparation for next generation sounders.

3.1 Availability of data and processing systems

The basis for the operational sounding mission is the NOAA TOVS, including the IR component HIRS, the MW component MSU and SSU for stratospheric sounding in IR. Due to the limited swath (or better, to the low orbital height), global coverage is achieved four times per day only at latitudes higher than some 40 degrees). All weather MW sounding from the SAM/T onboard the DMSP satellite also are available to NOAA. The GOES VIS/IR imager/sounder VAS is also being used, mainly for atmospheric instability monitoring.

Access to TOVS is possible in real-time either in S-band, multi-plexed with AVHRR and other data, or in digital VHF from the beacon transmitter: this reception mode is less popular.
A number of processing systems have been developed, some more suited to operational use, and others more research-oriented. Many different algorithms have been developed, either for dealing with the cloud problem, or for the profile retrieval. However, the International TOVS Working Group, beside fostering processing developments, has provided for a standard package, continuously updated and improved, compatible with most computer infrastructures, including workstations and PCs.

Coarse resolution (500 km) global sounding data, are routinely processed and distributed by NOAA over the GTS, both as temperature and humidity profiles (SATEM), and as clear air radiances (SARAD). Sets of high resolution soundings (generally 100 km) produced by NOAA and a few others centres are also exchanged over GTS lines in front of bilateral agreements. Stratospheric sounding from SSU are available from the UK Meteorological Office on request.

There is no apparent problem in availability and access to raw TOVS data for local processing. The only serious shortfall is the limited distribution of high resolution processed data over the GTS, mainly restricted by lack of capacity.

3.2 Progress in data use and impact analysis

TOVS-derived sounding data circulating over the GTS are used operationally in many meteorological services, particularly those running global NWP models. Negative reports about the TOVS impact in the Northern Hemisphere are now becoming less, after the latest improvements in TOVS processing at NOAA and the increasing practice to directly use clear air radiances instead of inverted profiles. More care is also placed in TOVS data acceptance within the assimilation model, due to a better knowledge of error structure, particularly biases in TOVS-derived soundings. Nevertheless, the impact on the performance of NWP continues to be substantial only in the Southern Hemisphere, whilst in the Northern Hemisphere it is still reported to be marginal.

With regard to high resolution sounding, or rather clear-air radiances, a start has now been made in using in mesoscale NWP models, designed for true 3D or 4D assimilation. Theoretical studies have been carried out showing that considerable information is contained in TOVS radiances which can only be exploited in this way. Latest findings show that direct assimilation of raw radiances (i.e. not even cleared from clouds) could be more beneficial, as this allows exploitation of information about clouds which is inherent to TOVS raw radiances. At the present time there is little evidence to indicate the gains which can be actually achieved with this technique.

Great progress has been made in the use of high resolution TOVS data in nowcasting. Plotting pseudo-images of derived products such as thicknesses and thermal winds, also in overlay with AVHRR images and conventional field maps, has been shown to be a powerful tool in frontal analysis and also in cloud structure analysis. Maps of ozone, for which a single dedicated channel exists, but associated to the information on temperature profile (thus the height of the most contributing layer), show many details of the tropopause and of jet streams associated with tropopause fractures.

The use of the ozone channel is being studied for a number of purposes. It provides verification of ozone distribution as observed by other dedicated instruments (SBUV and TOMS).

Tracing ozone patches on successive 6-hourly NOAA passages has been used for inferring stratospheric winds. Based on this experience, inclusion of an ozone channel in the Meteosat Second Generation (MSG) imager has been planned.

Sounding from geostationary satellite (GOES/VAS) is of course used for nowcasting purposes. Various derived parameters are mapped and animated as pseudo-images. The main operational application is monitoring of atmospheric instability through the observation of surface temperature, air temperature and water vapour. The quality of the products is rather poor due to instrument limitations, but sufficiently convincing as to plan for a sounding mission on GOES-next and for an atmospheric instability mission on MSG.

3.3 Preparation for new generation sounders

The previous discussion has enlightened the progress in using TOVS and VAS data in operational meteorology. Unsuspected value of sounding from present instruments for nowcasting has been found, but the basic limitation of these instruments in providing substantial information to global NWP cannot be forgotten. Also, the possible contribution to mesoscale NWP models could be provisional: when these models are well developed and refined, it is probable that only good quality information will have a real impact on their performances. Particularly, vertical resolution (something basic in mesoscale models) will be a drastic limiting factor, as there are physical limitations in what can be achieved with present radiometers (some 3 km in the middle troposphere, and worse above).

Scientific work has already started for better utilization of the next series of instruments to replace TOVS in 1995. ATOVS will include essentially the same IR component (HIRS), but much improved MW radiometers, AMSU-A for temperature and AMSU-B for water vapour. Improved vertical resolution in the stratosphere is expected, and much improved coverage in cloudy areas, which also means less biases in the data. The vertical resolution in the troposphere, which is determined by the IR sounder, will however remain essentially the same.

Sharp improvement is expected from the next generation of IR sounders, based on the high resolution spectroscopy potentially able to ensure a vertical resolution of 1 km in the troposphere. Whilst these instruments (AIRS in the US, IASI in Europe) are implemented, a tremendous amount of scientific work is still needed in order to improve the knowledge of atmospheric spectroscopy for adequate support to data processing, and to develop an approach for appropriately handling clouds (not necessarily filtering them out), and to study the most appropriate 4D assimilation schemes.

4. USE OF CLOUD MOTION WINDS

Waiting for technological development to occur in the future (development of space doppler lidar), cloud motion tracking represents the only way how to achieve winds in the free atmosphere from satellites. All geostationary satellites concur to this task, by means of their imagers operating in VIS and IR atmospheric windows or specific absorption bands, e.g. of WV. The following aspects will be considered:

- present availability, use and limitations
- ideas for quality improvement

4.1 Present availability, use and limitations

Cloud motion wind data are provided by any operator of geostationary meteorological satellites (METEOSAT, GOES, GMS and INSAT). Methods vary as a consequence of the performance of the different satellites, some of which have more channels than others. Generally an IR window channel is used (with the exception of INSAT which uses VIS); other channels are ancillary for target identification or height assignment. Data are coded as SATOB messages and distributed over the GTS. Data are generally produced at 6-hourly intervals (INSAT once per day) and cover about 50 degrees geocentric angle around the equatorial sub-satellite-points (INSAT only on a restricted area of the Indian Ocean). Data tend to cluster in the low and high tropospheric levels (just as clouds do), but middle levels are also populated (not for GMS).

The discussion above already shows the first problem with satellite winds, which is an inhomogeneous coverage in the horizontal as well as in the vertical dimensions. However, a much more serious problem is that data are achieved only where clouds are present and, moreover, at only one level (multiple-level clouds shade each other). Over large anticyclone areas winds can be missing for many successive days. Furthermore, low-level winds over the continent tend to be rejected by the quality control procedure.

In spite of all these deficiencies in coverage, cloud motion winds constitute an essential input to global NWP models. Their impact is quite remarkable in the intertropical zone, but also positive in the extra-tropical ones, even in the Northern Hemisphere.

The quality of cloud motion winds has been gradually improved in the past years. At present, with the exception of INSAT, the accuracy is statistically comparable with that of radiosondes. A negative speed bias is however evident at high levels, particularly in the extra-tropical regions, which is due to the difficulty of measuring the temperature, thus assigning the correct height, of semi-transparent cirrus which tend to grow in atmospheric layers with strong vertical wind shear.

The average good quality of data is, however, counter-balanced by the anomalous frequency of grossly erroneous data. These may be due to a selection of unsuitable traces (e.g. orographic clouds) or computation mistakes. Man-based quality control at the editing stage continue to be essential to reduce the number of gross errors, but a certain probability of erroneous tracers has to be accepted in order not to unduly degrade the yield. The temptation to smooth out erroneous tracers by using more intensively the forecast first guess field during the wind extraction procedures should be avoided if one wants to preserve the added value of the observation versus the first guess.

4.2 Ideas for further improvements

Contrary to the sounding case, where perspectives exist to improve instrumentation, both in the short-term (ATOVS) and in the middle-term (AIRS and IASI), in the case of winds the availability of advanced instrumentation such as doppler lidar is not for the foreseeable future. Therefore, an attempt should be made to improve the present methodology, based on cloud-motion tracking. Many scientific works have been carried out, most of them very convincing, which indicate the way forward.

First of all, it has been demonstrated that a reduction of the image cycle to, e.g. 15 min. would greatly increase the measurement accuracy allowing more consistent tracers to be followed. It would also improve the yield, as more short living targets would be traced. Yield and quality would also improve if longer sequences of images were to be compared. An improvement of image resolution would also, of course, imply better quality and improved yield.

The problem of coverage in the vertical cannot be solved with clouds, as far as the trend of clouds to grow either in the low or in the high levels is part of the physics of the atmosphere. However, experiments have demonstrated that WV patches, after image enhancement, also can be used as atmospheric tracers; and WV is, of course, present in all tropospheric layers. As mentioned in Section 3.2, ozone has also been shown to be a possible tracer in the stratosphere.

The most outstanding problem in the near future still remains the height assignment, which is probably the major source of both casual errors and biases. The use of WV channels to correct cloud radiation from emissivity effect has been shown to solve part of the problem, but not all satellites have the system installed, and more channels would be preferable. The use of an air temperature channel, particularly the CO2 13.4 micron channel (available on GOES VAS), has been able to provide an absolute evaluation of cloud top height. Other methods, such as stereoscopic viewing from nearby satellites, have been able to provide accurate results, but they would be applicable only over limited areas and probably would involve high operational costs.

One negative consideration in this area is that all the above mentioned improvements (better image resolution, more frequent imagery, more WV channels, air temperature and ozone channels, intensive processing perhaps also for stereoscopy) need to be implemented by all of the satellite operators, as wind inference from satellites is a global affair. It will certainly take up to the year 2000 before such kind of harmonization of the space segment is approached. In the meantime, is it necessary find a way to improve the assimilation procedure of cloud motion winds into the numerical models. One way for this is to establish agreed quality control indexes and append them as ancillary information to the wind data ("flagging"), in order to help the assimilation model in its handling with noisy data. The way wind data, particularly in the extra-tropical regions are handled by the model is not very convincing, as suggested by some contradictory reports from certain organizations, e.g. ECMWF.

5. USE OF NEW OBSERVATIONS

In the previous sections we have reviewed the present status of the use of satellite data belonging to the "classical" meteorological missions, e.g. imagery, sounding and cloud motion winds. We have also considered the extension of use of meteorological imagery, complemented by other traditionally available satellite data, in the nearby fields of hydrology, agriculture and coastal water activity. New satellite systems are now becoming available, of potential interest to a number of WMO programmes, particularly after the WMO transfer of interest from operational meteorology to climate and environment.

5.1 New available observations

One new observation which may be of interest to operational meteorology is sea-surface wind by means of a radar scatterometer being flown on ERS-1. These data are routinely made available from ESA to the GTS through the Rome RTH. Coverage characteristics are perhaps sufficient for global scale applications but rather poor for regional and national scale. Experimental use is being performed at a number of meteorological centres running global scale models. A number of scientific teams are using the data for pilot projects, also over limited areas. A challenging problem of assimilation exists for these data, which are measured in a totally different way from conventional data (they are derived from the radar reflectance of capillary waves under three different viewing directions), and have very irregular distribution with big gaps in space and in time. Nevertheless, preliminary results are qualitatively very encouraging though quantitative impact assessment are still reported inconclusive.

Also from ERS-1, and also through the GTS, wave significant height and wind stress are now available. Although the data coverage is very poor (only along the sub-satellite track), data are used for validation of wave models as developed at large meteorological centres such as ECMWF. The simultaneous observation of wave height and wind stress is used to derive empirical co-efficients to tune post-processing models for sea-state forecasting. Precision processing of altimetric data allow determining the mean sea level, which is a fundamental parameter for ocean dynamics (it has the same role of surface air pressure for meteorology). A similar mission, more oriented towards the determination of the geoid, is being performed by the French/US Topex-Poseidon. The altimeter is also used to measure the thickness of polar ice sheets.

Wave spectra are available through the GTS, derived from a Synthetic Aperture Radar (SAR) being flown on ERS-1. The use is for the verification of wave models. Present assessments are still inconclusive.

Sea surface temperature of unprecedented accuracy, designed for use in climate monitoring are derived from a VIS/IR radiometer, ATSR, being flown on the ERS-1. This data (neither the original images, nor the processed temperatures) are not available on the GTS. They may be supplied by the instrument provider (UK). The preliminary assessment of achieving the objective is positive. The derivation of the bulk temperature (what is needed for climate monitoring) from IR observations of the skin temperature implies new modelling problems.

SAR images are available both from the ESA ERS-1 and the Japanese JERS-1. A great scientific movement has arisen around these new data. Most applications are attempted over the soil, where these high resolution (10s of metres) all weather MW images are being used in a number of investigations and pilot projects for hydro-geology, agriculture, forestry and environmental monitoring. Over the sea SAR images are used for bathymetric studies, small-scale circulations in coastal areas, internal wave studies and oil spill detection. Perhaps the most consolidated use, and also the most interesting for a number of meteorological services, is for ice surveillance in polar and sub-polar regions, particularly to monitor navigation conditions in certain seas during the frosting and de-frosting seasons.

5.2 Problem areas

At the present it is premature to make statements on the validation of these new observations and their impact on operational activities. One very positive signal is the incredible number of scientists who are playing an active role in the initial experiments: some 500, only accounting for Europeans. However, there is a long way to go before real applications can reach a routine status. The operational characteristics of the data are rather poor (incomplete and infrequent coverage, access time of three hours as a minimum, lack of synergism with optical sensors), and all data need appropriate assimilation models and supportive ancillary information (e.g. GIS). Another potential problem is the cost of the data. So far, most of the experimenters have received data free of charge, in front of an Announcement of Opportunity process, and most of them are financially supported by their national space agencies. When this will be over, only national meteorological centres connected to the GTS will continue to have free of charge data, limited to scatterometer, altimeter and wave spectra data.

The comment has been made on previous occasions that the people involved only belong to the scientific community, whilst the end-user has not really been involved. There is a need to establish pilot projects designed to include the end-user from the beginning, and to establish user-oriented information services designed to be easily understood and operated by people not necessarily familiar with sophisticated informatic tools.

6. USE OF SATELLITES IN CLIMATE AND ENVIRONMENTAL RESEARCH

With the advent of the Global Change issue, the interest for satellite data has sharply increased in scientific communities which, until a few years ago, were very traditional in nature. Now planning for the Global Climate Observing System (GCOS), the role of satellites as a unique tool for synergistic observation of atmosphere, ocean, ice caps and land has been well understood, to the extent that today climatologists are perhaps more supportive of satellites than operational meteorologists.

6.1 Main applications

The most traditional use of satellite data in climatology is the Earth radiation budget.

Scientific works are dated from the early 1960s, based on global cloud mapping and polar ice extent monitoring by means of multi-temporal image analysis, generally calibrated against ground truth. The International Satellite Cloud Climatology Programme, ISCCP, has established a long standing database intensively used for evaluating the performances of climate simulation models (the ability of to restitute correct average cloud distribution is a kind of bench-mark test for a climate model). Due to the extreme variability of the quality of information in this database (diurnal biases in data from sun-synchronous orbits; total lack of calibration and broad spectral channels in geostationary images), a strong scientific effort is being focused on developing models for inter-calibration and absolute calibration.

The Global Precipitation Climatology Project (GPCP) also is substantially based on satellite imagery. In this areas, beside calibration, the main scientific effort is validation. The algorithms to infer precipitation indexes from satellite imagery are very rough, particularly due to the fact that spectral information in present imagery is rather poor (few channels, broad bandwidths). The availability of passive MW imagery from SAM/I is found to be very valuable.

The International Satellite Land Surface Climatology Project (ISLSCP) is also a long standing activity, aimed at improving the parameterization of land surface in long-range weather forecasting and climate modelling. High resolution images are used together with meteorological images.

Satellite data, particularly sea surface temperatures, have a basic role in the Tropical Ocean-Global Atmospheric programme (TOGA). The programmes allows for a better understanding of the El Nino Southern Oscillation (ENSO) and to verify the ability of ocean/atmosphere models to predict this important factor of climate variability.

The planning of the Global Energy and Water Cycle Experiment (GEWEX) relies very much on satellite data. Inference of energy and WV fluxes between surface and atmosphere through the Planetary Boundary Layer (PBL) requires sea surface and land temperatures, as well as wind stress over the ocean. Within the atmosphere, clouds and precipitation control the energy transformations, and clouds also control the radiative budget. A great amount of scientific work is being developed to compute energy fluxes with the support of satellite data. A dedicated satellite in support of GEWEX will be launched by Japan and US (TRMM) in 1997 and will be carrying a VIS/IR imager, a MW passive radiometer, a rain-radar and an Earth radiation budget instrument in a low-inclination orbit for frequent coverage of the intertropical regions at more times in the day, in order to avoid diurnal biases.

With the advent of the International Geosphere-Biosphere programme (IGBP) the need for high-resolution data is increasing. Monitoring global vegetation by means of global 1-km AVHRR images collected by means of a network of co-operation with direct read-out stations has been initiated. Large-scale deforestation in the equatorial regions and desertification processes can be conveniently monitored by this database. However, the need for higher resolution (LANDSAT/SPOT type) has become apparent, at least over limited areas particularly sensitive to climate changes (e.g. coastal erosion due to change of sea level or regime of coastal water circulation), particularly effective in triggering climate changes (e.g. polar ice edges).

There has been a marked increase in the number of oceanographers using radar altimeter data (available now from ERS-1 and Topex/Poseidon, before from GEOSAT) for ocean circulation studies. The World Ocean Circulation Experiment (WOCE), whose observation phase will be running until 1997, is perhaps the most extensive user of ERS-1 altimeter and scatterometer data, as well as wave spectra derived from SAR images.

Climate applications of satellite data are also attempted at the national and local level. Studies to derive insulation from VIS imagery and cloud statistics, and precipitation indexes, have now been consolidated and give rise to routine operations in many cases.

As regards environment, satellite data are probably still less popular. Even the formulation of data requirements for environmental applications is only at an early stage. Of course, the concept of "global environment", on which satellites can play a major role, is only very recent, as a consequence of the discovery of the ozone problem, the long-range transport of hazardous atmospheric pollutants (see Chernobyl), the acid rain matter, etc. until that time the question of environment was considered a local affair, thus at a level difficult to be observed from a satellite.

Perhaps one of the first big programmes for the application of satellite data to the environment is the CEC/ESA Tropical Ecosystem Environment Observations by Satellites Project (TREES), centred on the application of multi-temporal analysis of SAR images of the tropical rainforest.

As regards atmospheric chemistry, most works deal with ozone, both based on data from dedicated instruments such as SBUV and TOMS, and on the ozone channel of the operational TOVS sounder. Of course, a large number of papers are now appearing based on data from UARS (Upper Atmospheric Research Satellite),which is now being flown, but it is too early to report on this satellite.

6.2 Comments

Many aspects emerge from the short positive review on climatic applications. Perhaps the most important aspect is the ability of the scientific community to embark on the implementation of databases many of which now have become very substantial. The second positive feature has been the attitude of the scientific community, which has not been discouraged by the rather poor quality of the basic data in respect of scientific applications. They have used data from instruments primarily defined for operational use, poorly calibrated or not calibrated at all. Nevertheless, they have been able to develop procedures to calibrate the data and also to merge data from different sources, with different characteristics of resolution, spectral responses, biases, etc.

Coming to the negative aspects, perhaps the worst is the extreme redundancy of efforts. Papers are often presented which are very similar to others already presented 10 years before, sometimes by somebody belonging to another institute. There is a strong preference to develop a new personal algorithm rather than to adopt available algorithms, often with no justification of the need for a new development. It can be inferred that the main interest is to develop models per se rather than for using the model to draw conclusions about the scientific problem. There is certainly a need to improve the transfer of knowledge among scientists (assuming they so wish it) in order to reduce duplication of efforts and focus more resources on the true scientific challenges.

Another critical point is the apparent difficulty to accomplish with the WMO requirement for a higher involvement of developing countries in Global Change research. There are many studies and applications which would be quite feasible at the local level, both for local benefit and for feeding back new information in the system. However, most applications require access to many information sources, very much spread around the world. Knowledge of the existence of these sources and access to them is difficult for any newcomer, particularly from developing countries.

These deficiencies are even more severe in the case of the environmental community who have difficulties in specifying their requirements for satellite data. Their problem in identifying the available data is enhanced due to the wide number of databases necessary to access for environmental applications.

7. SUMMARY CONCLUSIONS AND INDICATION OF ACTION ACTIVITIES

The indications of deficiencies, problems, perspective, etc. have been embedded in the discussion of the individual items. In this final chapter an overall assessment will be reported, as well as indications of a few possible action activities that appear of a rather general nature, such as:

* the need for well designed pilot projects
* the need for a new strategy in education and training
* the need for improved information services

7.1 Overall assessment

The discussions reported in the previous chapters show that the level of satellite data use is much more advanced in operational meteorology (i.e. the WWW Programme) than in all other WMO Programmes.

In operational meteorology (see chapter 1 for imagery, chapter 3 for soundings and chapter 4 for winds), it appears that the limits in satellite data use are mainly determined by the limitations of the space segment, either in terms of completeness or in terms of technology. The following have been identified:

* as for the coverage and/or data access, there are gaps from geostationary imagery (thus cloud-motion winds as well) over the Indian Ocean, and there is the bottle-neck of the APT and WEFAX capability, which prevent small centres from acquiring more information (e.g. full frequency of geostationary imagery in inter-tropical developing countries subject to convective-type weather);

* as for technology, there are the poor vertical resolution of present sounding radiometers and the limitations of yield and vertical resolution of cloud-motion winds; also, automatic cloud classification is sometime illusory because of insufficient number of spectral channels (and perhaps geometrical resolution outside the s.s.p.) in present imaging radiometers. The lack of good-resolution MW imagery makes precipitation estimates rather illusory.

However, there is good awareness of data limitations and deficiencies, and many efforts are being made to circumvent these, generally by handling satellite data in association with physical models and assimilation schemes, whilst awaiting for the next generation of satellites and instruments.

The situation appears very different as regards satellite data use in other WMO Programmes. The discussions under chapter 2 (imagery for hydrology, agriculture and coastal waters) and chapter 6 (climate and environment) show a number of problem areas, the main being:

* the need to access data from more satellites (including some with limited access), complemented by substantial ground-based information and Geographical Information Systems (GIS): which raises problems of education and training, as well as the need for user-friendly information services to locate the data; not to forget the high cost of some type of data;

* the difficulty in identifying "true" end users from others whose primary interest is to transform information to be handed over, with added value, to somebody who, in reality, has not been involved; which also makes difficult to get authoritative long-term validation of applications theoretically demonstrated;

* the difficulty to specify satellite data requirements for environmental use, due to mixed scales of interest between "global environment", which is more likely to rely on satellite data, and "local environment", which still is the dominant concern of environmental agencies;

* the persistent difficulty to involve developing countries in climate change issues, although the driving forces of the global change research, i.e. the main international programmes, have developed full awareness of satellite data potential, and defined (and implemented in few cases) relevant data bases.

This summary assessment shows that there is still a great deal of promotion needed to get cost-effectiveness from satellite data applications outside the field of operational meteorology. In the following (final) three sections, some action activities have been identified to this purpose.

7.2 The need for well designed pilot projects

It has been shown that, except in the case of meteorology,, there is a tendency to concentrate efforts on data production rather than on data use. In many cases, the end- user, who should be the "paying" customer of satellite data and derived products, and the only one entitled to make responsible statements on the data impact, particularly as regards long-term quality standard, is not really involved. Pilot projects, necessary to demonstrate the application, even if satisfactory, often do not give rise to routine applications.

There is a continuing need to promote well designed pilot projects, which involve the end-user in the early stages and are planned to be transferred to the end-user, if successful, for operational continuation. Pilot projects should also be co-ordinated in order to exploit all possible occasions of transportability between comparable local situations.

7.3 The need for a new strategy in education and training

Due to duplication there is a large waste of resources of efforts for data pre-processing and development of known applications. Furthermore, the personnel who are educated and trained often have the objective of handling information, to transform it, possibly with added value, rather than using the information for the scientific disciplinary application.

Education and training methods should be approached with a new strategy, primarily aimed at reaching the end-user, and make use of all modern tools which have been developed in recent years.

One example of approach is to establish a database of E&T events, and an efficient information service to allow users to access the database. Distribution of standard E&T packages to be used locally should be strengthened, according to the principle that information should be moved around, rather than people. The ideal would be if satellite matters were fully embedded in the local E&T organization, as the notation "satellite training course" often appears still too intellectual, thus attracting the wrong people (sometimes just for a problem of foreign language capability) instead of the end user.

7.4 The need for improved information services

The useful application of satellite data requires in most cases, particularly for Global Change studies, access to a variety of data sources, from more instruments of more satellites, as well as from ground-based data often spread across many locations. For a true end-user, often not domestic with the information production chain, it may be sometimes difficult even to know whether data relevant to his problem exist, and where they are located. This problem is particularly difficult for newcomers, e.g. from developing countries, who have in principle an opportunity to benefit from participating in the Global Change research programme, and could provide important feedback to the system.

There is a need to improve the worldwide network for information services by using as much as possible user-friendly procedures, in order to improve the overall returns of the large investments being made for Global Change monitoring and study, and to involve more intimately developing countries in Global Change matters, according to WMO requirements.