P6.4 WMO SATELLITE ACTIVITIES AND PERSPECTIVES

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1. INTRODUCTION

The Thirteenth World Meteorological Congress, (Cg-XIII) held in May 1999 recognized that a need existed for WMO to convene direct discussions with operators of environmental satellites to address policy and important funding issues. WMO agreed that, because of the long-term nature of most issues and the expected large investments required, such a dialogue would be mutually beneficial between appropriate high-level representatives of WMO and operators of environmental satellites. In particular, WMO felt that it should receive advice from those entities that were providing satellite systems that required major investment in order to meet WMO Member needs, including those missions of a research nature not normally included in the space-based component of the World Weather Watch's (WWW) Global Observing System (GOS). WMO thought it appropriate to have discussions with those satellite operators who had the capability, or would have the capability, to provide data, products and services in support of WMO Programmes and international projects and activities sponsored by WMO. WMO also recognized that satellite operators needed to receive WMO approved requirements to help justify the necessary financial investments. As a result, WMO agreed to the establishment of Consultative Meetings on High-Level Policy on Satellite Matters and endorsed the guidelines for such meetings (WMO No. 915)

The First Consultative Meeting on High-Level Policy on Satellite Matters was held at the World Meteorological Organization (WMO) Headquarters in Geneva, Switzerland from 22 to 23 January 2001. The recommendations from the First Consultative Meeting were insightful and will have a profound impact on WMO. The immediate impact will be an expansion of the space-based component of the GOS to include relevant Research and Development satellite missions which will enable WMO Members to provide improved meteorological and hydrological services due to the availability of new satellite data, product and services. The recommendations have already been formally endorsed by the WMO Executive Council at its fifty-third session held in June, 2001 and activities related to their implementation have commenced.

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2. PRESENT SPACE-BASED COMPONENT OF THE GLOBAL OBSERVING SYSTEM

Before, reviewing the specific recommendations endorsed by the WMO Executive Council, it is appropriate to first consider the present configuration of the space-based component of the GOS. There are two major constellations in the current space-based component of the GOS (see Figure 1). One constellation is the various geostationary satellites, which operate in an equatorial belt and provide a continuous view of the weather from roughly 70°N to 70°S. At present there are satellites at 0° longitude and 63°E (operated by the European Organisation for the Exploitation of Meteorological Satellites - EUMETSAT), a satellite at 76°E (operated by the Russian Federation), a satellite at 105°E (operated by the People's Republic of China), a satellite at 140°E (operated by Japan), and satellites at 135°W and 75°W (operated by the USA).

The second constellation in the current space-based GOS comprises the polar-orbiting satellites operated by the Russian Federation, the USA and the People's Republic of China. The METEOR-3 series has been operated by the Russian Federation since l991. The polar satellite operated by the USA is an evolutionary development of the TIROS satellite, first launched in April l960. The present NOAA series, based on the TIROS-N system, has been operated by the USA since l978. FY-1C, the third in the series of China's polar-orbiting satellites, is now operational. These spacecraft provide coverage of the polar regions beyond the view of the geostationary satellites and fly at altitudes of 850 to 900 km.

The ability of geostationary satellites to provide a continuous view of weather systems make them invaluable in following the motion, development, and decay of such phenomena.

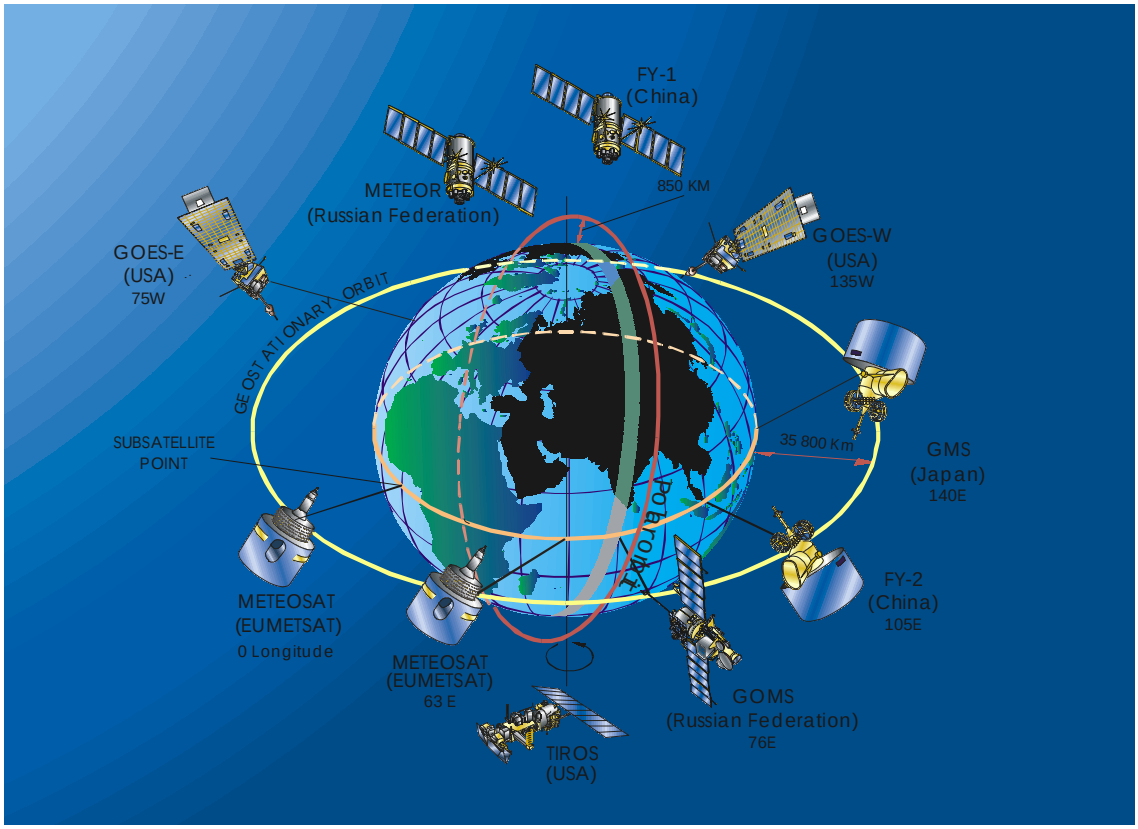

Figure 1, Present space-based component of the Global Observing System

Even such short-term events such as severe thunderstorms, with a life-time of only a few hours, can be successfully recognized in their early stages and appropriate warnings of the time and area of their maximum impact can be expeditiously provided to the general public. For this reason, its warning capability has been the primary justification for the geostationary spacecraft. Since 71 per cent of the Earth's surface is water and even the land areas have many regions which are sparsely inhabited, the polar-orbiting satellite system provides the data needed to compensate the deficiencies in conventional observing networks. Flying in a near-polar orbit, the spacecraft is able to acquire data from all parts of the globe in the course of a series of successive revolutions. For these reasons the polar-orbiting satellites are principally used to obtain: (a) daily global cloud cover; and (b) accurate quantitative measurements of surface temperature and of the vertical variation of temperature and water vapour in the atmosphere. There is a distinct advantage in receiving global data acquired by a single set of observing sensors. Together, the polar-orbiting and geostationary satellites constitute a truly global meteorological satellite network.

3. THE FUTURE SPACE-BASED COMPONENT OF THE GLOBAL OBSERVING SYSTEM

As part of the preparations for the First Consultative Meeting on High-Level Policy on Satellite Matters, a review of the support provided by the present Research and Development (R&D) satellite missions to WMO Programmes was made. The review highlighted the significant contributions already made by R&D satellite missions in support of WMO Programmes. WMO was convinced of the value in articulating the positive impacts experienced by its Members in utilizing data from R&D satellite missions. Feedback from the operational user community to the satellite agencies was identified as crucial and pivotal in highlighting the potential value of R&D data. In order to maximize the usefulness of R&D data, early involvement of the users was deemed essential. It was recognized that one of the

benefits from utilizing R&D satellite data would be a learning process for future systems. Additionally, it would be necessary, where appropriate, to identify impacts on operations within the NMHSs as well as to find where limitations to data access to R&D data occurred. WMO stressed that access to R&D data should be expanded by the satellite operators with the expectation that the impact in operational use would be increased.

Thus, WMO reaffirmed the need to develop persuasive arguments related to the impacts of satellite data justified through feedback from the operational user community. In doing so, it agreed to prepare a report that would be a synthesis of input from the operational user communities on the utility of existing R&D data including persuasive arguments related to their impacts from R&D satellite missions. Furthermore, it suggested that an active interaction between R&D satellite agencies with missions planned for the near-future and perspective operational users be established. Furthermore, it suggested that an active interaction between R&D satellite agencies with missions planned for the near-future and perspective operational users be established.

In recognizing that there were substantial differences between operational meteorological and Research and Development satellite missions, WMO developed and endorsed the *Guidelines for requirements for observational data from operational and R&D satellite missions* (see Chapter 4) in order to provide operational users a measure of confidence in the availability of operational and R&D observational data, and data providers with an indication of its utility.

WMO recognized that there was an increasing convergence between research and operational requirements for the space-based component of the GOS and that it should seek to establish a continuum of requirements for observational data from R&D satellite missions to operational missions. These requirements should be prioritized in the light of both scientific priorities and practicalities and cross-mapped against the needs of the scientific disciplines and Earth system components embraced by WMO, including areas such as the atmosphere, oceans and hydrology, observations needed to improve the monitoring and forecasting/prediction of weather and climate, and impacts of weather and climate variability on natural, social and economic resources. The establishment and maintenance of this continuum of requirements would require a vigorous interactive dialogue fostered by WMO amongst data users, operational satellite providers and R&D agencies. Commitments to address these requirements would allow an evolution of the space-based component of the GOS that would help characterize the total Earth and climate system on a variety of time and space scales and would also provide for the effective transition of research to operational platforms based on the progression of scientific understanding and maturity of required technologies. The global monitoring of water resources (water cycle), ecosystems (carbon cycle), snow and ice and others were important categories in which observations were needed to improve prediction models and address global impacts. Issues and questions related to research categories such as these had proceeded well beyond the research domain and reflected items raised by policy makers and the general public. Consequently, such research categories were becoming, *de facto*, operational needs that would have to be addressed. The existing operational meteorological satellites in geostationary and low earth orbit (LEO) were the best starting point for defining an evolutionary and flexible architecture for the future GOS. WMO envisaged that such a system should be flexible enough to: (1) accommodate proven and existing operational meteorological and other related environmental observations and services; (2) enhance these capabilities based on evolution of scientific understanding and technological innovations; and (3) adopt new and mature capabilities and provide the associated services mandated by emerging requirements.

WMO also reviewed possible configurations for the space-based component of the GOS that included R&D missions as well as the existing constellations of environmental geostationary and near-polar-orbiting satellites. In reviewing the basis for the need to propose new configurations, WMO recalled the requirements setting process within WMO. It noted that it followed a process that resulted in a hierarchical set of requirements. At the highest level, WMO was guided by its Long-term Planning Process. The Fifth Long-term Plan was the current plan and spanned the time frame 2000 to 2009. WMO also noted, that in the nearer term, its four year Programme and Budget contained guidance, objectives, opportunities and challenges that were based on the long-term objectives. WMO recalled that detailed observational requirements for the various application areas found within the WMO and supported programmes were available. Furthermore, the Commission for Basic System in meeting its mandate to provide the basic infrastructure for all WMO Programmes was already considering a redesign of the GOS.

WMO recalled that the Rolling Review of Requirements (RRR) process had been formally approved by the Commission for Basic Systems. The RRR process had four distinct steps: a compilation and review of observational requirements resulting in a consolidated set of observational requirements unique to an application area, development of expected performances for both *in situ* and satellite-based observing systems, an objective comparison of how well the requirements were met by the observing systems, and a Statement of Guidance that was an evaluation of the objective comparison by experts in the various application areas. WMO has conducted and published three such Statements of Guidance as WMO Satellite Activities Technical Documents (TD No. 913, TD No. 992, TD No. 1052).

In view of the existing process within WMO to provide a hierarchical set of requirements, WMO felt that the most appropriate manner to satisfy the full suite of present requirements, while recognizing the capabilities of both operational meteorological and Research and Development satellites, would be to expand the present definition of the space-based component of the GOS to include Research and Development satellites, complementing the existing two operational meteorological satellite constellations (geostationary and near-polar-orbiting). Enhancements to the overall space-based component of the GOS would be incremental as new contributions from the R&D satellites were realized. WMO agreed that the expansion of the definition should be through a resolution by WMO constituent bodies, especially the Commission for Basic Systems, thus formalizing the high-level system requirements that would provide the necessary observational data for WMO and supported programmes.

Therefore, WMO at the fifty-third session of its Executive Council requested the Commission for Basic Systems to review, as a matter of urgency, the space-based component of the GOS with a goal of defining an overall system that included appropriately identified R&D satellite missions. The Commission should be guided by the WMO process for its hierarchical set of requirements in order to ensure that the new space-based component would be justified by WMO needs.

WMO also encouraged its Commission for Basic Systems to be forward looking in proposing enhancements to the space-based component of the Global Observing System. It should account for the differences between operational environmental satellites and R&D satellites. There were different levels of maturity within the various R&D satellites. Flexibility and adaptability must be included into the new design. Those Research and Development space agencies that have or will have satellite missions contributing to WMO Programmes and supported Programmes have been approached to establish a dialogue towards including their missions into the space-based component of the GOS.

WMO suggested that CBS review and make appropriate changes to the definitions as contained in the Guide and Manual for the GOS for the present polar-orbiting and geostationary satellites. The changes should be flexible enough to: (1) accommodate proven and existing operational meteorological and other related environmental observations and services; (2) enhance these capabilities based on the evolution of scientific understanding and technological innovations; and (3) adopt new and mature capabilities and provide the associated services mandated by emerging requirements such as, but not limited to:

- Improved understanding of the structure and dynamics of the atmosphere through, for example, soundings of temperature and humidity, improved wind profiles and better rainfall estimates;
- Improved knowledge of the ocean structure and circulation through, for example, operational surface wind vectors and ocean surface topography;
- Better knowledge of the chemistry of the atmosphere, for example, through measurement of ozone, carbon dioxide, and other trace gases;
- Better understanding of the changes in the terrestrial and marine ecosystems and their role in the carbon cycle;
- Improved knowledge of the cycling of water and energy through the earth system to enable better management of global fresh water resources;
- Increased emphasis on calibrated instruments with a view to a better understanding of climate change;
- Improved global coverage from geostationary orbit using at least six operational spacecraft;
- Improved detection and monitoring of hazardous atmospheric phenomena such as fog and volcanic ash.

4. GUIDELINES FOR REQUIREMENTS FOR OBSERVATIONAL DATA FROM OPERATIONAL AND R&D SATELLITE MISSIONS

As noted earlier, there are substantial differences between Research and

Development and operational meteorological satellite missions, e.g., data access, data continuity and data policy. The following are the *Guidelines for Requirements for Observational Data from Operational and R&D Satellite Missions* as agreed upon by the fifty-third session of the WMO Executive Council. The Guidelines serve to provide a basis for using Research and Development satellite data within an operational context.

Preamble

Whilst there is a distinction between operational and research satellite programmes, there is an increasing convergence between their requirements for the space-based component of the Global Observing System and WMO should seek to establish a continuum of requirements for observational data from R&D satellite missions to operational missions. These requirements should be prioritized in the light of both scientific priorities and practicalities and cross-mapped against the needs of the scientific disciplines and Earth system components embraced by WMO, including areas such as the atmosphere, oceans and hydrology, observations needed to improve the monitoring and forecasting and prediction of weather and climate, and impacts of weather and climate variability on natural, social and economic resources. The establishment and maintenance of this continuum of requirements require a vigorous interactive dialogue fostered by the WMO amongst data users, operational satellite providers and R&D agencies. Commitments to address these requirements should allow an evolution by the space-based component toward a comprehensive Global Observing System that should help characterize the total Earth and climate system on a variety of time and space scales and should also provide for the effective transition of research to operational platforms based on the logical progression of scientific understanding and maturity of required technologies. The global monitoring of water resources (water cycle), ecosystems (carbon cycle), snow and ice and others are important categories in which observations are needed to improve prediction models and address global impacts. Issues and questions related to research categories such as these have proceeded well beyond the research domain and reflect items raised by policy makers and the general public. Consequently, such research categories have become, *de facto*, operational needs that should be addressed. The existing operational meteorological satellites in geostationary and low earth orbit (LEO) are the best starting point for defining an evolutionary and flexible architecture for the future Global Observing System. It is envisaged that such a system should be flexible enough to: (1) accommodate proven and existing operational meteorological and other environmental observations and services; (2) enhance these capabilities based on evolution of scientific understanding and technological innovations; and (3) adopt new and mature capabilities and provide the associated services mandated by emerging requirements.

Guidelines

1. In order to maximize the impact of data from operational and R&D missions and the associated expenditures in resources (manpower and financial) by operational users, there should be agreed upon guidelines in the form of requirements that must be met by space agencies responsible for potential R&D missions that would contribute to the space-based component of the Global Observing System. These requirements need further definition but, as a preliminary set, should include considerations relating to:

(a) Data dissemination;
(b) User preparation for R&D data; and
(c) Data continuity for sufficient periods of time.

2. The agreed Guidelines for the Requirements for operational and R&D missions that contribute to the space-based component of the Global Observing System are, in outline, that:

(a) Data dissemination should be:

(i) Available to WMO Members taking into consideration user and provider data policies;
(ii) In data formats (standardized where possible but well publicised in all cases to allow data access);
(iii) Timely;
(iv) Readily accessible from supported infrastructures (capabilities beyond current GTS capabilities must be established) (If possible, use the existing dissemination procedures of the meteorological satellite operators);
(v) Based on a dialogue, encouraged and facilitated by WMO, between users and satellite agencies concerning data dissemination on a regional basis;

(b) User preparation for R&D data implies that:

(i) Resources to enable use of research data must be provided;

(ii) Training new users of new data and products must be organized and financially supported;

(iii) On-line training systems, such as the Virtual Laboratory concept, should be used;

(iv) International working groups should be used as fora for information;

(v) Spending on technology must be supplemented with resources for utilization;

(vi) WMO programmes using satellite data should put in place systems to provide early operational evaluations and feedback to satellite operators concerning the utility and benefits they have derived from usage of the data;

(vii) WMO should encourage activities that focus on a dialogue between users and the satellite agencies concerning data usage on a regional basis;

(c) Data continuity for sufficient periods of time requires that:

(i) A clear path for research capabilities to be adopted by operational agencies must be identified;

(ii) Political high level agreements must be encouraged;

(iii) More active participation of research satellite agencies in operational coordination and planning groups must be encouraged and expanded;

(iv) Opportunities need to be fostered for satellite remote sensing capabilities to evolve;

(v) R&D satellite operators must identify and confirm an intention to provide data for an identified period of time;

(vi) There be continuity of calibration of data sets (bias estimations);

(vii) Responsibility for long-term maintenance of data sets be identified.

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REFERENCES

WMO Executive Council, fifty-second session, Geneva, 16-26 May 2000, WMO-No. 915, Annex II, pg 67.

Preliminary Statement of Guidance Regarding How Well Satellite Capabilities Meet WMO User Requirements in Several Application Areas, WMO TD No. 913 (SAT-21).

Statement of Guidance Regarding How Well Satellite Capabilities Meet WMO User Requirements in Several Application Areas, WMO TD No. 992, (SAT-22).

Statement of Guidance Regarding How Well Satellite and *In Situ* Sensor Capabilities Meet WMO User Requirements in Several Application Areas, WMO TD No. 1052 (SAT-26).