International Cooperation of Meteorological/ Earth Observing Satellites

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International cooperation over the last 40 years has proven to be highly effective to implement the space component of the WMO World Weather Watch Global Observing System (WWW/GOS). The formation of the World Weather Watch (WWW) was stimulated by the advances in computer and space technology at the end of the 50'^{s} and the beginning of the 60'^{s}. The first launches of artificial satellites beginning with Sputnik on 4 October 1957 by the then USSR and with Explorer I by the USA on 2 January 1958 heralded a new era of Earth observation. The first meteorological satellite TIROS – 1 (Television InfraRed Observation Satellite) launched on 1 April 1960 for the first time provided pictures of the distribution of clouds previously undreamed of. The potential for such a new observing system was immediately recognised.

WORLD WEATHER WATCH

In response to the Resolution 1721 (XVI) of the General Assembly of the United Nations of 20 December 1961 on "International Co-operation in the Peaceful Uses of Outer Space" two outstanding scientists, Academician Bugaev (USSR) and Dr. Wexler (USA) prepared a report which was submitted by WMO in June 1962 to the United Nations. The authors highlighted the enormous potential resulting from satellite data to both the operational and research meteorological community and they proposed a new structure, the World Weather Watch(WWW). Based on their report, the General Assembly requested in its Resolution 1802 (XVII) of 1962 that the development of meteorology and atmospheric science "be for the benefit of all mankind". As a result, the WWW concept was further elaborated and the idea of a Global Atmospheric Research Programme (GARP) emerged during the following years.

In 1963 the concept of the WWW with its sub-systems - Global Observing System (GOS), Global Data Processing System (GDPS) and Global Telecommunication System (GTS) - was approved by the 4th WMO Congress and finally the WWW Plan and Implementation Programme by the 5th WMO Congress in May 1967.

SPACE-BASED SUB-SYSTEM OF GOS

The GOS in this first plan was composed of 5 conventional observing components and the meteorological satellites. Since at this time only polar-orbiting satellites existed, the GOS needed only one or two of such satellites. In addition the plan under the heading "Meteorological Satellites" made a very important statement: "The WMO should assist in bringing about co-ordination of the satellite programmes of individual countries (or groups of countries)".

During the following years two important technical developments took place. On

28 February 1966 the first operational polar-orbiting meteorological satellite equipped with real-time picture transmission, the so-called APT (Automatic Picture Transmission), was launched by the USA. It allowed the countries of the world to receive, in real-time, twice a day, imagery data in their area of reception. In December of the same year a technology demonstration communication satellite ATS-1 (Advanced Technology Satellite) flew in geostationary orbit with a meteorological payload. This satellite successfully confirmed the potential of frequent satellite observations (every 30 min) from geostationary orbit.

These advances paved the way for significant progress in the development of the GOS and of GARP, specifically in the planning for the First Global GARP Experiment (FGGE). Both the upgraded WWW Plan and Implementation Programme 1972-1975 as well as the planning documents for the FGGE contained a new requirement for satellite configuration for the GOS and the observational system of the FGGE. Two or three polar-orbiting and four geostationary satellites were now asked for.

In the early 70'S the USA launched its Synchronous Meteorological Satellites SMS-A and SMS -B as forerunners of its Geostationary Operational Environmental Satellites (GOES) which were stationed at 60 W and 140 W respectively. At the same time the European Space Research Organisation (ESRO) – which later became the European Space Agency (ESA) – and Japan, started their geostationary satellite projects to fill the gaps over 0 degree and 120 E in time for the FGGE.

CO-ORDINATION OF GEOSTATIONARY METEOROLOGICAL SATELLITES

When the Europeans and the Japanese announced their separate programmes it was realised that it was time to **coordinate** the different activities and a meeting was convened in Washington on 19 September 1972 with participants from ESRO, Japan and the USA. WMO and the Joint Planning Staff for GARP attended as observers.

The meeting identified several areas for coordination, in particular for the collection of fixed and moving platforms and for the so-called WEFAX analogue real-time image dissemination. It was decided to establish two working groups, one on "System Engineering" and the other on "User Considerations". In 1973 at the second meeting the group adopted the name "Co-ordination of Geostationary Meteorological Satellites (CGMS)". WMO representing the user community, and the USSR - when it announced its plan to set up a geostationary satellite project – also became members of CGMS.

The CGMS satellite operators were able to implement a constellation of five geostationary satellites in time for FGGE (1 Dec. 1978 – 30 Nov. 1979). The USA provided three, one over the Western Atlantic, another over the Eastern Pacific and a third over the Indian Ocean. Europe stationed one over 0 degree and Japan over 140 E.

India joined CGMS in 1979 after the decision to embark an imaging radiometer on its geostationary telecommunication satellites INSAT, the first launched in 1983. EUMETSAT and

the PR of China came on board in 1987 and 1989 respectively.

When EUMESAT and the PR of China announced in the late 80's their intentions to
fly not only geostationary satellites but also polar-orbiting ones, it became obvious that there was a need to extend the coordination to include polar-orbiting satellites. Recommended by the WMO Executive Council Panel of Experts on Satellites in October 1989, CGMS agreed to incorporate this new task and adopted a new chapter by 31 January 1992. The group changed the name accordingly to “Co-ordination Group for Meteorological Satellites”. The Panel of the Executive Council further recommended to extend the coordination to include the extraction of meteorological parameters and contingency planning

EXTRACTION OF METEOROLOGICAL PARAMETERS

CGMS had in previous years already directed its attention beyond purely technical and operational items such as common data and transmission formats, to the enhancement of the utilisation and the improvement to the quality of satellite products. Under its auspices the International TOVS (TIROS Operational Vertical Sounder) Study Conference has been meeting since 1983. This group was instrumental in developing and distributing common software packages for temperature and moisture profile retrieval algorithms to be used by the meteorological community. The Working Group on Cloud Motion Vectors, established in September 1991, focused their efforts on the science and operational development and the use of atmospheric motion winds from geostationary and since 2004 also from polar-orbiting imagery data. In 2000 a Working Group on Precipitation was added.

CONTIGENCY

At the request of WMO to deal more actively with the important issue of contingency, a first meeting of the Working Group on Global Contingency Planning was called in October 1992 and was attended by EUMETSAT, Japan, USA and WMO. In the discussion it was recognised that the only realistic way forward was to build the global contingency planning on regional plans based on the “help your neighbour” philosophy. The possibility of redeployment was ruled out due to financial and technical constraints.

The “help your neighbour“ philosophy had already been tested in the past by moving GOES-4 over the middle of the Atlantic when the data collection service on board METEOSAT-2 failed in 1984. The next positive demonstration took place in 1991 in response to a request by the USA when the only fully operational geostationary satellite, GOES-7, was left to cover the USA. METEOSAT-3 was moved to 50 W by August 1991 and from February 1993 until May 1995 moved again to 75 W. As a result of this successful and very positive experience, EUMESAT and the USA signed a long-term agreement on back-up of operational meteorological satellites in July 1995.

Three other regional contingency activities have occurred. In May 1989 EUMESAT moved its METEOSAT-5 over the Indian Ocean to 63 E when the USSR geostationary satellite GOMS-Electro N1 failed. Then in the autumn of 1992 Japan provided support in the Pacific region for data collection of Regional Data Collection Platforms. The USA helped out with GOES-9 from May 2003 to July 2005 over the Eastern Pacific when the Japanese GMS-5

stopped operating. This experience led to Japan and the USA signing a long-term agreement in February 2005 to guarantee continuous geostationary satellite coverage over East Asia and the Western Pacific.

When China and Eumetsat established their respective polar-orbiting programmes in the 90's it became a reality to extend the contingency planning to polar-orbiting satellites. Based on the then basic WMO requirement for two satellites in polar orbit, one in the morning (AM) and one in the afternoon orbit (PM), a constellation of four polar-orbiting satellites would be required to meet the contingency needs. Each of the satellites in the morning or the afternoon orbit would be backed up by one satellite. Since then, based on the very positive impact of the sounding data from more than two polar-orbiting satellites in Numerical Weather Prediction models the number of satellites required by WMO in polar orbit has been increased from two to four. As a consequence the discussion on contingency planning for polar-orbiting satellites is continuing. The main issues are back-up arrangements and equator crossing times.

USER REQUIREMENTS

As already mentioned, the original constellation of the Space-based Sub-system of the WWW/GOS, as it was called in 1975 was implemented by 1977 in time for the FGGE. It demonstrated its importance for the day-to-day operation of the WWW and it was obvious as stated in the famous 1977 WMO publication "The role of satellites in WMO Programmes in the 1980s" by Johnson and Vetlov, that the satellites will play an "increasingly important role … in support of various programmes". WMO responded to this challenge and initiated the definition of user requirements by its Programmes. The requirements subsequently included in the form of a rolling review process; meteorology, hydrology, climatology, oceanography, climate and global change related disciplines. The process also responded to the requirements for education and training. CGMS responded to this from 1995 onward with the establishment of a system of Regional Meteorological Training Centres (RMTC); upgraded to centres of excellence in satellite meteorology and evenly distributed around the world by the continuing support of some of its member space agencies. In addition a "Virtual Laboratory" concept was developed in 1999 and implemented in the following years.

REVIEW OF GOS

At the end of the 90's, during discussions, the need for a review and update of the GOS, including its Space-based Sup-system became evident. In 1999 CGMS reviewed the compliance of the space-based component of the GOS in post 2010 time frame. The upgraded component should not only include operational meteorological but also research and other Earth observing satellite systems. Since 2000, the "Consultative Meetings on High-Level Policy on Satellite Matters (CM)" involving the heads of the operational and R&D satellite operators and senior officials of WMO have provided a forum for high-level policy discussions. It paved the way for the inclusion of R&D Earth observing satellites into the space-based component of the

GOS after approval by the 14th WMO Congress in June 2003. Accordingly several R&D Space Agencies have become members of CGMS since (CNSA, CNES, ESA, JAXA, NASA, ROSCOSMOS). As early as 2001, UNESCO/IOC joined CGMS to represent the oceanographic community. The total number of CGMS members is presently 15.

WMO SPACE PROGRAMME

As a consequence of this WMO established by 1 January 2004 a Space Programme which together with the “Consultative Meeting” and the CGMS pushed several initiatives ahead. The Integrated Global Data Dissemination System (IGDDS) of WMO based on the regional data dissemination systems of the operational CGMS members, e.g. CMA, EUMETSAT and NOAA has been operational since the end of 2006. In April 2007 the Global Space-based Inter-Calibration System (GSICS) began its operation as a component of the Space-based Sub-system of the GOS and the concept of a global network of Regional Specialised Satellite Centres for Climate Monitoring (RSSC-CM) was approved by potential participants.

GLOBAL EARTH OBSERVING SYSTEM OF SYSTEMS

In February 2005 the Global Earth Observing System of Systems (GEOSS) was approved by its participating countries. Responsible for the implementation is the Intergovernmental Group on Earth Observations (GEO). Within this system WMO has responsibility for the weather, water, climate and disaster social benefit areas of the GEOSS and is a sponsor of component systems of the GEOSS. The WMO Space Programme is the coordinator for the Space Segment of the GEOSS and the Space-based Sub-system of the GOS would be a component of the Space Segment of GEOSS. As a consequence CGMS has a concomitant responsibility to GEO and since November 2006 is a Participating Organisation in GEO.

When the international cooperation in the field of meteorological and Earth observing satellites started in 1972 with the coordination of the WEFAX dissemination and the collection of data from moving and fixed platforms by meteorological geostationary satellites nobody could envisage that after some 45 years, CGMS would be responsible for the coordination in many areas of the Space-based Sub-system of the forthcoming WMO Integrated Global Observing System (WIGOS) and part of the Space Segment of GEOSS. It demonstrates how highly effective and efficient an unofficial group can be, which is not part of an official organisation, nor does it report to any organisation. CGMS is a “joint venture” by space operators and the user organisations (WMO, UNESCO/IOC) they serve.