CEOS VIRTUAL CONSTELLATIONS

PROCESS PAPER

UPDATED NOV 2013

1. INTRODUCTION

Understanding the Earth system is crucial to maintaining and enhancing human health, safety and welfare, alleviating human suffering including poverty, protecting the global environment, reducing disaster losses, and achieving sustainable development. Observations of the Earth system constitute a critical input for advancing such an understanding. This has been the driving force behind the establishment of the Group on Earth Observations (GEO), four ministerial-level Earth Observation Summits, and the development of the Global Earth Observation System of Systems (GEOSS).

The purpose of GEOSS is to achieve comprehensive, coordinated, and sustained observations of the Earth system, in order to improve monitoring of the state of the Earth, increase understanding of Earth processes, and enhance prediction of the behavior of the Earth system. GEOSS meets the need for timely, quality long-term global information as a basis for sound decision- making, and enhances delivery of benefits to society. The implementation of GEOSS requires effective consultation and cooperation, with international and national agencies sponsoring or co-sponsoring the component observing systems upon which GEOSS is built. GEOSS leverages the value of Earth observation research programs, and facilitate their transition to sustained operational use. It provides a means to share observations and products with the system as a whole, and takes the necessary steps to ensure that the shared observations and products are accessible, comparable, and understandable, by supporting common standards and adaptation to users needs. GEOSS includes *in situ*, airborne, and space-based observations.

In support of GEO objectives and in order to harmonize efforts among space agencies to deploy Earth observation missions and with the aim to close emerging data gaps, the Committee on Earth Observation Satellites (CEOS) has established the concept of Virtual Constellations for GEO, whereby a number of both existing and already approved satellites or instruments and their observations, when coordinated in their operation and exploitation, can merge or integrate data and derived information to contribute to a (quantitative) analysis/measurement goal. The value of the Constellations concept is its guidance (requirements) for design, development and operation of future systems to meet the broad spectrum of Earth observation requirements. GEO and GEOSS will benefit from this effort because Virtual Constellations can help agencies avoid duplication and overlap in Earth observation efforts, close information gaps for all GEO Societal Benefit Areas (SBAs), and establish and sustain a global Earth observation network.

A brief account of the early historical development of the CEOS Virtual Constellation concept is provided in Annex 1.

DEFINITION: A CEOS Virtual Constellation is a set of space and ground segment capabilities operating together in a coordinated manner, in effect a virtual system that overlaps in coverage in order to meet a combined and common set of Earth observation requirements. The individual satellites and ground segments can belong to a single or multiple owners. The Constellation concept builds upon or serves to refocus already existing projects and activities. The Virtual

Constellations (hereinafter referred to as Constellations) effort provides a unique forum to achieve political visibility and increase mutual benefit among space and other environmental agencies in support of crosscutting GEO Tasks and Targets. In particular, it offers opportunities to share experience in the development of algorithms; standardize data products and formats; exchange information regarding the calibration and validation of measurements; facilitate timely exchange of and access to data products from existing and planned missions; and facilitate planning of new missions—ranging from coordinating orbits to optimizing observational coverage to sharing implementation of mission components. The interim goal of a Constellation is to demonstrate the value of a collaborative partnership in addressing a key observational gap; the end goal is to sustain the routine collection of critical observations. Implementation of Constellation activities is ultimately dependent on the coordination of formal agreements among participating agencies.

This definition of CEOS Constellations for GEO was formally adopted together with this document at the 2008 CEOS Plenary.

The concept of Virtual Constellations has not been "invented" by CEOS. Several satellite Constellations pre-date the CEOS initiative. Examples of cooperation include the World Meteorological Organization (WMO) Global Observing System, the "A-Train," the Global Precipitation Measurement mission, ocean altimetry satellite cooperation, and the International Charter "Space and Major Disasters," which could be regarded as models for new CEOS Virtual Constellations. Additional information on these examples of Virtual Constellations is provided in Annex 2.

CEOS recognizes the strength of the Constellations concept, and the benefits that would stem from its adoption. The original intention of the Constellations was to provide CEOS with an outcome-focused vehicle for thematic coordination of space agency missions. As far as possible they were to be tightly-focused projects with a fixed duration and measurable achievements - rather than be ongoing, general coordination frameworks. In practice, the evolution of the original and subsequent Constellations has resulted in a range of different emphases, some of which stress the importance of long-term coordination of some measurement types through the relevant Constellation team.

2. GOALS

The concept of the "CEOS Constellations" has been agreed by CEOS Agencies as a means to better address space-based Earth observation needs on a global basis – without eroding the independence of individual agencies. CEOS recognizes that national/regional observing requirements will continue to dominate space agency spending and that any grand design for implementation of global observing systems will always be dependent on individual agency funding priorities. CEOS Constellations will:

- Move space agencies' coordination efforts from the generic to the specific – *i.e.*, adopting a problem-focused approach to achieve significant results in terms of actual implementation and physical outputs (such as new products or contribution to Fundamental Climate Data Records) within a relatively short time;
- Improve considerably the extent to which the combined outputs of the various agency programs are relevant to specific applications, such as climate and other GEO SBAs, and respond to the requirements for space-based observations expressed in, *e.g.*, Integrated

Global Observing Strategy (IGOS) Theme reports and the Global Climate Observing System (GCOS) Implementation Plan;

- Facilitate the participation of smaller contributors;
- Recognize that existing assets could be used more effectively in support of the ongoing GEOSS 10-Year Implementation Plan;
- Realize the overall potential benefits at global scale that would result from reduced redundancy and improved continuity and overlap among missions;
- Create the conditions, through the adoption of a series of requirements and guidelines which satisfy key GEOSS requirements, whereby all agencies – large and small – as well as other contributors, are able and indeed encouraged to make their contributions to the common objective of developing the space segment of GEOSS; and,
- Use an accreditation/recognition process, based on an agreed set of metrics, to ensure that proposed contributions to a Constellation will help to satisfy the relevant community needs.

Processes for proposing, initiating, developing, implementing and promoting a CEOS Virtual Constellation are outlined in Sections 4 and 5.

3. THE CURRENT CEOS CONSTELLATIONS

As of November 2013, the seven current CEOS Constellations are:

- **The CEOS Constellation for Atmospheric Composition (AC-VC)**: The AC-VC's objective is to collect and deliver data to improve monitoring, assessment and predictive capabilities for changes in the ozone layer, air quality, and climate forcing associated with changes in the environment through coordination of existing and future international space assets. The AC Constellation directly addresses the SBAs of disasters, health, energy, climate, and ecosystems.
- **The CEOS Constellation for Land Surface Imaging (LSI-VC)**: The LSI-VC's objective is to define a broad range of detailed guidelines for optimal capabilities to acquire, receive, process, archive, and distribute land surface image data to the global user community. Information from the LSI Constellation primarily benefits the SBAs of disasters, energy, climate, water, ecosystems, agriculture, and biodiversity.
- **The CEOS Constellation for Ocean Surface Topography (OST-VC)**: The OST-VC's objective is the implementation of a sustained, systematic capability to observe the topography of, and the significant wave height on, the surface of the global oceans ranging from basin-scale to mesoscale. It focuses on global sea level rise, the role of the oceans in climate, and operational oceanography. Information from the OST Constellation supports the SBAs of disasters, climate, water, and weather.
- **The CEOS Constellation for Precipitation (P-VC)**: The P-VC's objective is to establish an international framework to guide, facilitate, and coordinate continued advancements of multi-satellite global precipitation missions. Through this framework, existing and planned missions can work synergistically to meet international user community requirements. Information from the Precipitation Constellation primarily benefits the SBAs of disasters, climate, water, and weather.

- **The CEOS Constellation for Ocean Colour Radiometry (OCR-VC)**: The OCR-VC's objective is to provide a time series of calibrated aquatic radiances at key wavelengths from ocean color satellite sensors. Well-calibrated aquatic radiances enable the estimation of many optical, biological, biogeochemical, and ecological properties of Earth's aquatic environments. Activities include on-orbit and vicarious calibration, data validation, merging of satellite and *in situ* data, product generation, as well as development and demonstration of new and improved applications for scientific and management purposes. Information from the OCR Constellation primarily supports the SBAs of climate, water, and weather.
- **The CEOS Constellation for Ocean Surface Vector Winds (OSVW-VC):** The OSVW-VC's objective is the implementation of a sustained, systematic capability to observe the wind fied at the surface of the oceans from basin-scale to mesoscale. It focuses on the role of ocean surface wind fields in operational oceanography and meteorology, such as in supporting improvements in operational marine warnings and forecasts through the use of ocean surface vector winds from satellite scatterometry (together with significant wave height, SWH, from the Ocean Surface Topography Virtual Constellation). OSVW also characterizes the OSVW field for use in climate-quality data records and facilitates research related to the influence of wind forcing on the circulation of the oceans. Information from the OSVW Constellation primarily benefits the SBAs of weather, disasters, climate and water.
- **The CEOS Constellation for Sea Surface Temperature (SST-VC):** The SST's objective is the development and improvement of sea surface temperature products including the SST Essential Climate Variable. SST seeks to develop and implement metrics for SST services, products and users, to improve calibration and validation of the relevant instruments, and to develop training activities for satellite SST practitioners. SST serves as the formal link between CEOS and the Group for High Resolution Sea Surface Temperature (GHRSST). Information from the SST Constellation primarily benefits the SBAs of climate, weather and water.
- Each of the current Constellations is defined by one or more Earth properties and one or more satellite measurement techniques:
- Single property with single measurement technique:
    - Ocean Surface Topography Constellation: altimetry supplemented with tide gauges and other *in situ* sensors.
    - Ocean Surface Vector Winds Constellation: microwave scatterometry supplemented with other microwave measurements.
    - Ocean Colour Radiometry Constellation: calibrated ocean colour radiances (OCR) at key wavelength bands supplemented by in-situ data for vicarious calibration, validation et al.
- Single property with multiple measurement techniques:
    - Precipitation Constellation: precipitation radar supplemented with microwave radiometry.
    - Sea Surface Temperature Constellation: infrared and passive microwave imaging radiometers complemented by in situ observations.
- Multiple-property/domain-based with multiple measurement techniques:

- Atmospheric Composition Constellation: various parameters (radiative and chemically active gases, aerosol, etc.) in the atmospheric column with multiple measurement techniques;
- Land Surface Imaging Constellation: various parameters (related to land use/cover, fire, volcanic eruptions, etc.) with multiple measurement techniques.

Each Constellation is unique and matures at its own pace. Constellation Leads/Co-Leads work together with the CEOS SIT Chair in addressing what SIT and CEOS, through its agencies, might do to assist Constellation implementation. They are also involved in GEO Tasks and contribute in a timely manner to their implementation. The CEOS Systems Engineering Office (SEO) is prepared to assist CEOS Constellations, as appropriate, to develop traceable system-level requirements to facilitate SBA impact assessments, to perform instrument and mission gap analyses, and to support future architecture planning. Constellation Leads/Co-Leads meet with the SIT Chair every four months to review progress and adjust implementation plans; provide Task Team-related progress reports to the GEO Secretariat, as required; and brief the SIT and CEOS Plenary Meetings on Constellation developments, as required.

The distribution and application of data products and services from a given Constellation may involve a range of Service Providers, external to CEOS, providing integration and value-added support tailored to the needs of different SBAs. The Constellations and the products and services supported by them in most cases typically support multiple SBAs in a cross-cutting fashion (as noted in the descriptions of the above current Constellations).

4. PROPOSING NEW CONSTELLATIONS

CEOS SIT will address new Constellation proposals on a case-by-case basis in connection with procedures outlined in Section 5. Lessons learned from the existing Constellations will also be taken into account when designing an overall strategy and selecting new Constellations. A new CEOS Constellation may be proposed by two or more CEOS Agencies, be they Members or Associates.

CEOS endorses the following set of procedures for development and implementation of potential future CEOS Constellations, and encourages existing Constellations to also adapt to them, as practicable, realizing, however, that each Constellation is unique. This process will normally consist of two phases:

Phase I – An *Initial Proposal* to the SIT with a request to determine CEOS Agency interest in a possible Constellation;

Phase II – A *Full Proposal* for SIT approval – including an Implementation Plan.

5. PHASES OF THE CONSTELLATION PROPOSAL PROCESS

5.1. PHASE I – INITIAL PROPOSAL

The *Initial Proposal* should be a short explanatory paper (four to six pages) provided to the SIT Chair at least four weeks in advance of an upcoming SIT Meeting (or SIT session at CEOS Plenary). The core of the paper should be the *Draft Terms of Reference* for the proposed Constellation, following the structure and headings provided in Annex 3.

The purpose of the *Initial Proposal* is to allow SIT and its member agencies to understand the

scope and scale of the proposed constellation, and to accurately characterize its context among existing constellations and related ongoing or planned activities in the community. It should seek to develop a consensus among those agencies sponsoring the related satellite missions to support the development of the proposed Constellation and can serve as a focus for the necessary coordination.

If given a go-ahead by the SIT Chair, the proposers of the candidate Constellation will make a presentation on the *Initial Proposal* at the upcoming SIT meeting.

5.2. PHASE II – FULL PROPOSAL & IMPLEMENTATION PLAN

The SIT will decide whether the *Initial Proposal* has sufficient support to proceed and whether any adjustments are necessary to the proposed scope, objectives etc – given the context of CEOS strategic objectives and activities. If positive, the SIT Chair will request the proposers proceed with developing a *Full Proposal & Implementation Plan* - due to the SIT Chair within six months of the SIT meeting at which the *Initial Proposal* was presented.

The *Full Proposal* should be a comprehensive characterization of the proposed Constellation, and should expand on all the points listed in the *Initial Proposal*, including expanded and Final Terms of Reference, covering:

- Confirmed space agency members and representatives; desired space agency members; nomination of Constellation Co-Lead agencies and representatives. CEOS Agencies are expected to fully support Co-Leads from their Agencies, also ensuring their continued active involvement. It must be made clear where participation and resources have been agreed and where these still remain to be sought.
- Identification of the critical decisions and actions regarding CEOS agency mission coordination (at any level: space segment, ground segment, products/services etc) that represent the value-add of the constellation against the context of the existing plans of the contributing agencies. These issues will represent the basis/substance of the reports to SIT and the metric for managing and monitoring progress of each of the VCs. Impediments to achievement of the VC outcomes and deliverables should be clearly communicated as the challenges for CEOS to address.
- Definition of the outcomes and deliverables from the VC activities, including support for relevant ECVs. The accomplishments resulting specifically from the VC value-adding activities should be defined – distinct from the individual existing plans of contributing agencies.
- An outline of requirements and guidelines for potential contributors to the VC - including technical measurement criteria, inter-comparison and calibration/validation targets, data access and format guidance, including an assessment of compliance to GCOS requirements, including the GCOS Climate Monitoring Principles (GCMPs), wherever applicable. Particular attention should be paid to continuity and comparability of contributing measurements.

The *Implementation Plan* should provide a credible way forward for realization of the Constellation objectives and for achievement of the deliverables and outcomes. Outputs may well be on several different timescales, and a phased approach should be adopted, focusing initial effort on a small number of achievable results - described in terms of the output (product, service, Fundamental Climate Data Record, continuity, etc.) rather than technology.

The Team should ensure the necessary involvement of the relevant user communities, to ensure that the products envisaged are compatible with their stated needs (as, for example, in the GCOS Implementation Plan for climate). Outlining of an end-to-end "value chain" involving such users is desirable.

The *Implementation Plan* must include the following items:

Requirements and Specifications

The Constellation must encompass all aspects of the user experience, such as:

- The science value and justification for the measurements being undertaken, consisting of a specification of the spatial, spectral and radiometric performance required;
- Current accepted technical specifications for inter-calibration with other spacecraft in the Constellation and with ground systems, and a definition of accepted calibration practices; and,
- Current technical specifications for the data formats and existing inter-operability of the data acquisition and distribution networks.

Documentation of these specifications as they currently exist will support the evaluation of Constellation progress and allow assessments or gap analyses.The CEOS System Engineering Office (SEO) may be available to support development of requirements and assessments/gap analyses. The expertise of the CEOS Working Groups should be called upon as necessary (eg Working Group on Calibration and Validation (WGCV) - to help define calibration requirements; and the Working Group for Information Systems and Services (WGISS) - to help define data and services requirements).

Schedule

A detailed time schedule is required, indicating the various steps and milestones proposed for implementation (*e.g.*, negotiation of a Memorandum of Understanding) and, wherever possible, identifying potential obstacles. This schedule would enable SIT to monitor progress and, where necessary, assist in obtaining contributions which are behind schedule. Implementation reports will be provided to the SIT at regular intervals, providing opportunities for measuring the successful development of the project.

Accreditation and Recognition Metrics

Teams must formulate accreditation/recognition criteria, which are measurable against an agreed set of metrics. This requirement is intended to streamline and focus the process and bring maximum benefit to the relevant user communities within reasonable timescales. It is important to stress that it is not the intention of CEOS to offer an evaluation of the submitted programs as such; this is strictly the business of the owners of the programs.

The criteria need to be tied very closely to the user requirements (including CEOS strategic objectives, GEO SBAs or GEO Work Plan Tasks) and the Team should resist the temptation to add further criteria, which would unnecessarily complicate the implementation of its proposed Constellation.

The underlying Constellation concept encourages participation from all space agencies, as well as other entities that may have data holdings or other contributions to offer. Care will therefore need to be taken in defining criteria and metrics, which do justice to the sometimes conflicting

desires for inclusiveness and efficiency. Technical interoperability, data quality, formats, integration and merging, timeliness, availability and compatibility, access and dissemination, storage, compliance with GEO data sharing principles, are amongst the criteria to be used. A lightweight, easy-to-use, end-to-end user test scenario, involving non-CEOS users, can be developed and applied as appropriate.

Funding

CEOS has no budget of its own. Therefore, *Implementation Plans* must indicate where additional funding is required with, where possible, a suggestion as to the agency or agencies which might be persuaded to provide this support or which have already pledged such support. Potential agency funding obstacles ought to be identified as early as possible in the process, rather than appear when significant work has already been invested.

Following receipt of the *Full Proposal & Implementation Plan*, the SIT Chair, in consultation with SIT Members, will decide at the next scheduled SIT or CEOS Plenary meeting, whether to approve the proposed Constellation.

6. THE ROLE OF SIT IN THE CONSTELLATIONS PROCESS

The SIT is responsible, under the authority of the CEOS Chair, for approving the Constellation *Proposals* & *Implementation Plans*. The assessment and approval process will be done by discussion and decision during regular SIT meetings or SIT sessions at CEOS plenary. Reports and other papers intended for decision in SIT meetings need to be sent to the SIT Chair 4 weeks before a scheduled meeting. It is recognized that this approval process should not lead to unnecessary delays, and the SIT Chair will take the necessary steps to ensure timely responses.

The SIT Chair and/or Vice-Chair, together with their supporting staff, are encouraged to have regular consultations with Constellation Co-Leads and may well be able to help Constellation teams in obtaining support from agencies, provided that the request can be precisely defined and its utility explained. Co-Leads should also bear in mind the possibility of contributions from the SEO and CEOS Working Groups. This can be sought either directly from the Chairs of the Working Groups, or through the SIT Chair.

The purpose of asking the CEOS Constellations to develop and maintain standard Terms of Reference (as of 2013) is to support SIT in communication with, and management of, the various Constellation Teams. Significant emphasis is put on the outcomes and deliverables anticipated of each Constellation; and on identifying the value-added that Constellations seek to deliver – distinct from individual CEOS agency programmes and plans. The periodic dialogue between SIT and Constellation Teams will focus on the critical decisions and actions regarding CEOS agency mission coordination that represent this value-added.

SIT Chair is required to report annually to CEOS Plenary on the progress towards the GEOSS Space Segment. The inclusion of future horizons for deliverables and outcomes from the Constellations in the Terms of Reference format allows SIT Chair to develop ‘big picture’ snapshots of the space segment coordination in CEOS – for reporting internally and externally.

7. USER COMMUNITY ENGAGEMENT

It is important to have a clear and common statement of the primary user community requirements as the basis for any Constellation. Full use should be made of existing requirement statements – IGOS-P theme reports, GEO 10-Year Implementation Plan, GEO Work Plans, GCOS Implementation Plan, CEOS Work Plan etc – and the team should avoid as far as possible introducing new requirements. As noted above, Constellations are encouraged to develop end-to-end value chains in planning engagement with the user community.

Throughout the proposal and implementation phases, it is essential to have regular contributions from senior representatives of the appropriate user community, in order to better serve their needs. Their cooperation is essential in validating the proposed Constellation's criteria, requirements, and ensuring worthwhile objectives and measureable results.

ANNEX 1 – SOME HISTORICAL BACKGROUND

The following piece of text is based on excerpts from the CEOS Virtual Constellation Concept Paper prepared by Daniel Vidal-Madjar and Stephen Ward in March 2006.

The 19th CEOS Plenary, held in London in November 2005, recognized that the *CEOS Implementation Plan for Space-Based Observations for GEOSS* should:

- Identify the supply of space-based observations required to satisfy the requirements expressed by the 10-Year Implementation Plan for GEOSS; and
- Propose an innovative process whereby the many disparate types of Earth observing programs funded by CEOS Member agencies might contribute to the supply of the required observations.

CEOS further recognized:

- The variety of national/regional needs and capacities – scientific, industrial, economic, etc.– that drive Earth observing programs of the countries and regions covered by CEOS. At least part of this difficulty has stemmed from the lack of a clear and common statement of need from the target user communities.
- The notable exceptions of the relatively well-organized meteorology and defense user communities whose ability to express and demonstrate pressing needs for data provision has secured continuity of relevant observing programs.
- The lack of a common requirement for observations for other domains – including most of those which are addressed within the GEOSS Societal Benefit Areas (SBAs) – which has meant that continuity of supply of observations and consistency of technical performance and application of observations has not been systematic, but rather *ad hoc* – except in some instances.

This situation creates a number of shortcomings and impediments from a user perspective:

- Instruments are often not comparable in terms of performance and types of measurement;
- There is no guarantee that data from a group of missions with the same general objectives can be used in an integrated way;
- Data formats, distribution, and access can vary tremendously from agency to agency;
- The absence of a procurement strategy to ensure the continuity of missions results in a waste of financial resources and substantial additional costs.

The concept of the "*CEOS Virtual Constellations*" has been proposed as the basis for a process aimed at addressing these shortcomings in the international planning process for space-based Earth observations without eroding the independence of individual agencies. The basic idea for the establishment of the *CEOS Virtual Constellations* is:

- To extract from the target user communities, a clear and common statement of requirements – as the basis for planning by CEOS space agencies; the heritage of application of space-based observations is now such that this is feasible in most domains – and the GEO process and GEOSS 10-Year Implementation Plan can serve as the reference for many of these requirements (recognizing that some SBAs are more mature than others).
- To define a series of 'Virtual Satellite Constellations' to satisfy these requirements; each Constellation would be the focus for the planning and coordination by CEOS agencies

individually and collectively; each definition would serve as a guide to all agencies as to the characteristics of the space and ground segment for their mission which would best satisfy the needs of the agreed users.

- At the heart of the application of the Constellations concept is the definition of a series of standards – required to be satisfied for a mission to be included in the Constellation – and a process of recognition/acceptance, whereby an agency applies to CEOS to have one or more of their missions (ideally from the outset of planning) recognized as meeting the Constellation standards and thereby satisfying the relevant user community needs. Since part of the purpose of the Constellations Concept is to allow all space agencies, from the largest to the smallest, to plan to contribute to the coordination effort, the standards should be set using a balanced approach.

The Constellations approach will at least provide optimal circumstances for the user communities to make best use of whatever observing assets are provided by CEOS agencies, and will allow space agencies to see how best their planned missions could help meeting the needs of the SBAs. The minimum standards will include:

- Science requirement for the measurement being undertaken, consisting of a specification of the spatial, spectral and radiometric performance required to use the measurement for the intended application.
- Technical specifications for inter calibration (with other spacecraft in the Constellation and with ground systems) and definition of common calibration practices;
- Technical specifications for the data format and inter-operability of the data acquisition and distribution networks;
- Agreement on some general principles of data policy, e.g., the WMO resolution 40 or, preferably, the GEO Data Sharing Principles currently under preparation, at least for a part of the data, taking into account that the mission could have been decided for other purposes than to fulfill GEOSS requirements.

With the objective to build an inclusive coordination process, which means that it must remain open to all agencies or institutions, participation in a particular virtual Constellation could include such contributions as: a fully-fledged space mission, which could comprise instruments, satellite, ground segment and a distribution system or a part of it; an instrument on-board a third-party mission; a part of a receiving network; or, an element of a ground calibration system.

ANNEX 2 – EXAMPLES OF EXISTING VIRTUAL CONSTELLATIONS

It is worth noting that the concept of Virtual Constellations has not been "invented" by CEOS. Actually several satellite Constellations pre-date the CEOS initiative. Examples of cooperation include the World Meteorological Organization (WMO) Global Observing System, the "A-Train," the Global Precipitation Mission, ocean altimetry satellite cooperation, and the International Charter "Space and Major Disasters," which could be regarded as models for new CEOS Virtual Constellations.

- The space-based component of the Global Observing System of the WMO World Weather Watch includes a Constellation, involving a number of satellites in geosynchronous and polar orbits, each being provided by different national or international agencies, and coordinated by the CGMS (Coordinating Group of Meteorological Satellites).
- The international "A-Train" is a "real" Constellation, involving a number of satellites flying in formation, provided by the U.S., Canada and France.
- The Global Precipitation Measurement mission (GPM) with cooperation among the U.S., Japan and Europe, as well as other nations, has long been proposed as a "mission cooperative", indeed a Constellation. And it's predecessor, TRMM (Tropical Rainfall Measuring Mission), has been producing global integrated products of precipitation from a de facto real constellation of US, Japanese, and European satellites since 1998.
- The series of ocean altimetry satellites, including the U.S.-French Topex/Poseidon and Jason, the European ERS-1, ERS-2 and Envisat, and the U.S. Geosat, have been operated as a *de facto* Constellation, and all their data are quasi-operationally merged into integrated products for ocean users, even in the absence of established agreements between all mission providers.
- The International Charter "Space and Major Disasters" operate a Virtual Constellation of Earth observation satellites providing data to support disaster management through a voluntary agreement among space agencies.

ANNEX 3 – TERMS OF REFERENCE FOR THE CEOS VIRTUAL CONSTELLATIONS

INTRODUCTION

Each of the CEOS Virtual Constellations (VCs) has its own scope, objectives, emphasis, approach and membership. These terms of reference format adopted in 2013 seek to characterise each of these unique teams in a consistent way that supports their clear characterisation and value-added in the context of the development of the space segment for the GEOSS and of the multitude of outcomes and deliverables that CEOS seeks to provide – for GEO and for other users and frameworks. Emphasis is given to the outcomes and deliverables provided by the VCs and to identifying the coordination and implementation decisions and actions required of CEOS SIT – as the basis for the communication and management of the progress of each of the VCs.

Terms of Reference are required as part of the process of proposing a new VC and all VCs are required to maintain current Terms of Reference – being updated at least every 2 years and with changes clearly highlighted to CEOS SIT so as to identify changes to schedule or objectives.

This document provides the template for development of VC Terms of Reference.

TERMS OF REFERENCE FOR THE CEOS VIRTUAL CONSTELLATIONS

CONSTELLATION NAME: Following the convention of the existing Constellations (e.g. Sea Surface Temperature Virtual Constellation, SST-VC).

MISSION STATEMENT & OBJECTIVES: A mission statement with a succinct description of the objectives, the problem being addressed, the relevant user communities, the value the Constellation would add, and the benefits it would bring - wherever possible, in terms of the GEOSS 10-Year Implementation Plan long-term objectives. A clear statement of the primary user community requirements as the basis for the Constellation.

CHARACTERISATION OF THE MEASUREMENTS AND DATA COLLECTIONS WITHIN SCOPE: Including the status of, and plans for, data discovery and access to the relevant data collections. Requirements and guidelines including technical measurement criteria should be included for contributing agencies.

CHARACTERISATION OF THE SPACE SEGMENT CONCERNED: Identification of the core missions and agencies within scope of the constellation's ambitions. Inclusion of a timeline chart.

ACTIVITIES, OUTCOMES AND DELIVERABLES: Definition of the outcomes and deliverables from the VC activities using the following headings, and including support for relevant ECVs. The accomplishments resulting specifically from the VC value-adding activities should be defined – distinct from the individual existing plans of contributing agencies. The space segment characterisation should identify the missions or sensors contributing to the VC, and which might be regarded as part of the GEOSS Space Segment.

	3-year horizon	5-years or more horizon
Space Segment		
Ground Segment & Information Systems		
Products & Services		

Reports to SIT from the VCs will emphasise progress towards achievement of these outcomes and deliverables and the issues and obstacles for SIT attention.

IMPLEMENTATION AND COORDINATION ISSUES TO BE ADDRESSED BY SIT: Identification of the critical decisions and actions regarding CEOS agency mission coordination (at any level: space segment, ground segment, products/services etc.) that represent the value-add of the constellation against the context of the existing plans of the contributing agencies. These issues will represent the basis/substance of the reports to SIT and the metric for managing and monitoring progress of each of the VCs. Impediments to achievement of the VC outcomes and deliverables should be clearly communicated as the challenges for CEOS to address.

SCHEDULE: Further detail on the overall schedule in addition to the requested 3- and 5-year horizon outcomes and deliverables.

MEMBERSHIP AND LEADERSHIP: Identification of the agencies involved, the proposed or current lead agencies and individuals, and relevant partners outside CEOS.

RESOURCES: the costs of developing and maintaining the Constellation, and how these will be met by CEOS agencies and their partner organisations. Identify dependencies on, and relationships with, the CEOS Working Groups for transverse activities such as capacity building, information systems etc.