Implementation Plan for the CEOS Biodiversity Virtual Constellation

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This document follows the format described in the CEOS Virtual Constellation Process Paper.

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Introduction

This Implementation Plan provides an overview of the types of activities the Biodiversity Virtual Constellation (B-VC) will focus on, following the content guidance provided in the CEOS Virtual Constellation Process Paper. The Requirements and Specifications section explains that the B-VC is a domain-based virtual constellation focused on the needs of the biodiversity community that were identified in the Biodiversity Study Team's stakeholder assessment. The B-VC activities that will address those findings are then discussed and timeframes for their development are presented. A short section explaining how the B-VC will assess its level of success is followed by an overview of the role of other CEOS entities and how the B-VC will coordinate with them. The document concludes with a section on funding that summarizes how the B-VC will be resourced.

The overarching objective of the B-VC is to increase utilization of space-based Earth observation (EO) for understanding, monitoring and managing biodiversity to support the needs of the biodiversity user community. Activities include identifying needed EO data products and tools and facilitating their development; enhancing EO utilization through outreach, engagement, and capacity building; facilitating development of prototype monitoring systems[2] that utilize EO and that act as testing grounds for new products and capabilities; and ideas on a user engagement mechanism. Because EO is periodic and nearly global, it is well-suited for the monitoring needs of the biodiversity community.

Definitions. To ensure that all readers have a common understanding of the terminology used in this document, definitions of some key terminology are provided.

Biodiversity	In the strict sense, this refers to the variety of living organisms at all levels of organization including genes, species, and ecosystems. However, it is commonly used much more broadly to include all of the living natural world and its processes, roughly synonymous with "nature". This broader meaning is used here and in other BST and B-VC documents unless otherwise indicated.
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
Indicator	A measure reflecting the status of a target of interest (e.g., an ecosystem or species).

Requirements and Specifications: Mapping user needs to EO opportunities

The B-VC is a domain-based virtual constellation driven by biodiversity community requirements. Following its mandate, the Biodiversity Study Team completed a stakeholder assessment that identified specific user needs for utilizing space-based EO for advancing biodiversity understanding, monitoring, and management. The user organizations contacted are listed in Appendix 1. Because of the high degree of overlap across organizations, these needs were consolidated into a focused list, summarized in Appendix 2, that was shared with CEOS Agencies and entities for review and comment.

This assessment, consistent with the findings in the Ecosystem Extent Task Team's White Paper, made clear that the value of space-based EO is not yet fully exploited by the biodiversity community. In particular, the limited availability of fit-for-purpose products was identified as an unfulfilled user need.

[2] Conceptually similar to the demonstrators developed by the EETT, these focus on providing a laboratory to develop and test new capabilities and facilitate user engagement.

For example, users identified ecosystem and land cover maps, assessments of ecosystem health and function, and maps of where species live as three product categories where their needs are not well-met (App. 2). This is not surprising since, for most Agencies, processing beyond product Level 2 is quite limited, yet these products are at higher levels.

While many products within these categories can be generated using currently available observations, forthcoming observations from innovative missions will greatly enhance both their quality and breadth. In particular, these missions (both passive and active) will enable global and periodic characterization of three basic categories of ecosystem characteristics[3]—vertical and horizontal physical structure, functional processes such as photosynthesis, and taxonomic composition--for the first time. Particularly when data from multiple missions are combined, this will be a step-change in the ability to monitor ecosystems from space: its importance should not be underestimated.

Activities

Based on the information provided by users and discussed in the previous section, the B-VC plans to initially focus on the six priority areas listed below. These areas encompass those that can reasonably be expected to be addressed in the first years of this new CEOS Biodiversity entity. This list should be understood as dynamic; the B-VC will adjust its activities based on a variety of factors including resource availability, updates in user needs and priorities, data availability, and what is learned as the activities move forward.

1) **Identify and facilitate filling gaps in priority observations and data products.** These gaps include status indicators such as those identified by various international conventions as well as other Essential Biodiversity Variables. Addressing the gaps identified by the BST is a multi-step process:
    - Prioritize needed products based on the balance between value to users and cost of implementation
    - Develop the plan and methods to fill gaps
    - Implement the product gap-filling plan and assess results (incremental, with partners)
    - **Outcome**: Increased availability of needed products and utilization of space-based EO
2) **Facilitate enhancement of data utilization tools[4].** The stakeholder assessment reinforced the need for enhanced data access and analysis tools to help users understand how to apply the data to assessment and decision making processes. Steps include:
    - Assess current tools and identify and prioritize enhancements
    - Develop plan and methods for enhancements
    - Implement tool enhancements (incremental, with partners)
    - **Outcome**: More/better tools and increased utilization and impact of space-based EO for improved decision making and action

[3] These categories are a foundational concept in modern biodiversity science and are embedded in a variety of international agreements such as the Convention on Biological Diversity Kunming-Montreal Global Biodiversity Framework.

[4] Needed tools vary widely in their capabilities and function. They include visualization tools that can map spatial data or show trends in temporal data, but may also include tools that can transform data in ways that facilitate understanding and analysis.

3) **Demonstrator and prototype monitoring system development[5].** The demonstrators developed as an Ecosystem Extent Task Team (EETT) activity have a new role in the B-VC. Such prototype systems provide a framework within which to develop and test new products and capabilities, including those mentioned above, and for user engagement. Plans include:
    - Continue development of the three EETT demonstrators (Hudson Bay—ECCC; Costa Rica—CNES; Great Western Woodlands—CSIRO)
    - Seek new prototype monitoring system activities to use as a framework for the other B-VC activities, including aquatic systems
    - **Outcome:** An environment to facilitate real-world development and testing of new capabilities, and new pathways for user engagement and partnerships
4) **Capacity building.** Work with WGCapD and other organizations to prioritize and enhance capacity building activities
    - **Outcome:** Increased ability by biodiversity users to utilize space-based EO data for understanding and monitoring biodiversity
5) **Biodiversity community engagement.** Increasing utilization of EO requires 1) increased visibility and awareness of the value of EO and 2) closer and ongoing ties with the biodiversity community. Approach:
    - Develop informational webinars and brochures
    - Hold sessions at conferences (e.g., BIOSPACE25) and utilize social media to provide both visibility and information
    - Identify B-VC members to lead engagement activities for key organizations
    - **Outcome**: A stronger communications channel leading to improved understanding of user needs and increased utilization of space-based EO
6) **Coordinate with GEO BON and its Global Biodiversity Observing System (GBiOS) concept[6].** GEO BON's global monitoring concept requires coordination with space-based observations, products, and capabilities. Approach:
    - Identify GBiOS needs, gaps, challenges, and areas for coordination (jointly with GEO BON)
    - Guide concept development to enhance EO utilization (jointly with GEO BON)
    - **Outcome**: Embedding of space-based EO in GBiOS for global biodiversity monitoring

[5] Prototype monitoring systems such as the EETT Demonstrators enable real world application of many activities, act as laboratories to improve products and tools, and provide a context for additional activities such as cal/val sites.

[6] GBiOS: GEO BON's concept for a Global Biodiversity Observing System; it would combine in situ, space-based EO, models, and expertise to facilitate biodiversity monitoring for societal benefit

Schedule

The proposed schedule for B-VC activities follows, recognizing that the detail and timeframe will evolve over time in accordance with CEOS Agency priorities and stakeholder needs:

Activity Topic	Milestones	Timeframe
Data product gaps	Prioritize needed products to fill observation and product gaps	Year 1-2
	Develop plan and methods to fill gaps	Years 1-3
	Implement product gap-filling plan (incremental, with partners)	Years 2-5+
Data utilization tools	Assess current tools and identify and prioritize enhancements	Years 1-3
	Develop plan and methods for enhancements	Years 2-4
	Implement tool enhancements (incremental, with partners)	Years 2-5+
Prototype monitoring system development	Continue development of the existing EETT demonstrators and seek new prototype options, including aquatic systems	Years 1, 2-5
Capacity building	Work with WGCapD to prioritize and enhance capacity building	Continuous
Stakeholder engagement	Outreach and engagement via informational webinars, brochures, and other means	Continuous
Space arm of GBiOS	Identify needs, gaps, and challenges (jointly with GEO BON)	Years 2-3
	Integrate space-based EO into the GBiOS concept and architecture (jointly with GEO BON)	Years 3-7+

Accreditation and Recognition Metrics

The B-VC's success over time will ultimately be measured by the increase in incorporation of space-based EO into the activities of the biodiversity community, by the utilization of the products and tools the B-VC focuses on, and by the overall value of the B-VC's activities to the biodiversity user community. As mentioned above, the B-VC will adjust its activities in response to changing conditions and interim results. Additionally, as part of its engagement activities the B-VC will help connect users to the new products or tools developed and promote and facilitate their utilization. This will not only increase the impact of the new products or tools but ensure that the sponsors and developers are properly recognized.

Working with CEOS WGs, VCs and Other Entities

Consistent with CEOS's Mission Statement and B-VC's Objective 3 (see the B-VC ToR), the B-VC will coordinate, work with, and as appropriate, utilize the expertise in other CEOS entities. The B-VC is also available to support the activities of other VCs and WGs where needed. While specific areas of interaction will be refined as the B-VC develops, areas with some of the highest potential are briefly mentioned below.

- **WGCapD.** User capacity is often limited and enhancing it will require active coordination with WGCapD.
- **WGClimate**. Climate and biodiversity are intertwined and climate is a key factor in determining where species live; land cover and species distributions are among the areas of particular interest.

- **WGCV**. New biodiversity data products (e.g., EBVs) will combine different types of sensors and inter-sensor calibration will be important.
- **WGDisasters**. Natural disasters such as river or coastal flooding often have an ecosystem component; forecasts for, and mitigation of, some of these hazards is possible and coordination will likely be mutually beneficial.
- **WGISS**. Some of the challenges that biodiversity users have are related to CEOS Agency information systems that generate and provide access to data products. WGISS can provide guidance to the B-VC on standards, interoperability issues, and other areas.
- **COAST-VC.** The coastal environment is a particularly important area for biodiversity and collaboration with the COAST-VC will be needed.
- **LSI-VC.** The Forests and Biomass subgroup will be of particular importance; the LSI-VC's work on CEOS-ARD and the AFOLU Roadmap are also highly relevant to the B-VC.
- **OCR-VC.** Ocean color provides key information on phytoplankton, primary production, harmful algal blooms, water quality, and other measures, all of which provide insights into ocean biodiversity and condition.
- **SST-VC.** Sea surface temperature is a controlling factor for a variety of biological activities, including species distribution and algal blooms and is a key input for monitoring coral reefs.
- **SEO.** The SEO's CEOS Analytics Lab will be particularly useful for experimenting with new products or methods.

Funding

Three categories of support will provide the necessary resources to enable the B-VC's activities and to meet its objectives:

Biodiversity Virtual Constellation team members. Interest by CEOS Agencies in biodiversity has continually increased, as indicated by the support provided for the Biodiversity Study Team (App. 3) and the Ecosystem Extent Task Team before it. As discussed in the Activities section above, one of the first activities of the B-VC will be to prioritize gaps in products and tools and to plan how the B-VC can facilitate filling those gaps. This process will enable refinement of B-VC membership and the specific roles that members have. B-VC member time and associated resources will be supported by their sponsor Agencies in a manner similar to that for the BST. The B-VC will also utilize the support that other CEOS Working Groups and Virtual Constellations can provide.

In addition to CEOS Agency involvement, members of the research and applied biodiversity communities, such as those at universities, institutes, and other organizations, will be invited to participate in the B-VC and to support its activities. In-kind participation is expected where there is alignment with an activity such as development of a product (product development is a common activity at universities, often by a graduate student under the guidance of their professor).

Agency Research and Development Programs. Some of the B-VC's planned activities, such as algorithm and product development and prototype monitoring systems, align with Agency research and development programs that already support these types of activities, often by soliciting proposals. Universities, institutes, and NGOs have focused on EO utilization for biodiversity for many years, as exemplified by the many proposals that space agencies have funded. The exceptionally high interest in

ESA's BioSpace25 conference (February 2025) is an example of the level of interest in this topic. It is noted that each of the three EETT Demonstrators was funded by a CEOS member Agency. Prototype systems such as those have components that support all of the B-VC's planned activities and are a valuable tool for users seeking to enhance their use of space-based EO to meet their needs.

External Support. Another source of support for B-VC activities is proposals submitted to non-CEOS Agency organizations by B-VC external partners. For example, a national science agency, an agency within an Environment Ministry, a foundation, an NGO, or a private company may solicit proposals or look for partners for work relevant to the B-VC's activities. This work might focus on development of a product or tool and a biodiversity expert at a university could then submit a proposal. An important role of the B-VC is to continue engagement with such external partners so they are aware of, and encouraged, to engage with potential B-VC activities.

Appendix 1: User Organizations Contacted

Ecosystem Extent	This is an Essential Biodiversity Variable that is not tied to a single organization, but a universally needed product across the biodiversity community that underpins numerous applications
GEO BON	GEO Biodiversity Observation Network
IOC/UNESCO	Intergovernmental Oceanographic Commission of UNESCO
IPBES	Inter-governmental Platform on Biodiversity and Ecosystem Service (analogous to IPCC)
Ramsar Convention on Wetlands	International treaty on Wetlands (signed in 1971 in Ramsar, Iran)
TNFD	Taskforce on Nature-related Financial Disclosures (other "nature finance" organizations were also considered)
UNCBD	UN Convention on Biological Diversity
UNCCD	UN Convention to Combat Desertification
UNSEEA	UN System of Environmental-Economic Accounting

Appendix 2: Identified User Needs

This table summarizes the results of the Biodiversity Study Team's stakeholder assessment and provides a list of user needs that guide the Biodiversity Virtual Constellation's activities. Additionally, Agencies, Working Groups and Virtual Constellations provided feedback to indicate which needs they may be able to contribute to; this will continue to be used to help coordinate the B-VC's activities with those of other entities.

General Need Category	Example Conservation Applications	Example Products or Tools Needed with Direct Relevance to EO
Species Distribution	● Invasive species detection ● Endangered species management ● Extinction risk assessment	Environmental data
		Mapping/visualization tools
		Multi-sensor products (e.g., optical + SAR + lidar) that characterize ecosystem structure, composition, function
Ecosystem Extent	● Managing ecosystems & protected areas ● Monitoring & assessing ● Planning ecosystem restoration	Ecosystem extent maps
		EO-based tools for mapping ecosystem types
		EO-based methods for monitoring changes
		Time series & change maps
		Distinguishing natural from plantation ecosystems
		Multi-sensor products (e.g., optical + SAR + lidar) that characterize ecosystem structure, composition, function
Ecosystem Condition	● Monitoring health & function of ecosystems ● Monitoring ecosystem degradation & restoration ● Identifying eutrophication	Ecosystem condition metrics
		Time series & change maps
		Trend maps & figures
		Multi-sensor products (e.g., optical + SAR + lidar) that characterize ecosystem structure, composition, function
Increased user capacity, data access, & usability	All	Data access tools to simplify finding/accessing data
		Data utilization tools to simplify analysis, particularly for SAR & hyperspectral data
		Guidance on data to use for particular applications

Ecosystem Services	● Monitoring food, lumber, carbon sequestration, hydrological buffering, natural beauty, etc.	Data & products that characterize ecosystem functions & products that are useful to humans
Various	● Ecosystem conservation (all aspects)	Vegetation indices, productivity, biomass
		Change detection & mapping
		Identification/mapping threats to biodiversity (e.g., climate change, LULCC, roads, invasive non-native species)
Ecosystem connectivity	● Animal movement planning ● Ecosystem condition assessment	Ecosystem extent & condition maps
		Combines Ecosystem Extent & Ecosystem Condition
Species extinction risk	● Conservation planning	Identification of threats (e.g., climate change, LULCC, roads, shipping lanes, invasive non-native species, acidification)
		Change in species distribution
Ecosystem degradation and restoration	● Degradation & restoration assessment ● Restoration planning and reporting	Frequent plant productivity time series (10m or less, since 2000)
		Land cover change (10m or less, annual) or marine area use change
		Plant cover (or macroalgae), soil carbon, & soil moisture for dry, sparsely vegetated areas
		EO standards for land degradation assessment

Appendix 3:
Agency Support for the Biodiversity Study Team

Biodiversity Study Team membership was supported by the following agencies:

- CNES
- CSA
- CSIRO (co-lead)
- EC
- ECCC
- ESA (co-lead)
- ISRO
- JAXA
- NASA (co-lead)
- NOAA
- UKSA
- USGS