Proposal for a CEOS Land Surface Imaging Constellation

1. Introduction

This proposal has been prepared in general accordance with guidelines provided in the CEOS Constellations Process Paper for establishing new CEOS Constellations. It is submitted to the CEOS SIT for review and approval of the plan presented herein for establishment of a CEOS Constellation for Land Surface Imaging.

Background

The CEOS Task Force charged with drafting the *CEOS Implementation Plan for Space-Based Observations for GEOSS* (Implementation Plan) have stated their belief that such a plan should be the focus for a new planning process that takes account of international users and their requirements from the outset of satellite projects. Furthermore, the 19th CEOS Plenary concluded the Implementation Plan should:

- identify the supply of space-based observations required to satisfy 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.

The CEOS Constellations Concept has emerged as the "innovative planning process" referenced above that is being proposed by the CEOS Implementation Plan Task Force. It is intended to address the shortcomings in the international planning process for space-based Earth observations without eroding the independence of individual agencies. The concept is envisioned as a process that will engage disparate Earth observing programs of CEOS member agencies and ultimately facilitate their contribution in supplying the space-based observations required to satisfy the requirements expressed by the 10-year Implementation Plan for GEOSS. The fundamental idea of the CEOS Constellations Concept is to extract clear requirements from target user communities and translate those requirements into standards which can serve as guidance in the development of future systems and against which future proposed Earth observing systems can be assessed.

Problem

Fundamentally, satellite land remotely sensed data are tools for studying the Earth system, including the land surface and the processes that operate on or near it. These data are sources of information from which meaningful interpretations can be made about the Earth's biological conditions and resources, geologic and hydrologic processes and resources, and human dynamics. Scientists from all nations of the world that study the Earth from space seek similar information from remotely sensed data.

Since the launch of the first land surface imaging satellite system by the United States in 1972, literally dozens of countries have launched, or have cooperated in the development and launch of, scores of satellite systems that image the Earth's land surface from the ultraviolet to the microwave regions of the electromagnetic spectrum at spatial resolutions that range from kilometers to centimeters in detail. These systems, though frequently duplicative in the fundamental characteristics, have provided scientists with a wealth of data that have been meaningfully applied in countless important land surface-related scientific

and practical endeavors. Yet, as we look to the future, important opportunities exist for providing users with better and more consistent data more frequently and at lower cost through enhanced collaboration and coordination among nations in the planning, development, launch, and operation of the land surface imaging satellite systems of tomorrow.

Potential Importance of a Land Surface Imaging Constellation

The potential benefits offered by a constellation of satellites that routinely and frequently image the Earth's land surface in consistently calibrated wavelengths from the visible through the microwave and in spatial detail that ranges from sub-meter to hundreds of meters are enormous. Such a constellation would provide the fundamental data required by scientists to help predict, and certainly mitigate the effects of, natural disasters; to explore for critical energy and mineral resources; to monitor climate change; to study ecosystems and biodiversity; to address important human health issues; and to undertake many other equally important scientific and practical endeavors with efficiency and effectiveness not previously possible. A well-designed and effectively operated land surface imaging satellite constellation could have profound impact not only on the quality of life for citizens of all nations, but also on mankind's very ability to sustain life as we know on this planet long into the future.

2. Mission Statement

The fundamental mission of the CEOS Land Surfacing Imaging Constellation is to promote the efficient, effective, and comprehensive collection, distribution, and application of space-acquired image data of the global land surface, especially to meet societal needs of the global population, such as those addressed by the Group on Earth Observations (GEO) societal benefit areas (SBAs). Significantly, this mission addresses not only the building and launching of satellite systems, but also the development and operation of associated ground segments and their ability to get critical data efficiently into the hands of many interdisciplinary science users.

3. Objectives and Anticipated Outcomes

The objectives of the Land Surface Imaging Constellation will be those of the studies and associated activities that will be carried out by the members of the Land Surface Imaging Constellation Study Team formed for the purpose of conducting those studies and performing those activities that will lead to the definition and development of the CEOS Land Surface Imaging Constellation.

The primary objective of Land Surface Imaging Constellation studies is to define a broad range of rather detailed characteristics (or *standards*) that describe optimal, end-to-end capabilities (and policies) to acquire, receive, process, archive, and distribute to the global user community space-acquired land surface image data, which users will find optimally applicable to the broadest possible range of scientific and practical endeavors important in meeting the needs of mankind. The beneficial outcomes from defining such standards will be the guidance they provide for the coordinated development of future systems, as well as the foundation they provide for establishing criteria against which future proposed Earth

observing systems can be assessed. In that context, it will be an objective of the Land Surface Imaging Constellation studies to develop appropriate criteria, based on the defined standards, which CEOS can use to assess and endorse future systems proposed by its member agencies.

An important objective of these studies is to extensively engage broad segments of the land remote sensing user community, including those representing the GEO societal benefit areas, to fully determine the scientific information requirements desired to be met by the data acquired by and accessible from elements of the Land Surface Imaging Constellation. The beneficial outcome from user-defined requirements will be the enhanced ability to define standards, which will lead to systems that will more fully meet those requirements of the broad land remote sensing user community.

It also will be an objective of these studies to identify opportunities where near-term gains may be made by early determination of user requirements and development of applicable standards for urgently needed systems, from the application of newly developed policy recommendations to existing data systems, or by facilitating CEOS efforts to integrate data from multiple systems to fill a potential gap in the continuity of Landsat data, for example. The important outcomes from accomplishing this objective lie in the early benefits that will be derived by segments of the land surface imaging user community, as well as in the opportunity if provides CEOS to demonstrate the value the CEOS Constellations Concept can contribute to GEO and its members.

4. GEO Requirements Addressed

GEO has identified nine SBAs, which they expect will be meaningfully addressed by their Global Earth Observation Systems of Systems (GEOSS). Those areas are: 1. Reduction and Prevention of Disasters, 2. Human Health, 3. Energy Management, 4. Climate Change, 5. Water Management, 6. Weather Forecasting, 7. Ecosystems, 8. Agriculture, and 9. Biodiversity. The requirements of GEO are embodied largely within these nine societal benefit areas, and the requirement of greatest importance is data collected by in situ, airborne, and spaceborne systems that are needed to address countless problems and issues, which relate to each of these areas and which impact the quality of life for people of all nations.

The CEOS Land Surface Imaging Constellation will collect, process, and disseminate image data that will directly benefit endeavors undertaken in each of GEO's nine SBAs. Data collected the Land Surface Imaging Constellation will be of prime importance to several of these societal benefit areas, including disaster reduction, energy management, climate change, water management, ecosystems, agriculture, and biodiversity. The potential important applications of data from a land surface image constellation are virtually limitless.

5. User Communities

Since the launch of Landsat 1 in 1972, the satellite land remote sensing user community has been growing and diversifying at a rather steady pace until today that community is perhaps the largest and most diverse of all remote sensing user communities. It is this large and diverse community, comprised of many sub-communities that the CEOS Land Surface

Imaging Constellation seeks to serve. Among the greater land remote sensing user community are scientists and practical applicationists whose collective interests and expertise address virtually every conceivable object, condition, characteristic, and process that exists or operates on, at, or near the Earth's land surface.

Not only does the Land Surface Imaging Constellation seek to serve the needs and interests of the land remote sensing user community, the success that it achieves in doing so will depend on the extent to which the diverse requirements and interests of this community are represented in the definition, development, and operation of the constellation. As noted previously and as described in more detail subsequently in this proposal, every effort will be made to fully engage the diverse segments of the land remote sensing user community at every stage of this process.

6. Approach

The overall approach leading to the definition, development, and implementation of the CEOS Land Surface Imaging Constellation generally will follow guidelines laid out in the CEOS Constellations Process Paper. Yet, no two constellations are the same, and the Land Surface Imaging Constellation, because of its large and diverse user community, is perhaps the least similar of the constellations. Consequently, the methods employed and timelines adopted may differ from other constellations.

Methodology and Scope

Land Surface Imaging Constellation methodology will focus on the definition and accomplishment of a series of Constellation studies and activities carried out by and/or under the direction of the Land Surface Imaging Constellation Study Team. Among other things, but most significantly, these studies and activities will result in definition of the *standards* that describe optimal future Land Surface Imaging Constellation capabilities, characteristics, and policies. Constellation studies and activities also will address shorter-term problems and issues facing the land remote sensing community today, such as seeking ways to work more cooperatively in the operation of existing land surface imaging systems.

Land Surface Imaging Constellation standards will not all be defined by a single study. Rather, many studies, each focusing on a spatial-resolution-based or spectral-based subset of the full scope of land surface imaging sensor systems will be needed. These will be conducted in a phased approach based on urgency of definition. In terms of general scope, studies leading to the definition of standards for a land surface imaging constellation need to address **user requirements,** and they need to examine at least three fundamental areas of the systems comprising a Land Surface Imaging Constellation: the **space segments**, the **ground segments**, and relevant **policies and plans**.

User requirements. User requirements will be the foundation of Land Surface Imaging Constellation studies, and determining those requirements will become a major undertaking of this work. Yet, this endeavor is not the first to seek to identify comprehensive user requirements for land surface imaging data. The Land Surface Imaging Constellation Study Team will utilize, to the extent possible, results of other well-substantiated requirements studies conducted by CEOS organizations and by other reputable researchers. Examples of requirements studies that this study team might draw upon include those conducted by the

Global Climate Observing System, the U.S. National Science and Technology Council's Future of Land Imaging Interagency Working Group, the IGOS Integrated Global Observations Land Theme, the Landsat Data Continuity Mission, and the GMES Programme. Building upon results of such other requirements studies, Land Surface Imaging Constellation Studies will implement processes to further define and compile the comprehensive set of requirements that will be translated into standards for various segments the CEOS Land Surface Imaging Constellation. Such processes might include working with established instrument science teams such as exist for ASTER, MODIS, VIIRS, the new LDCM mission, and others. Particular attention will be given to fully identifying those requirements that are important in addressing the nine SBAs defined by GEO.

Space Segments. Standards developed for the space segments of the CEOS Land Surface Imaging Constellation will focus on the characteristics of various sensor systems that must comprise the constellation in order to satisfy the full spectrum of user requirements. It is premature to speculate exactly how the studies will categorize sensor systems for the constellation. However, some combination of spectral coverage and spatial resolution are likely candidates such that user requirements for imaging in the visible, short-wave infrared (IR), thermal IR, and microwave (both passive and active) regions of the electromagnetic spectrum at high, medium, and coarse spatial resolutions are fully addressed. Geographic coverage and temporal characteristics are two other important sensor system parameters that must be addressed in the context of user requirements. Additional sensor characteristics for which constellation standards must be developed include radiometric accuracy and precision, dynamic range, polarization sensitivity, radiometric stability, pointing and geolocation accuracy, angular resolution and accuracy, band-to-band registration precision, modulation transfer function specifications and uniformity, spectral uniformity and band shape, and others.

While sensor system characteristics are the most important space segment components the CEOS Land Surface Imaging Constellation must address, they are not the only ones. Other potentially important space segment characteristics this study will examine include launch services, platform, orbital characteristics, on-board data recording capabilities, and others.

Ground Segments. Standards developed for the ground segments of the CEOS Land Surface Imaging Constellation will focus on the characteristics of data reception, data processing, data archiving and data distribution systems needed to satisfy identified user requirements. The design and operation of each of these ground system components can affect the ability of users to fully utilize the data collected by the space segment sensors. For example, a system that includes globally distributed receiving stations or a space-borne data relay system most likely will be preferable to one that employs only one or two ground receiving stations, because the latter likely will not be able to acquire global data on a routine basis. The ease with which users can apply data from a given system is affected by the level of processing applied by the provider, the metadata provided with the image data, and the format in which the data are delivered. Ground systems that provide for long-term preservation of data will be more beneficial over time because of the historical value of the data preserved. As a final example, ground systems that include media distribution options will be able to serve more users than one that only offers delivery via file transfer protocol (ftp). In addition to these primary ground system functions, characteristics of satellite command-and-control systems and functions, availability and qualifications of user services

staff, and characteristics of associated data and information systems are examples of various other ground system components for which this study will define standards.

Policies and Plans. As equally important as optimal sensor systems and proficient ground systems to the efficient and effective application of land surface image data are data policies and plans that promote, rather than inhibit, use of the data. Consequently, this effort will examine various policies and plans, including data acquisition strategies and data distribution policies, that can affect user access to data and thus their ability to effectively apply those data in pursuit of the common good. Standards related to data policy will be developed that encourage easy access to global land surface image data and promote beneficial application of the data by users around the world.

Timeline

Definition, development, and implementation a CEOS Land Surface Imaging Constellation will not be a trivial undertaking, because the studies required must be both broad in scope and comprehensive and detailed in determining diverse user requirements and in defining the *standards* that describe optimal Land Surface Imaging Constellation systems, capabilities, characteristics, and policies. Complete definition of the CEOS Land Surface Imaging Constellation may be a lengthy process, possibly requiring several years to fully complete. It is a process that will require implementation in a phased approach based on determined priorities.

Each year, Land Surface Imaging Constellation studies and activities will be described in detail in the annual CEOS Land Surface Imaging Constellation Work Plan. For 2007, that plan will be ready for review and approval by CEOS SIT by March 15th. Land Surface Imaging Constellation studies and activities during its initial year will focus on three objectives that present opportunities for early successful results: 1) documenting formal agreement among the space agencies currently operating mid-resolution land surfacing imaging satellite systems to cooperate more closely together to operate those assets as a real prototype Land Surface Imaging Constellation; 2) develop preliminary standards for a mid-resolution Land Surface Imaging Constellation; and 3) meaningfully contribute to the production of a fundamental climate data record (FCDR).

Results from the studies completed each year will be reported in the CEOS Land Surface Imaging Constellation Annual Study Report. Results from the studies and activities planned for 2007 are expected to be available for reporting at the CEOS Plenary in November and to be included the CEOS Report to the GEO Summit shortly thereafter.

7. Participation

As one of four initial prototype CEOS Constellations, responsibility for leading its Land Surface Imaging Constellation study already has been assigned by CEOS to the U.S. Geological Survey. Other space agency members of CEOS with land surface imaging programs have been invited by the USGS to participate on the study team, and many have named their study team participants:

Space Agency Participants

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In the process of securing participants to work on the Land Surface Imaging Constellation, the USGS placed early emphasis on securing study team members from land imaging space agencies. Good representation on the study team from these space agencies was deemed particularly important for preparation of the initial scoping paper and now this formal proposal, because they largely frame the studies that will define various standards that ultimately may impact programs and plans of those space agencies.

Particularly as the study moves into a requirements gathering and definition mode, participation on the study team by representatives from various segments of the land remote sensing user community will be extremely important for getting the user requirements right and for linking those requirements to GEO societal benefit areas. Additionally, as requirements are translated into standards, user validation of standards proposed will be key to securing general acceptance of the land surface imaging constellation that we define. Even as this formal proposal is being prepared, efforts are underway too add study team members who represent various segments of the land remote sensing user community. Nevertheless, some representation from the user community at the earlier stage of study definition seemed important and logical, and the following representatives of the land surface imaging user community have agreed to serve as study team members:

User Community Representatives

EC-JRC: Alan Belward (alan.belward@jrc.it)
IGOS: John Townshend (jtownshe@mail.umd.edu) – Input/Review

Current efforts to expand user community representation likely will result in the addition of at least six additional study team members who represent various segments of the land remote sensing user community. In the future, as circumstances may warrant, additional members from the land remote sensing user community will be added. Likewise, it is probably that additional and/or different members from CEOS space agencies will be added to the study team.

8. In Conclusion

The CEOS Land Surface Imaging Constellation Study Team proposes to undertake compressive studies that will define, based on identified user requirements and in terms of specific standards, the characteristics of optimal land surface imaging systems (space segments, ground segments, and related policies). Standards defined by the study can serve as guidance in the development of future systems, as well as criteria against which future proposed Earth observing systems can be assessed. The studies should be conducted such that their results will be relevant for up to 10 years after completion. The study team will seek opportunities for near-term accomplishments, such as enhancing beneficial use of existing land surface imaging data by the global land remote sensing user community.

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