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Acta Astronautica 56 (2005) 25–34

ACTA ASTRONAUTICA

www.elsevier.com/locate/actaastro

Low/medium density biomass, coastal and ocean carbon: a carbon cycle mission

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Abstract

As part of the Global Carbon Cycle research effort, an agency-wide planning initiative was organized between October 2000 and June 2001 by the NASA Goddard Space Flight Center at the behest of the Associate Administrator for Earth Science. The goal was to define future research and technology development activities needed for implementing a cohesive scientific observation plan. A timeline for development of missions necessary to acquire the selected new measurements was laid out, and included missions for low–medium density terrestrial biomass/coastal ocean, and global ocean carbon. This paper will begin with the scientific justification and measurement requirements for these specific activities, lightly touch on the options for having separate low Earth orbiting missions, and follow-up in more detail with a combined implementation study centered on a hyperspectral imager at geosynchronous altitudes, highlighting both its merits and challenges.
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1. Introduction

1.1. Why study carbon?

The major regulators of climate change are “internal”, including processes associated with the carbon cycle and photosynthesis. Warming of the Earth’s climate is driven primarily by the absorption of re-emitted solar energy by heat-absorbing “greenhouse” gases such as water vapor, carbon dioxide and methane, and light-absorbing aerosols such as smoke and soot. Cooling on the other hand results from reflective clouds and other aerosols such as dust. Removal of greenhouse gases by the Earth’s terrestrial vegetation and its oceans by photosynthesis also acts to cool the Earth.

By examining the Earth’s carbon budget, the climate-carbon connection can be clearly seen. The annual increase in atmospheric CO_2 of about 3 Petagrams/year (Pg/y), results from the emission of nearly 7 Pg/y of carbon from the combustion of fossil fuels. However, roughly half of this fossil fuel emission is absorbed by the land (2 Pg/y) and oceans (2 Pg/y), resulting in a much slower increase in atmospheric

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0094-5765/$ - see front matter Published by Elsevier Ltd.
doi:10.1016/j.actaastro.2004.09.044

carbon dioxide. Thus, these natural ecosystems provide a service to the global economy worth billions of dollars through natural mitigation of climate change. The reasons for this capacity of the Earth's land and oceans to absorb carbon dioxide are not adequately understood, and therefore future uptake cannot be estimated. Given the global importance of forecasting climate change, it is of utmost urgency to understand these processes.

1.2. Carbon cycle study

A team of scientists and engineers from the NASA Goddard Space Flight Center (GSFC), at the request of NASA Headquarters, led an inter-center and interagency planning activity for future studies of the sources, sinks, and transport of carbon in the atmosphere, on land, and in the oceans [1]. Working from the US Global Climate Change Research Program (USGCRP) Goals [2], the GSFC team and workshop participants examined the measurements and missions planned by the NASA Headquarters Earth Science Enterprise and identified critical gaps associated with carbon research. Three critical gaps were defined: (1) global time series of CO_2 atmosphere-surface exchange, (2) ecosystem carbon storage due to land biomass and its change as well as the carbon consequences of disturbance, and (3) measurements of critical biochemicals mediating global ocean surface layer uptake and export of carbon. The observations required to fill these gaps were also defined and include: (1) satellite-based observations of column and profile carbon dioxide concentration, (2) reprocessing of the historic land satellite record to track land use changes over time and quantify their carbon consequences, (3) satellite-based measurement of low/medium-density and high-density biomass, and (4) satellite measurement of chlorophyll and related organic and inorganic compounds in the coastal and upper deep ocean. A set of nominal missions designed to provide these measurements was developed and endorsed by the science team. Two of these missions are being introduced here, and will be cast first as individual low earth orbiting (LEO) implementations, and then as a combined Geosynchronous (GEO) mission. Information on the spectral consideration underlying the measurement of carbon may be found in Ref. [3].

6. Conclusions

This preliminary study demonstrates both the advantages and challenges of a GEO hyperspectral platform. Combined measurements of low/medium density biomass and ocean carbon are possible and highly desirable. Advantages are full diurnal hemispheric coverage of the Earth, or near-global coverage at a minimum rate of once every 2 days, all achievable with a single spacecraft. The challenge still remains to obtain desired high resolution, high SNR hyperspectral images. Although the telescope aperture was sized at 1.2-m for 100-m diffraction-limited resolution, acceptable SNR can only be achieved at affective resolutions nearing 250-m and greater. This becomes more problematic for scenes with low irradiance values, such as the open ocean, and less so for land observations. Large-scale optics and advanced detectors are among two of the technologies that need further exploration and development. Notwithstanding, a more detailed analysis is needed in order to bring about alternative solutions not considered during this initial feasibility study.

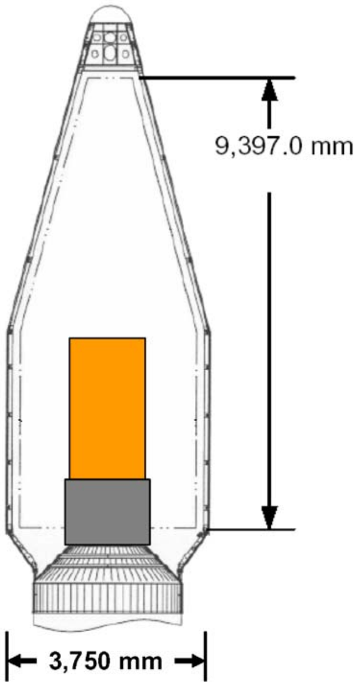

Fig. 4. Static envelope for the Atlas V 400 series, 4-m LPF.