

Naval EarthMap Observer (NEMO) Program

Mr. Mike Hurley

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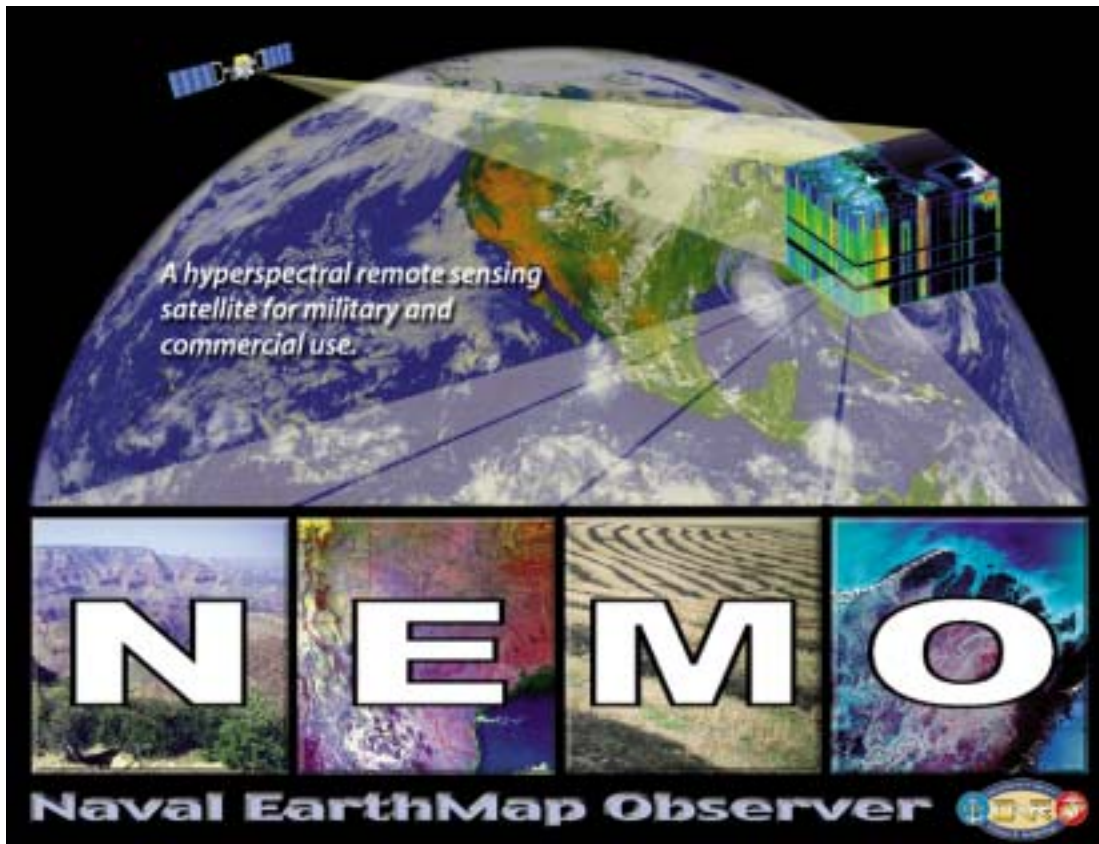
Naval Research Laboratory

4555 Overlook Avenue, SW

Washington, DC 20375-5000

phone: 202-767-1744 fax: 202-404-7234 e-mail: mhurley@ncst.nrl.navy.mil

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LONG-TERM GOAL

NEMO has the long-term goal of characterizing the dynamics of the littoral environment through the use of hyperspectral imagery (HSI) and the development of coupled physical and bio-optical models of the littoral ocean. The collected images provide critical phenomenology to model the littoral environment. Specific areas of interest for the Naval applications include water clarity, bathymetry, underwater hazards, currents, oil slicks, bottom type, atmospheric visibility, tides, bioluminescence potential, beach characterization, atmospheric water vapor, and subvisible cirrus along with terrestrial images of vegetation and soil. These data support identified requirements for Joint Strike and Joint

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14. ABSTRACT NEMO has the long-term goal of characterizing the dynamics of the littoral environment through the use of hyperspectral imagery (HSI) and the development of coupled physical and bio-optical models of the littoral ocean. The collected images provide critical phenomenology to model the littoral environment. Specific areas of interest for the Naval applications include water clarity, bathymetry, underwater hazards, currents, oil slicks, bottom type, atmospheric visibility, tides, bioluminescence potential, beach characterization, atmospheric water vapor, and subvisible cirrus along with terrestrial images of vegetation and soil.					
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Littoral warfare, particularly for environmental characterization of the littoral ocean and intelligent preparation of the battlespace for amphibious assault.

OBJECTIVES

The primary function of the NEMO program is to develop and fly a satellite-borne earth-imaging HSI system to provide HSI data and to process the data to meet Naval and commercial requirements. The mission objectives are as follows:

1. Demonstrate use of hyperspectral imagery for the characterization of the littoral battlespace environment and littoral model development.
2. Demonstrate automated, on-board processing, analysis, and feature extraction using the Optical Real-Time Spectral Identification System (ORASIS).
3. Demonstrate the value of hyperspectral data for DoD operations and commercial applications.
4. Demonstrate support to the warfighter with at least three fleet demonstrations of real-time tactical downlink of hyperspectral end products directly from the spacecraft.

APPROACH

The Office of Naval Research (ONR) executed an *Other Transaction* with the Space Technology Development Corporation (STDC) of Alexandria, VA to develop the Naval EarthMap Observer (NEMO) in conjunction with the Defense Advanced Research Projects Agency (DARPA), Dual Use Applications Program (DUAP). DUAP is a joint program of the Army, Navy, Air Force, DARPA, Director Defense Research and Engineering (DDR&E), and the Deputy Under Secretary of Defense for International and Commercial Programs.

STDC signed “Teaming Arrangements” as a part of the *Other Transaction* with other corporations. These companies are Space Systems/Loral, AlliedSignal Technical Services Corporation, Science Applications International Corporation, Litton, Terma and Honeywell, Inc. STDC's principal technical manager is the Naval Research Laboratory (NRL). The NRL and industry team, under the management of ONR's Naval Space Science and Technology Program Office, will produce the first commercial hyperspectral remote sensing satellite for Naval use.

Utilizing the NEMO satellite system, the Navy will develop a hyperspectral imagery database which will be used to characterize and model the littoral regions of the world. To meet this objective, a sun-synchronous circular orbit at a 98.3° inclination with an altitude of 605 km and a 10:30 a.m. nodal crossing (ascending) has been chosen. This orbit will enable continuous repeat coverage of the whole earth.

NEMO will provide images using a Coastal Ocean Imaging Spectrometer (COIS) Instrument along with a co-registered 5m Panchromatic Imager (PIC). With 210 spectral channels over a bandpass of 0.4 to 2.5 μm and very high signal-to-noise ratio (SNR), the COIS instrument is optimized for the low reflectance environment of the littoral region. COIS will image over a 30 km wide swath with a 60 m

Ground Sample Distance (GSD), and can image at a 30 m GSD with ground motion compensation. Table 1 provides the characteristics of the COIS and PIC instruments.

Table 1: COIS and PIC Imager Characteristics

SIP Parameters	COIS - VNIR	COIS – SWIR	PIC
Ground Swath Width	30 km	30 km	30 km
Ground Sample Distance (GSD)/Ground Motion Compensation(GMC)	60 m GSD at GMC-1 30 m GSD at GMC-5	60 m GSD at GMC-1 30 m GSD at GMC-5	5 m GSD at GMC 1 through 5
Aperture Diameter	15 cm	15 cm	16.4 cm
Focal Length	36 cm	36 cm	120 cm
F#	2.4	2.4	7.32
Pixel Size	18 μm	18 μm	10 μm
Array Size	1024 x 1024	1024 x 1024	6000 x 1
# of Pixels/Spectral Band	6	6	na
FPA Material	Si	MCT	Si
FOV	2.86 degrees	2.86 degrees	2.86 degrees
Spectral range	0.4 to 1.0 μm	1.0 to 2.5 μm	0.49 to 0.69 μm
Spectral Bands	60	150	1
On-Orbit Sparing	1 for 1 Spare	1 for 1 Spare	1 for 1 Spare

A unique aspect of the NEMO system is the spectral feature extraction and data compression software algorithm developed by the NRL, the Optical Real-Time Spectral Identification System (ORASIS). ORASIS employs a parallel, adaptive hyperspectral method for real-time scene characterization, data reduction, and background suppression.

ORASIS will be implemented on the Imagery On-Board Processor (IOBP), an advanced high speed computer consisting of a highly parallel array of digital signal processors, capable of sustaining 2.5 GigaFLOPS.

NEMO will provide a demonstration of data downlink directly to the “field”, a minimum of two-three times, to the warfighter. An S-Band 1 Mbps transmitter along with the IOBP and ORASIS will allow for special demonstrations of real-time processing and downlinking of selected data products.

WORK COMPLETED

In 1999, the NEMO program made considerable progress in designing major satellite components and obtaining the licenses and permits necessary to operate a commercial remote sensing satellite. NRL completed the design of the NEMO on-board processor and Navy patented software systems, as well as several payload control and power systems that interface the payload to the spacecraft bus.

In 2000, STDC was unable to secure the funds required to continue the originally planned NEMO program. ONR has presently restructured the NEMO program in order to capitalize on progress to date, meet as many of the original program objectives as possible, and maintain restart options. The

hyperspectral optical sensors are in assembly at SAIC in San Diego, CA, and are scheduled to be completed by December 2001. Flight components from Honeywell, SEAKR Engineering, L3 Communications, Litton Amecom, and TERMA have been delivered and will be available for flight integration at full program restart. STDC continues to explore a wide range of options to obtain the funding required to complete the originally planned NEMO program.

ORASIS Development: Work on ORASIS algorithm development and product algorithm identification will be on-going throughout the program. Preliminary testing of ORASIS to determine acceptable compression ratios ($<10x$) was completed. All portions of ORASIS have been ported to the breadboard IOBP system and are running properly.

RESULTS

Innovations in sensors and algorithms; automated ground operations; and innovations in image processing and data distribution are some of the by-products of the NEMO program. The ultimate goal of demonstrating the utility of environmental hyperspectral remote sensing to support the warfighter will not be seen until well after launch (TBD) of the NEMO satellite.

IMPACT/APPLICATION

In addition to demonstrating the utility of hyperspectral remote sensing to support the warfighter, the NEMO program will build on the Navy's understanding of the dynamics of these coastal environments by using COIS measurements of characteristic study areas in the United States coastal waters as the basis for interpreting a global data set. NEMO will supplement ongoing long-term studies of Chesapeake Bay and the Mid Atlantic Bight (NSF, EPA, NOAA, NASA, ONR funding), the Florida Keys (NOAA, ONR), Monterey Bay (ONR, NSF, Packard Foundation) and Puget Sound (NOAA) with optical measurements as necessary for the validation of COIS data. Several years of on-orbit data are required to develop a thorough understanding of the variations due to seasonal cycles, storm events, and other variables to provide a solid interpretation of the COIS data that can be extrapolated to assess optical properties in other coastal regions. Two additional sites, which are monitored by NASA for validation of satellite ocean color data, will be used for a blind test to evaluate the success of extrapolation to other sites.

TRANSITIONS

Once the NEMO satellite is operational, operations will be performed by industry and the technology will be transferred to industry for potential follow-on satellite development.

RELATED PROJECTS

Hyperspectral imagery validation data will be collected jointly with the ONR Coastal Benthic Optical Properties (CoBOP) program and the Hyperspectral Coastal Optics and Dynamics Experiment (HyCODE).