Naval Earthmap Observer (Nemo) Program

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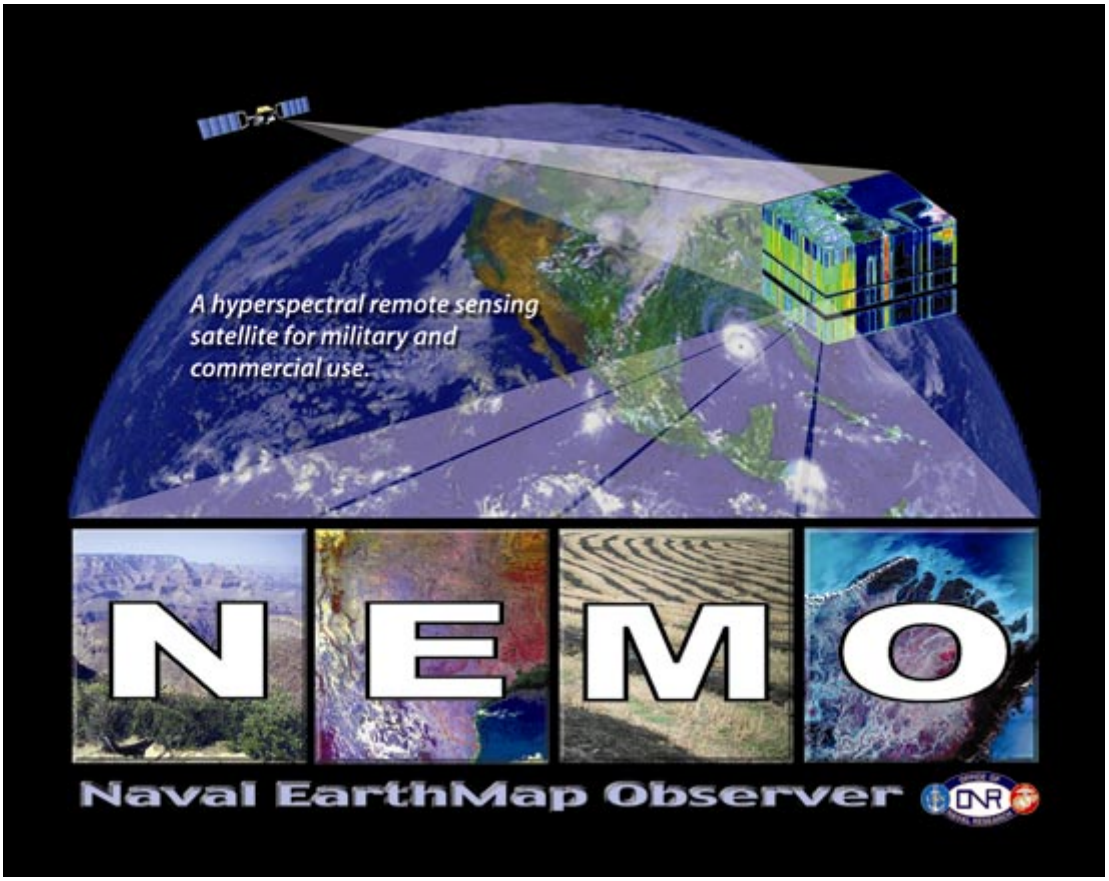

LONG-TERM GOAL

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 study for the Navy 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 Littoral warfare, particularly for environmental characterization of the littoral ocean and intelligent preparation of the battlespace for amphibious assault.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
1998		**00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Naval Earthmap Observer (Nemo) Program	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Code 8200,Washington,DC,20375**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**5**	

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 Naval Research Laboratory (NRL) developed 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 real-time tactical downlink of hyperspectral end products directly from the spacecraft to the field.

APPROACH

The Office of Naval Research (ONR) signed an *Other Transaction* with the Space Technology Development Corporation (STDC) of Arlington, 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 has signed “Teaming Arrangements” as a part of the *Other Transaction* with other corporations. These companies are Space Systems/Loral, AlliedSignal Technical Services Corporation and Applied Coherent Technology Corporation. STDC's principal government partner is the NRL. The Navy and industry team, under the direction of ONR's Naval Space Science and Technology Program Office, will produce the first commercial hyperspectral remote sensing satellite for Naval use to be launched in year 2000.

Through the NEMO satellite system, the Navy will develop a large hyperspectral imagery database which will be used to characterize and model the littoral regions of the world. To accomplish this 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 its 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 called 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. The use of ORASIS is essential for management of the massive amounts of data expected from the NEMO HSI system, and for development of Naval products.

ORASIS is 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. The ORASIS algorithm and the radiation tolerant IOBP allow the first demonstration of real-time processing of hyperspectral data in space.

NEMO is being designed to downlink directly to the “field”, a minimum of two times per year, for a demonstration of the use of hyperspectral data 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 data products.

The NEMO satellite will be launched in mid-2000 followed by an operational period of 3 to 5 years.

WORK COMPLETED

Development on the NEMO program falls into three categories:

1. NEMO Satellite Development: All major trades have been completed and a preliminary design has been baselined. The NEMO satellite is rapidly approaching the end of the design phase and will hold a critical design review in January of 1999. Vendors for key systems (solid state data recorder, spacecraft controller, RF systems, ground systems, launch vehicle, spacecraft bus) have been selected and fabrication has begun. NRL builds of the IOBP and Payload Controller are well under way with breadboard development accomplished and 80% of brassboard development completed.

Currently Integration and Test (I&T) plans are being developed with the goal of beginning I&T with the delivery of the spacecraft bus by Space Systems/Loral in February of 1999.

2. Sensor Development: The COIS and PIC imager designs have been baselined and passed the critical design phase. They are currently being fabricated and integrated by the NEMO Sensor Imaging Payload (SIP) vendor. Preliminary calibration and contamination control plans have been developed and will be completed before expected delivery of the SIP during Q3/FY99.

3. 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 rations (<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; experience in low-cost, high-volume satellite production; experience in small-staff, 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 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.

Hyperspectral imaging shows great potential to satisfy Navy surveillance requirements in support of littoral warfare. Flying the COIS instrument and the ORASIS processor will demonstrate this technology, including the value of repeat observations of areas of concern, and the automated processing of imaging spectrometer data.

TRANSITIONS

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

In addition to the collaboration with industry, NEMO is coordinating efforts among several Government agencies to enhance the HSI technology and knowledge:

1. NIMA and DIA: Collaboration to utilize already established NIMA and DIA systems to distribute data widely within the DoD.

2. MCIA: Compiled NEMO imaging target set from liaison with USMC and NAVOCEANO.

3. NAVOCEANO: Warfighting Support Center (WSC) is planning on-line access to NEMO archive and will task/utilize NEMO as a source of image data in support of fleet operations.

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).

REFERENCES

None.

PUBLICATIONS

Wilson, T.; Baugh, R; and Contillo, R 1997: Hyperspectral Remote Sensing Technology (HRST) Program, AIAA Defense and Space Programs Conference and Exhibit.