

# Upcoming Naval Space Missions for Remote Sensing of the Oceans, Atmosphere and Space

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**Abstract**—The U. S. Navy is permanently forward-deployed and depends critically on precise knowledge and predictability of global environmental conditions from under the ocean, throughout the atmosphere and into near-Earth space. To satisfy global mission needs, the Navy depends on space-borne remote sensing platforms to characterize and monitor each of these environments at wavelengths from the microwave to the ultraviolet. In the next five years, the Navy, in partnership with other agencies, will be launching a number of experimental, operational and quasi-operational remote sensing satellite instruments.

Traditionally, the Navy has used remote sensing in the microwave spectrum to characterize the sea surface wind speed, temperature, ice conditions and other land and atmospheric applications. This year the Defense Meteorological Satellite Program (DMSP) will launch the first in a series of operational Special Sensor Microwave Imager/Sounders (SSMIS's) aboard their Block 5D3 satellites. Also this year, the Air Force Space Test Program (STP) will launch the WindSat passive microwave polarimeter to test new techniques for determination of the sea surface wind vector. Along with SSMIS the next block of DMSP satellites will include the first of five Special Sensor Ultraviolet Limb Imagers (SSULI's) developed by the Navy for remote sensing of upper atmospheric density profiles and ionospheric electron density profiles. These data will aid the Navy and DoD in tracking objects in Earth orbit and help characterize the radio frequency environment for communication, radar, navigation and other applications.

To characterize the littoral regions using hyperspectral imagery, the Navy is developing the Naval EarthMap Observing satellite. This satellite is designed to measure optical water properties in shallow water and provide environmental characterization from the beach zone inland.

In 2005, in partnership with NASA NOAA and STP, the Navy will launch the Indian Ocean METOC Imager (IOMI) into geosynchronous orbit. The satellite will be positioned first over the continental U.S., and later over the Indian Ocean. Also known as the NASA Geostationary Imaging Fourier Transform Spectrometer (GIFTS) experiment, IOMI will provide quasi-operational GOES-like imagery at hyperspectral resolution for Naval operations in the Indian Ocean. On that same satellite, the Navy will deploy an experimental ultraviolet imager called the Ionospheric Mapping and Geocoronal Experiment (IMAGER) to provide GOES-like imagery of the ionosphere at high temporal and spatial resolution to improve ionospheric specification and forecast and help prevent communication and navigation outages.

These upcoming space-borne remote sensing missions will greatly improve global specification of ocean, atmosphere and space environments that affect Naval operations and the data from these satellites will improve a range of forecast models. A description of these space remote sensing missions will be presented including the capabilities and the current status of each satellite.

## I. INTRODUCTION

To maintain and support its global presence, the U. S. Navy depends on data from space-borne remote sensing platforms to provide specification and forecast of environments in which the Navy must operate. Even though the Air Force is the Executive Agent for Space and has primary responsibility for acquisition, launch and operations of space systems, the Navy has always maintained a strong experimental and demonstrational space program to satisfy unique requirements related to global maritime operations. These space demonstrations are usually done in partnership with other agencies (Air Force, NOAA, NASA) and involve remote sensing of the oceans, atmosphere and near-space environments. There are currently several Naval space remote sensing space missions in preparation and which will launch within the next five years. These sensors vary in wavelength from the microwave (primarily ocean sensing), near-infrared to visible (littoral waters, land and lower atmosphere) to the ultraviolet (upper atmosphere and ionosphere).

## II. MICROWAVE SENSING PLATFORMS

Microwave sensors on Defense Meteorological Satellite Program (DMSP) satellites designed to measure emitted and scattered microwave energy from the ocean, land and atmosphere, have provided valuable information to drive Naval weather assimilation models. The next generation of operational sensors consists of five instruments called the Special Sensor Microwave Imager/Sounder (SSMIS) for the new Block 5D3 DMSP satellites, the first of which is scheduled for launch October 2002 (see Fig. 1.). The SSMIS sensors use conical scanning (144° forward cross track) microwave radiometers to measure upwelling radiation from the oceans, ice, land and lower atmosphere. In addition to providing wind speed at the ocean surface, the SSMIS's have the capability to measure temperature profiles to 80 km and water vapor profiles to 10 km. Other parameters include ice (age and concentration), cloud parameters, land surface characteristics and moisture.

The Naval Research Laboratory (NRL) is preparing to launch a sensor suite of conically scanning passive microwave radiometers called WindSat [1]. WindSat is fully polarimetric and uses 11 feed horns and a spinning 6-foot parabolic reflector to measure microwave radiance. These data will be used to infer both wind speed and direction in addition to other oceanic and atmospheric parameters similar to SSMIS. The WindSat radiometers record signals at 6.8, 10.7, 18.7, 23.8, 37.0 GHz and the payload includes cold and

warm targets for in-flight calibration. WindSat will fly as the primary payload on the Coriolis Satellite (see Fig. 2) which is sponsored by the Air Force Space Test Program (STP). WindSat will serve as risk reduction for the Conical Microwave Imaging Sounder (CMIS) slated as the next generation of microwave sensors for the National Polar Orbiting Environmental Satellite System (NPOESS). The Navy's sponsorship of WindSat is in partnership with NPOESS and STP.



Fig. 1. SSMIS on DMSP Block 5D3 Satellite

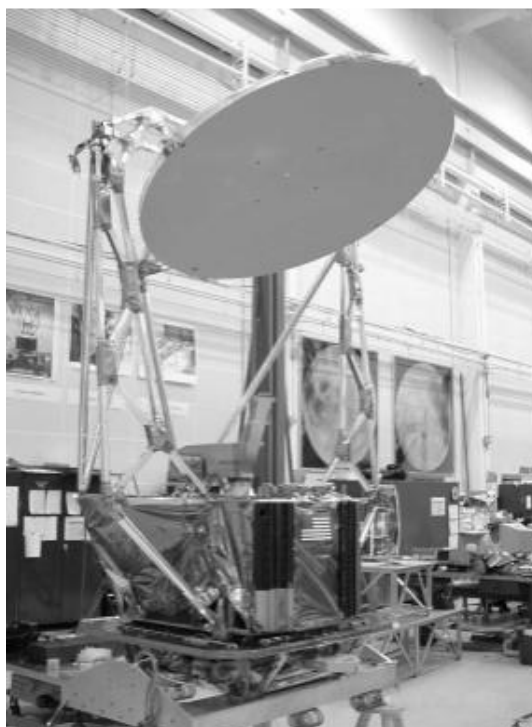


Fig. 2. WindSat Experiment on the Coriolis Satellite

### III. OPTICAL REMOTE SENSING SPACE MISSIONS

The Navy is participating in the development of two hyperspectral optical satellite systems for flight on future satellite missions. The first is a visible and near-infrared satellite program called the Naval EarthMap Observer

(NEMO)[2], and is designed to study the coastal regions of interest to the Navy. The NEMO satellite consists of two instruments, a hyperspectral imaging spectrometer called the Coastal Ocean Imaging Spectrometer (COIS) and a panchromatic imager (see Fig. 3). The spectrometer measures wavelengths from 400 nm to 2500 nm with a spectral resolution of 10 nm. The instrument would be flown in a push-broom mode with a 30 km swath width and selectable GSD's of 30m or 60 m. A panchromatic camera with a 5 m GSD is used as a sharpener. A key element of the NEMO hyperspectral concept is high signal to noise (> 200 SNR) sensing to allow measurement of weak signals from shallow water in the presence of strong surface and atmospheric scattering. The NEMO program is designed to satisfy global Naval littoral requirements including bathymetry, beach trafficability, water optical clarity and other properties.

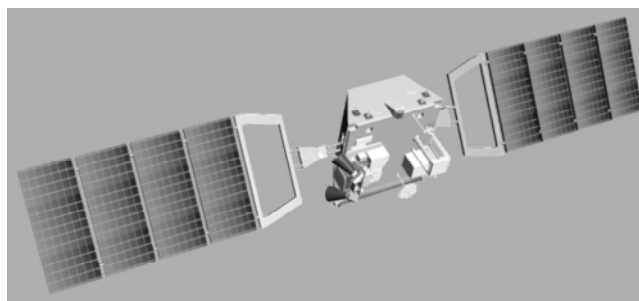


Fig. 3. Artist rendition of the NEMO satellite showing the COIS on the lower panel – left side.

A second hyperspectral satellite involves the flight of a high spatial resolution sensor at geosynchronous orbit to obtain GOES-like weather imagery combined with sounding profiles of temperature, winds and water vapor. The Naval mission is called the Indian Ocean METOC Imager (IOMI) (see Fig. 4) and is done in partnership with NASA and NOAA for the NASA Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) [3]. The GIFTS/IOMI spectrometer has a GSD of 1 km day and 4 km night and uses an interferometer to measure more than a thousand wavelengths per pixel. Data will be used to determine cloud properties and surface temperatures, 3-d wind fields, and profiles of temperature, moisture and trace gases.

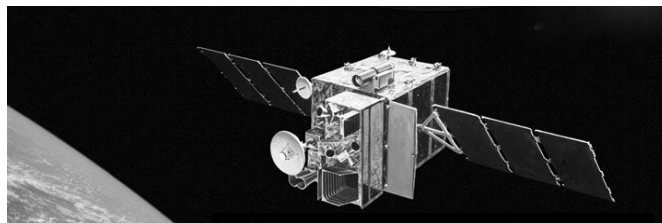


Fig. 4. Artist concept of the GIFTS/IOMI satellite. The instrument (right) and dishes are on the nadir panel.

GIFTS/IOMI will be launched in late 2005 as part of the STP MLV-05 mission. The satellite will be operated initially over a meridian along the East Coast of the U.S. and then moved to the West Coast after 3 months. After completion of

this 12-18 month phase, the satellite will be repositioned over the Indian Ocean. During this phase of the Navy and will obtain synoptic scale imagery and soundings over a region of the globe of high interest. The design lifetime of the satellite is seven years.

#### IV. NAVAL SPACE WEATHER MISSIONS

As with microwave and optical, the Navy has maintained a long term investment in remote sensing techniques in the ultraviolet. Most of the major atoms and molecules in the upper atmosphere and ionosphere have UV signatures in emission or absorption so the UV is the optimum band for remote sensing of the thermosphere and ionosphere. Naval interests in the ionosphere derive from systems involving radio propagation through the ionosphere (GPS navigation, HF communication, UHF satellite communications, radar and precision geolocation). The neutral atmosphere produces drag on satellites in low Earth orbit and is of interest to the Naval Space Command who tracks satellites with a radar "fence" arrayed across the continental U.S.

A series of five UV instruments will soon be flying aboard the next generation of DMSP satellites along with the new SSMIS series. These instruments, developed by NRL, are called, the Special Sensor Ultraviolet Limb Imager (SSULI). Each instrument (see Fig. 5) measures vertical airglow radiance profiles which are used to determine profiles of thermospheric neutral composition (O, N<sub>2</sub> and O<sub>2</sub>) and electron density. The limb scanning spectrographs measure wavelengths in the range 83 nm to 170 nm with 1.7 nm resolution. Airglow profiles are obtained from tangent altitudes from 50 km to 750 km with 5 km resolution. Data from the SSULI's will be used operationally by the Air Force Weather Agency to produce space weather products for the DoD. The data will be ingested by an assimilating model for the ionosphere currently under development by the Navy.



Fig. 5. Special Sensor Ultraviolet Limb Imager (SSULI)

The last in the list of major remote sensing experiments currently under development by the Navy is a multispectral ultraviolet imager designed to image ionospheric and thermospheric density variability from geosynchronous orbit. The experiment is called the Ionospheric Mapping and Geocoronal Experiment (IMAGER) and is slated to fly on the MLV-05 mission along with GIFTS/IOMI (Fig 4. top). IMAGER will measure airglow radiances with high

resolution (10 km x 10 km) over a 1000 km by 1000 km field of view. A two-axis gimbal will maneuver the instrument to view anywhere on the disk or limb of the Earth. IMAGER uses 4 discrete wavelengths (83.4 nm, 130.4 nm, 135.6 and 143.0 nm) to determine 3-d ionospheric density structure on the nightside and O/N<sub>2</sub> ratios on the dayside to track the effects of geomagnetic storms. On the limb, the 10 km resolution will provide altitude profiles of neutral and electron density. The primary objective of the IMAGER experiment is to demonstrate real-time tracking of ionospheric irregularities and scintillation storms. Tracking of these storms will provide advanced warnings of navigation and satellite communication outages.

#### IV. SUMMARY

To be able to respond rapidly to changing conditions around the world, the Navy must maintain a permanent forward-deployed global presence. Maintaining this posture requires accurate specification and forecast of ocean, atmospheric and space environments which are best obtained with space-borne remote sensing platforms. For these reasons the Navy has maintained a strong remote sensing space research program and has actively sought partners to fly space demonstrations. In the next five years the Navy will be involved with a number of microwave, infrared, visible and ultraviolet remote sensing space experiments and operational sensors. These demonstrations and experiments will help improve our understanding of the environment from ocean to space and help prove new technologies for future flights on DoD and NPOESS operational weather satellites.

#### ACKNOWLEDGMENT

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