

Comparing the performance of airborne and  
spaceborne imaging spectrometers (AVIRIS ,  
Hymap, Hyperion/EO-1, WF-1/Orbview-4,  
COIS/NEMO, and HYDICE)

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# NEMO/COIS

## Naval EarthMap Observer (NEMO) satellite

- Demonstrate the use of hyperspectral imaging
  - Characterization of the littoral environment
  - On-board processing using ORASIS algorithm
  - Dual-use (DOD and commercial) applications
  - Real-time downlink of data and end-products
- Sun-synchronous, 605 km altitude, 10:30 am equator crossing
- Seven day repeat coverage
- Coastal Ocean Imaging Spectrometer (COIS) under development at SAIC/San Diego

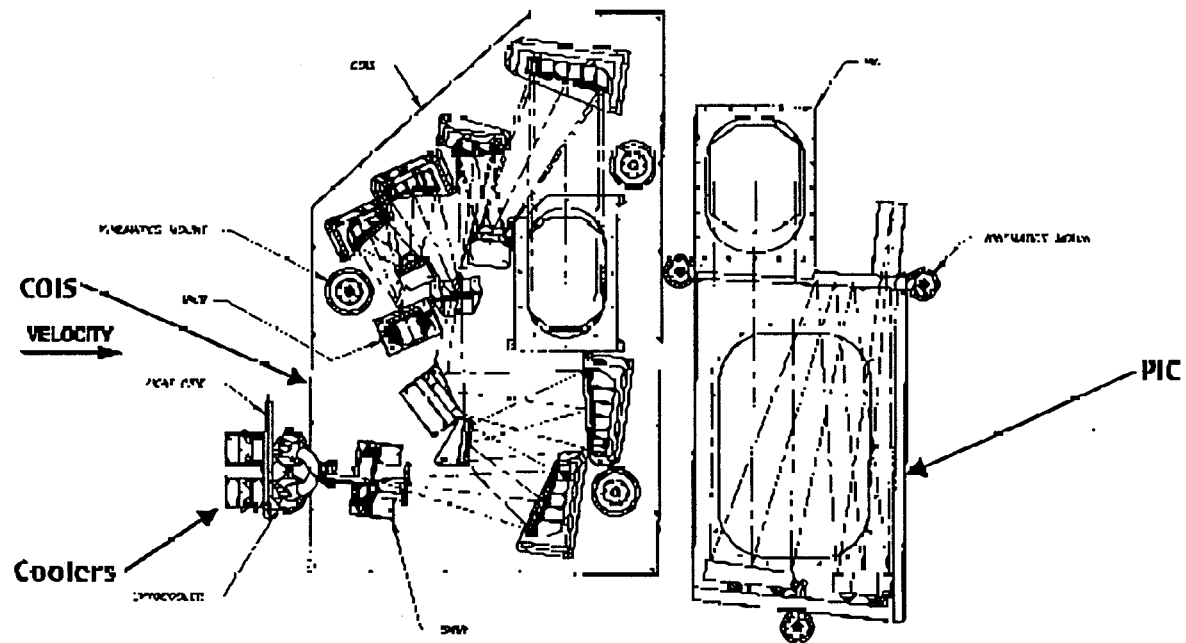
# NEMO Mission Drivers

- Ocean and shoreline character
  - 5% ocean reflectivity (fairly dark)
  - Straylight, polarization, and calibration impacts
- Trade spatial resolution
  - Wider swaths
  - Higher SNR
- 3 collection modes (60 m, 30m, 30m full)
  - To fulfill mission objectives

# COIS Details

- Pushbroom imaging spectrometer
- 0.4 to 2.5  $\mu\text{m}$  range,  $10 \pm 2$  nm resolution
- All-reflective optics
- Two spectrometers, dichroic after beam splitter
- Offner spectrometer form, holographic grating
- Silicon and MCT area arrays 1000 samples wide
- Boresighted to 5 m spatial resolution pan imager (PIC)

# COIS and PIC Sensors On NEMO



Z-axis - 3.2 inches above top plane of Optical Bench (includes Complete SIP)

COIS AND PIC ENCLOSURE REMOVED FOR CS ARMY

Reference: September 14, 1978 at 62-34235 FU

# NEMO References

Website: <http://nemo.nrl.navy.mil>

SPIE Proceedings Vol. 3437 (July 19, 1998)

Hyperspectral remote sensing technology (HRST) program and the Naval EarthMap Observer (NEMO) satellite (Paper #: 3437-44)

Naval EarthMap Observer (NEMO) science and naval products (Paper#: 3437-45)

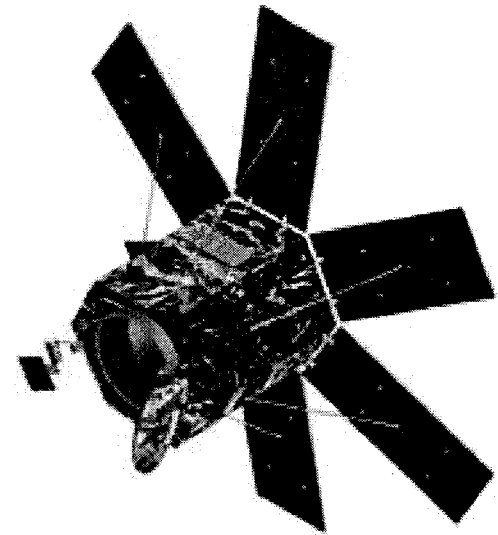
On-board hyperspectral compression and analysis system for the NEMO satellite (Paper #: 3437-46)

NEMO satellite sensor imaging payload (Paper #: 3437-47)

Contact: Tom Wilson, [wilson@ncst.nrl.navy.mil](mailto:wilson@ncst.nrl.navy.mil)

# Orbview-4/Warfigher-1

- Airforce Research Lab Sponsor
- Demonstration of hyperspectral technology for target detection and terrain categorization for the military
- WF-1 is a tag-along to Orbview-4 Satellite
  - 1 meter panchromatic
  - 4 meter multispectral
- Orbital Sciences is Prime Contractor
- WF-1 currently under construction at Northrop-Grumman



# WF-1 Details

- Pushbroom imaging spectrometer
- 8 meter spatial resolution
- 0.45 to 2.5  $\mu\text{m}$  range, 11 nm resolution
- All-reflective optics
- One spectrometer, 2 dichroics after grating
- Offner spectrometer form, e-beam grating
- Si, InGaAs, and MCT area arrays
- 640 samples wide
- Currently under construction



# OV-4/WF-1 References

- Very little published material exists for the Warfighter Sensor due to classification and commercial proprietary concerns
- Websites
  - <http://www.vs.afrl.af.mil/vsd/>
  - <http://www.orbimage.com/satellite/orbview4/orbview4.html>
  - <http://www.fas.org/spp/military/program/imint/warfighter.htm>

# EO-1/Hyperion

- NASA Code Y Sponsor
- Demonstration of:
  - Advanced Landsat imager technologies
  - Formation flying (Terra, Landsat 7, and EO-1)
- Hyperion a separate hyperspectral imaging sensor
- Other sensors on EO-1
  - Advanced Land Imager (ALI)
  - LEISA atmospheric corrector (LAC)
- TRW built and delivered Hyperion
- Launch is scheduled for April 2000

# Hyperion Details

- Pushbroom imaging spectrometer
- 30 meter spatial resolution
- 0.45 to 2.5  $\mu\text{m}$  range, 11 nm resolution
- All-reflective optics
- Two spectrometers, dichroics after entrance slit
- Offner spectrometer form, e-beam grating
- Si, MCT area arrays
- 256 samples wide

# Hyperion References

- Website: [eo1.gsfc.nasa.gov](http://eo1.gsfc.nasa.gov)

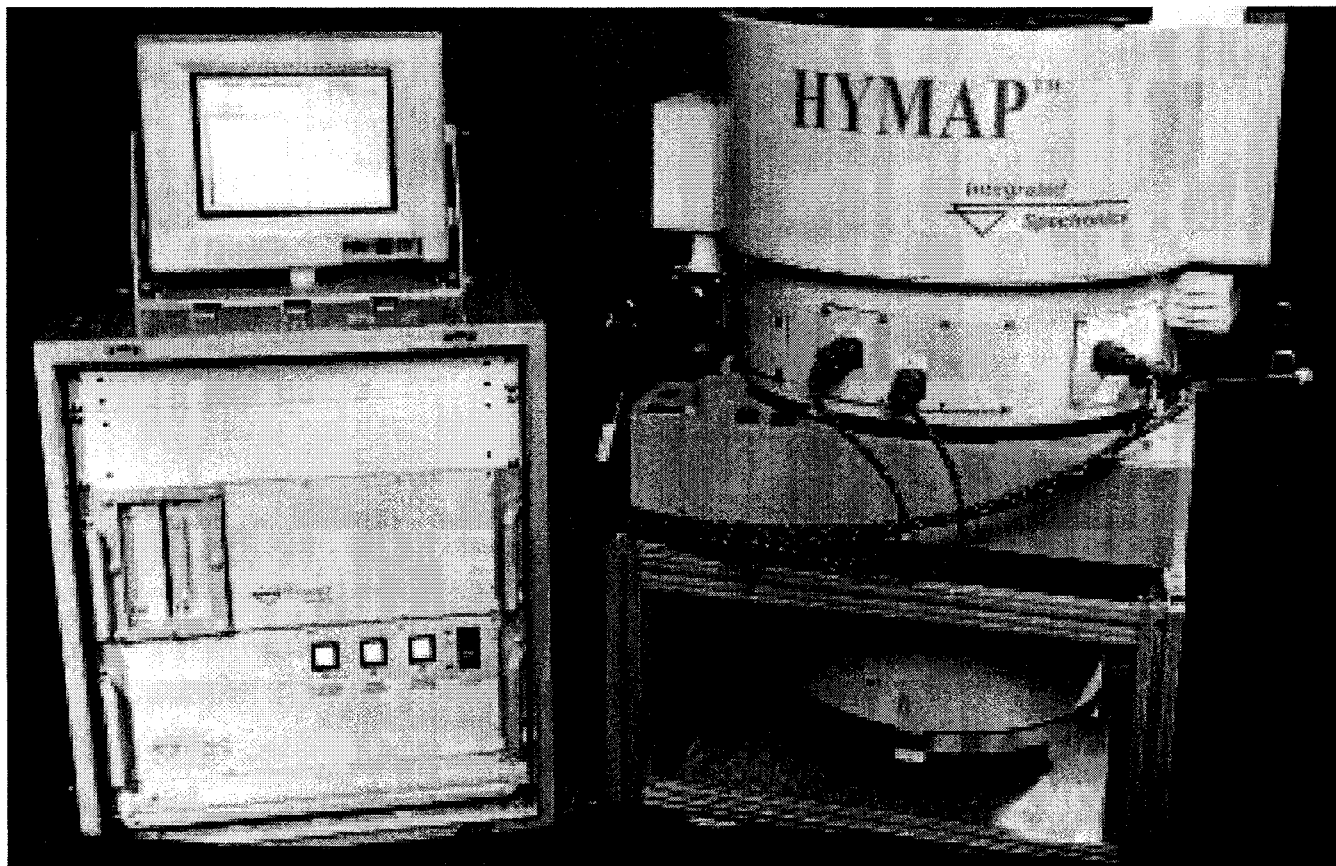
# HYDICE

- Naval Research Lab/CMO sponsor
- Hyperspectral Digital Image Collection Experiment
- Used primarily in support of the HYMSMO program
  - Hyperspectral MASINT Support to Military Operations
    - Measures and Signatures Intelligence (MASINT)
- Flies on ERIM International CV-580
- Sensor built by Hughes Danbury Optical Systems (HDOS)
  - Now Raytheon Danbury Optical Systems

# HYDICE Details

- Pushbroom imaging spectrometer
- 0.5 mrad IFOV (1 to 5 meter spatial resolution)
- 0.40 to 2.5  $\mu\text{m}$  range, 5 to 20 nm resolution
- Prism spectrometer
- Single InSb Area array 320 x 210 Format
  - Special passivation layer for visible response down to blue
- Selectable frame rate and integration time
- Sensor is cooled to 7°C to reduce thermal background
- Integrating sphere onboard calibrator
- Zeiss stabilization mount and DGPS

# Hymap sensor



# Hymap Details

Manufactured by Integrated Spectronics (Australia)

Whiskbroom scanner, 62 ° FOV

line array detectors

100 - 200 wavelength channels

bandwidths generally in 10 - 20 nm range

high signal to noise ratio, >500:1

2 - 10 metre spatial resolution

Operates in light aircraft with standard camera port

3 axis gyro-stabilised platform



# Comparison Table

	<b>COIS</b>	<b>Warfighter-1</b>	<b>Hyperion</b>	<b>AVIRIS</b>	<b>Hymap, Probe</b>	<b>HYDICE</b>
Sensor(s)	NEMO Satellite	Orbview-4	EO-1	ER-2, Twin Otter	Various	CV-580
Platform	ONR, NRL	AFRL/VS	NASA/GSFC	NASA	HyVISTA, ESSI, DeBeers	NRL, ERIM
Organization(s)	HRST	ISTD	NMP	Code YS	Commercial	HYMSMO
Program	SAIC, San Diego CA	Northop Grumman	TRW	JPL	Integrated Spectronics	HDOS
Sensor Manufacturer	605	470	705	20 km, 4 km	Various	2-10 km
Altitude	Circular	Circular	Circular	Airborne	Airborne	Airborne
Orbit	10:30 am Sun-Synch 97.81 ° inclination 7 Day Repeat	10:30 am Sun-Synch 97.3 3 day revisit (50° pointing)	10:00 am Sun-Synch 98 16?			
<b>SPECTRAL</b>						
Spectral Channels	210	200	220	224	126	206
Spectral Range	0.4 to 2.5 µm	0.45 to 2.5 µm	0.4 to 2.5 µm	0.37 to 2.5 µm	0.45 to 2.48 µm	0.4 to 2.5 µm
Spectrometers	VNIR, SWIR	VIS, NIR, SWIR	VNIR, SWIR	4 spectrometers	4 spectrometers	1 spectrometer
Spectral Sampling	10 nm	11.4 nm	10 nm	10 nm	13-17 nm	4-17 nm
Dispersion Method	Grating	Grating	Grating	Grating	Grating	Prism
Dichroic	Yes	Yes, 2	Yes	No	Yes	No
Order Sorting Filter	At FPA	At FPA	At FPA	< 1 octave	< 1 octave	N/A
<b>Spatial</b>						
Type	Pushbroom	Pushbroom	Pushbroom	Whiskbroom	Whiskbroom	Pushbroom
FOV	2.87	0.61	0.62	30	62	9
Swath Width	30 km	5 km	7.5 km	11 km, 2.2 km	1.5 - 5 km	
Ground Sample Distance	60m, 30m	8m	30m	20 m , 4 m	3 - 10 m	
Ground Samples	1000	640	256	614	512	312
IFOV	50 µradians	17 µradians	42.5 µradians	1 mrad	2.5 mrad	0.5 mrad
<b>Radiometric</b>						
Integration Time	8.7, 17.4, 21.7 msec	2.5, 5, 10 msec	4.4 msec	82 µsec		1-42 msec
Image Nodding	5:1, 4:1, 1:1	Yes	No	No	No	No
Aperture	15 cm Diameter	45 cm Diameter	12.5 cm Diameter	10 x 18 cm	100 mm diameter	27 mm
F/no	2.4	4	11.28	1	4 (?)	3
Effective Focal Length	360 mm	1586	1410	200 mm	400 (?) mm	81
<b>FPA</b>	18	17.28	15.36	14.72		12.8
VIS (silicon)	360x1000, 6x bin	80x640, 2x bin	Si 70x256	Si 32x1	Si 32x1	InSb 210x320
NIR		InGaAs 80x640		Si/InGaAs 64x1	InSb 32x1	
SWIR (MCT, TCM8060)	900x1000, 6x bin	MCT 80x640	MCT 172x256	2, InSb 64x1	2, InSb 32x1	100
Pixel Size	18 µm	27 µm	60 µm	215 µm	100 µm (?)	40 µm
Digitization	12 bit	12	12	12	12	12
SWIR Cryocooler	Sunpower	passive	TRW Pulse Tube	LN2	LN2	Stirling
<b>Other Details</b>						
Onboard Processing	ORASIS		Advanced Land Imager	CMIGITS	Zeiss Stabilization	Zeiss Stabilization
Other Sensors	5m GSD PIC	1 m GSD pan 4 m GSD msi	LEISA Atmospheric Corrector		CMIGITS	
Telemetry Data Rate	150 Mbps		760 Mbps	20 Mbps to tape		
Onboard Data Storage	56 Gbit		40 Gbits	10 Gbytes		