



## CT-Analyst® Deployed for the 2009 Presidential Inauguration

J. Boris,<sup>1</sup> G. Patnaik,<sup>1</sup> K. Obenschain,<sup>1</sup> M. Ronas,<sup>2</sup>  
C. Williams,<sup>3</sup> and J. Delaney<sup>4</sup>

<sup>1</sup>Laboratory for Computational Physics and Fluid Dynamics

<sup>2</sup>Center for Computational Science

<sup>3</sup>ITT Corporation

<sup>4</sup>National Medical Response Team

**The Problem:** Airborne contaminants in cities, ports, and bases, whether released accidentally or deliberately as a chemical, biological, or radiological (CBR) agent, present potentially lethal, round-the-clock threats to civilian and military personnel. A crisis manager or warfighter must make immediate life-and-death decisions about how to respond to such an emergency based on incomplete knowledge of the source and the contaminant plume's evolution. The critical speed-vs-accuracy dilemma has always been: Do we make quick decisions (a few seconds) based on crudely computed estimates about the spreading threat, or do we wait a long time (several minutes) for more accurate computations of how the contaminant cloud will evolve? A coordinated defensive response within 3 to 5 minutes of a contaminant's release can reduce casualties by a factor of four or five. Unfortunately, most urban plume predictions take 10 to 15 minutes today.

Even without the dire time constraint, computing wind-driven contaminant transport (CT) over a city or large facility challenges current-day modeling<sup>1,2</sup> because unsteady, turbulent, buoyant flow physics must be solved over large, complex geometry areas. These challenges can be met using a computational fluid dynamics (CFD) model called FAST3D-CT developed at NRL originally for aerospace applications based on NRL's Flux-Corrected Transport (FCT) algorithms and many years of related basic fluid dynamics and atmospheric research. Although the runs take up to a day on big computers, the advantages of using the heavily validated<sup>3</sup> FAST3D-CT model include accurately computing around the buildings while solving the dynamic, turbulent CT problem in cases where experiments are impossible or impractical. Although there is now a reliable computational ground truth, the dilemma has been to make this prediction capability useful in emergencies.

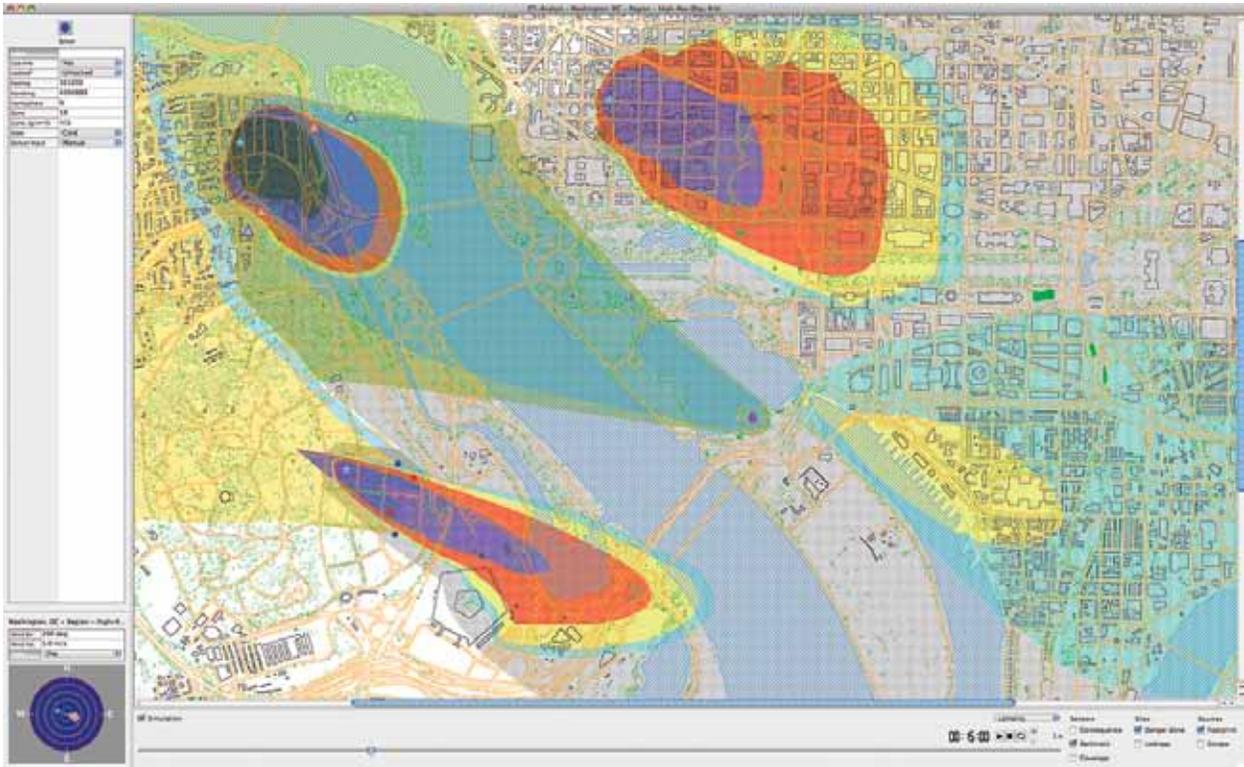
**The Achievement:** To resolve this speed-vs-accuracy dilemma, NRL invented a methodology to make 3D CFD instantly useful for crisis managers in operational situations. In the laboratory well ahead of time, we carry out detailed simulations of airflow

over the entire urban geometry of interest and save out wind-field databases for a full set of wind conditions and a number of test sources. The relevant information from these databases is compressed into 18 tables called Dispersion Nomographs™ to be used on PCs, one nomograf for each of 18 wind directions over the city. The implementation of this approach for crisis management is called CT-Analyst<sup>®1,2</sup> (Contaminant Transport Analyst). CT-Analyst takes full account of the building geometry on the airflow and is both faster and more accurate than other existing or proposed systems.

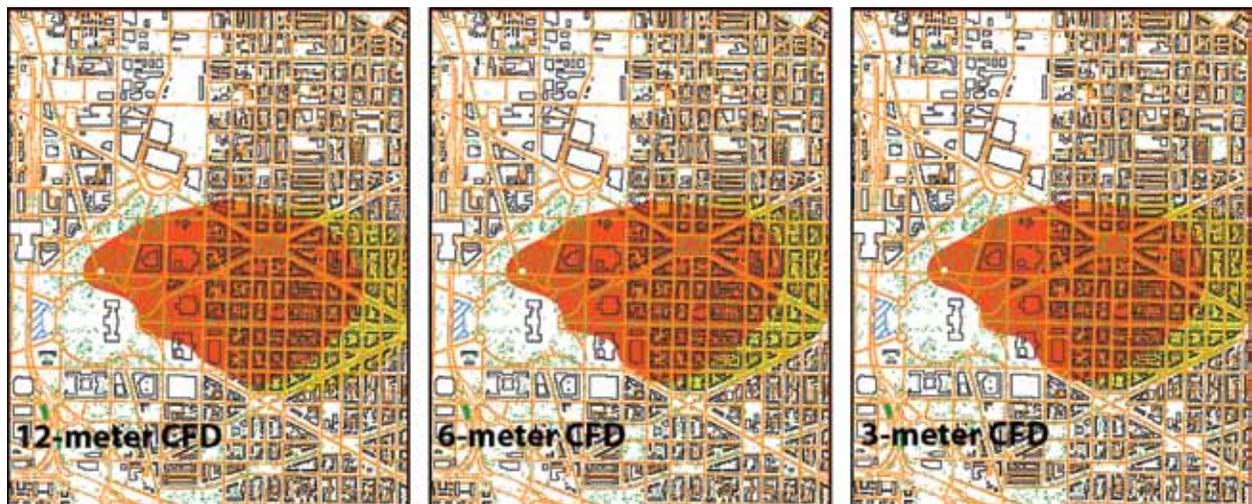
Figure 1 shows CT-Analyst as it appears interactively for a fictitious scenario with four distinct toxic chemical sources in downtown Washington, D.C. The notations near each source are added for clarity. Sources of different size can be released at different times and locations with extents and shapes controlled by the nearby buildings. When a source location is not known, a few local observations of the agent can be combined to estimate the unknown source location. This operation, called "backtrack," is illustrated for the lower left source in the figure. Figure 1 would require hours to compute using other "urban" methods but took ~0.4 s to compute using CT-Analyst. Extensive testing and validation of the CT-Analyst methodology has been performed,<sup>2</sup> one example of which is illustrated for Washington, D.C., in Fig. 2. This figure addresses the question of whether the underlying CFD computations, as reflected through the CT-Analyst predictions, are computed with a fine enough grid. For Washington, D.C., the FAST3D-CT runs were performed with 3-m, 6-m, and 12-m grids, and the results show that even 12-m spatial resolution is adequate for operational use.

**The Impact:** NRL's CT-Analyst system is the first operational *instantaneous* emergency assessment system for airborne contaminant threats in cities. Using CT-Analyst, the accuracy of CFD simulations can be recovered nearly instantly, with little loss of fidelity, by a crisis manager or a warfighter in the field. CT-Analyst is deployed for daily use with Federal emergency managers, police, and fire officials in Washington, D.C., and Chicago, Illinois. It was deployed during Operation Iraqi Freedom and was selected by the Missile Defense Agency for urban dispersion and consequence management.

CT-Analyst was deployed as the nation's crisis management model and used at the HazMat Reachback Center (HRC), hosted by NRL for the 2009 Presidential Inauguration under the auspices of the U.S. Secret Service and the National Medical Response Team. The HRC was designated to provide the crisis and consequence assessment for the Washington,



**FIGURE 1**  
 The entire CT-Analyst graphical user interface display predicting lethality for a scenario involving four separate toxic chemical releases in the mall area of Washington, DC. Notations have been added giving the amounts released and release times of the four sources. An upwind site danger zone and sensor fusion for a backtrack computation are also shown. Computation for this entire display takes about 0.4 s.



**FIGURE 2**  
 CT-Analyst display of a plume envelope for a release near Union Station in Washington, DC, using CFD computed at three different spatial resolutions. The yellow region in each panel shows where the plume is above the ground and has not yet touched down. Very little practical difference can be seen in the three different resolution predictions.

**FIGURE 3**

Hazardous Materials Reachback Center for the 2009 Presidential Inauguration. Experts from a number of agencies came together at NRL to provide situation and consequence assessments for any real or postulated release of hazardous materials in Washington, DC, during the Presidential Inauguration activities and subsequent events.

D.C., area in the event of an airborne contaminant release. The ViPR video teleconferencing capability was employed to transmit graphical results straight to the D.C. multi-agency operations center. Participants at NRL included the FBI, Secret Service, National Medical Response Team, D.C. fire and police personnel, Army and Marine chemical incident support teams, the National Oceanic and Atmospheric Administration (NOAA), the Department of Homeland Security (DHS), and the Defense Threat Reduction Agency (DTRA). Although no actual HazMat incidents took place, in numerous drills the results of the initial assessments by CT-Analyst were provided to the HRC commander, typically within a minute or two.

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[Sponsored by the National Medical Response Team]

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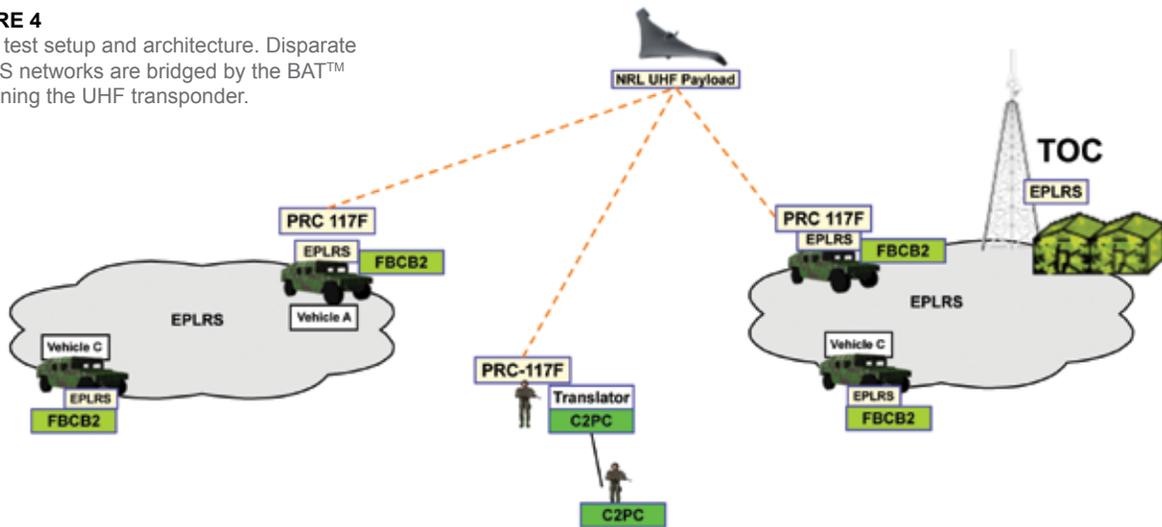
## Beyond-line-of-sight Tactical Communications Relay (BTCR)

M. Rupar, J. Doffoh, and B. Vorees  
*Information Technology Division*

**Introduction:** A joint Navy and Army team, led by the Naval Research Laboratory, has demonstrated a beyond-line-of-sight tactical communications relay (BTCR) capability to extend tactical networks for the Army and Marine Corps (USMC) using an NRL-developed surrogate UHF satellite transponder flown in a small unmanned aerial system (UAS) at low altitudes. This link extension integrated disparate networks and supported networked interaction between

**FIGURE 4**

Relay test setup and architecture. Disparate EPLRS networks are bridged by the BAT™ containing the UHF transponder.



simulated Army and USMC units using organic communications assets.

The objective of this effort, sponsored by the Office of the Secretary of Defense (OSD), was to develop and demonstrate communications range extension in an operational scenario for a Tier II UAS. In FY09, an NRL-developed surrogate UHF satellite transponder was integrated into the BAT™, a UAS built by Northrop Grumman, to provide tactical network range extension. The Army Communications–Electronics Research, Development, and Engineering Center (CERDEC) and NRL demonstrated this technology as part of the C4ISR On-The-Move (OTM) Event 2009 (E09) at Ft. Dix, New Jersey.

The demonstration objective was to link disparate Enhanced Position Location Reporting System (EPLRS)-based networks via NRL's UHF transponder on the BAT™ (Fig. 4). The Army and USMC situational awareness (SA) applications were to interact over this architecture.

NRL was responsible for technical and project management. CERDEC personnel partnered with NRL, and the Project Manager C4ISR OTM provided Army networking hardware and vehicles and hosted the demonstration.

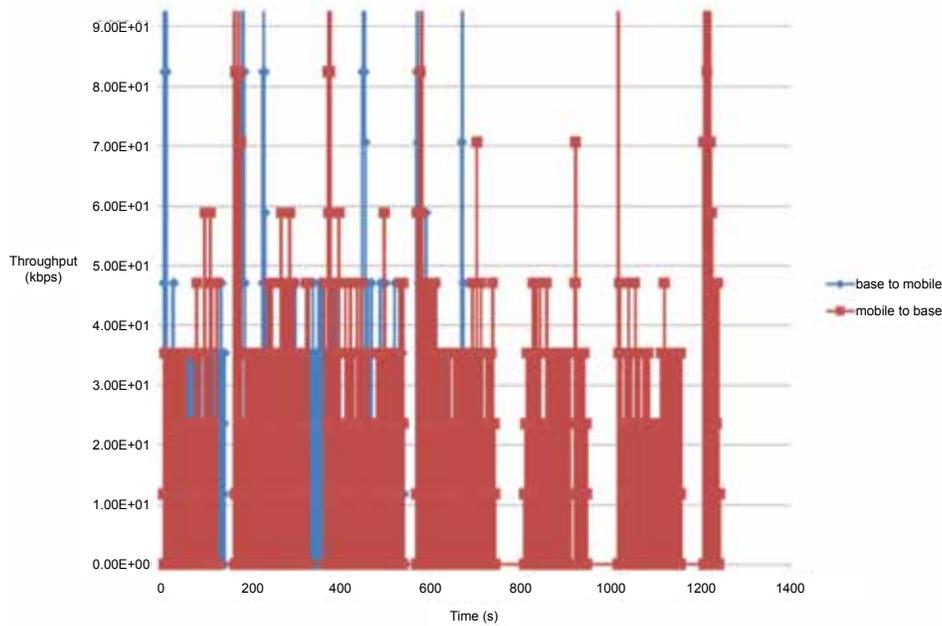
The successful interaction between the two SA tools, the USMC's Command and Control PC (C2PC) and the Army's Force XXI Battle Command, Brigade-and-Below (FBCB2), was accomplished by software developed by SPAWAR-Pacific. This software, as part of SPAWAR-Pacific's Software Interoperability Environment (SIE), enabled bidirectional exchange of tactical data between existing FBCB2 and C2PC systems. SPAWAR-Pacific personnel supported this effort.

**Preliminary Testing:** Initial testing of the UAS-mounted transponder with tactical radios (PRC-117F and PSC-5) was conducted in El Centro, California. A Viasat e-mail program (Vmail), Multi-Generator (MGEN) Tool Kit (an NRL application for measuring IP network performance), and C2PC/FBCB2 message traffic were all exercised over the link. Figure 5 shows MGEN throughput over the transponder using PRC-117Fs transmitting at 42 kbps. One node (base) was stationary, while the other node was mobile. These tests proved the viability of a Tier II UAS as a communications link in an environment using tactical resources.

**C4ISR OTM Event:** The BTCR demonstration was part of the C4ISR OTM event in August 2009. Four Army vehicles with tactical routers were configured to form two distinct EPLRS-linked local area networks, one of which also included the Army's Tactical Operations Center (TOC). A vehicle in each EPLRS network was outfitted with PSC-5 and PRC-117F radios to allow the two local area networks to communicate via the transponder.

A third vehicle, outfitted with the two tactical radios, simulated a dismounted USMC unit. This vehicle operated C2PC with the SIE Translator and communicated with the other units via the UHF transponder.

BTCR successfully demonstrated the transmission of voice and data over the UAS-mounted transponder. A variety of command and control messages were successfully communicated between the two SA applications over that link. Table 1 shows the results of the tested VMF (variable message format) messages. Traffic was initiated from the TOC and sent out to



**FIGURE 5**  
Throughput test results for MGEN at 42 kbps via the UAS-mounted transponder.

TABLE 1—Applications Performance for BTCR

Reception at Destinations				
Origin: TOC	PM 12	PM 13	PM 17	PM 81
Position Report	YES	YES	YES	YES
Spot Report	YES	YES	YES	YES
Free Text	YES	YES	YES	YES
Overlay	YES	YES	YES	YES
Call for Fire	YES	YES	YES	YES

the other nodes in the network. The simulated USMC node is labeled PM 81. The three other nodes, PM 12, PM 13, and PM 17, were all simulated Army forces.

**Conclusion:** BTCR successfully demonstrated the supporting of tactical IP networks over a surrogate UHF satellite transponder flown in a small (Tier II) UAS, the networking of Army nodes in separate EPLRS clouds through that UHF link, the moving of meaningful traffic through that network over the UHF link, and the demonstration of an SA message Translator that allowed USMC messages generated by C2PC to be injected into the Army’s FBCB2 (and vice versa).

This program successfully demonstrated the viability and interoperability of a new series of technology with the use of existing tactical communications on a platform that will greatly contribute to the overall common operational picture (COP).

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### Coastal Environmental Hyperspectral Imaging from the Space Station

M.R. Corson,<sup>1</sup> R.L. Lucke,<sup>1</sup> D.R. Korwan,<sup>1</sup> W.A. Snyder,<sup>1</sup> C.O. Davis,<sup>2</sup> N.R. Mcglothlin,<sup>3</sup> S.D. Butcher,<sup>3</sup> and D.L. Wood<sup>3</sup>  
<sup>1</sup>Remote Sensing Division  
<sup>2</sup>Oregon State University  
<sup>3</sup>Praxis Inc.

**Introduction:** Environmental characterization of the coastal ocean is a critical element in planning and executing naval operations in coastal areas. The coastal ocean is complicated, with in-water constituents including organic and inorganic dissolved and suspended matter that affect visibility, and various bottom types and depths that affect mobility. Accurate maps of bathymetry, in-water constituents, water optical properties, and bottom characteristics significantly enhance the speed and safety of operations from warfighting to humanitarian relief. In the mid 1990s, scientists at the Naval Research Laboratory began an ambitious program to develop instrumentation and techniques to produce these maps using remotely sensed hyperspectral imagery taken from aircraft platforms. In contrast to a conventional color camera, which images in only three wavelength bands, a hyperspectral camera for coastal characterization typically images in 50 to 100 contiguous wavelength bands, and this extra information can be exploited to understand and quantify the complicated coastal ocean environment.<sup>1,2</sup>

**Development of the Spaceborne Hyperspectral Imager:** Spaceborne environmental hyperspectral imaging is a natural next step for the NRL program, building on its extensive foundation of airborne experience. Space offers repeat access to many different coastal types worldwide, access that would be completely impractical using aircraft. Naval forces require coastal environmental information worldwide, and the spaceborne imager coupled with ground truth provides data to determine which retrieval algorithms work on particular coastal types, and the range of errors in the retrieved environmental products.

In March 2007, the DoD Space Test Program manifested the NRL Hyperspectral Imager for the Coastal Ocean (HICO), which is sponsored by the Office of Naval Research under its Innovative Naval Prototype program, to be launched to the International Space Station. To take advantage of the Space Station opportunity, HICO had to be designed, built, calibrated, and delivered for payload integration in 18 months. A small but dedicated team of scientists and engineers in NRL's Remote Sensing Division accomplished this feat ahead of schedule in 16 months. Figure 6 shows the flight imager in the laboratory during calibration.



**FIGURE 6**  
The HICO flight imager in the laboratory. The imager is incorporated into a larger payload module that attaches to the Japanese Exposed Facility on the International Space Station.

As an Innovative Naval Prototype, the HICO program has two primary goals. The first goal is to demonstrate a new capability to satisfy Naval needs. HICO demonstrates the ability to characterize the complicated coastal environment from space, providing a new capability that complements current methods. For this demonstration, HICO is optimized for coastal ocean imaging with design and performance requirements based on decades of airborne experience at NRL and at other laboratories. An important performance requirement is high

signal-to-noise ratio for water scenes. Water scenes have low albedo and are viewed through the atmosphere, which, due to scattered sunlight, is significantly brighter than the underlying coastal scene. The atmospheric signal must be removed from the image because it contains no information about the water scene, and this process degrades the signal-to-noise ratio after atmospheric removal. HICO has a signal-to-noise ratio greater than 200 to 1 for water-penetrating wavelengths when viewing a 5% albedo scene from space. HICO scenes are approximately 42 by 190 km, sufficient to capture the scale of coastal dynamics. HICO's ground sample distance, the size of a pixel on the water surface, is approximately 90 m, providing sufficient resolution for this proof-of-concept demonstration.

The second goal of the Innovative Naval Prototype program is the demonstration of methods to reduce cost and schedule. HICO addresses this by using commercial-off-the-shelf (COTS) components where feasible. The HICO spectrometer, CCD camera, and telemetry and control computer are COTS hardware. Because the camera and computer are not designed to operate in a vacuum, they are housed in hermetically sealed enclosures containing nitrogen gas. The camera enclosure also includes a small fan for forced convection. A novel use of a COTS component in HICO is a commercial motorized rotary stage, intended for use in laboratory vacuum systems, to point the imaging line of sight.

**Environmental Products from HICO on the Space Station:** On September 10, 2009, HICO was launched from the Tanegashima Space Center in Japan to the International Space Station and attached to the Exposed Facility of the Japanese Kibo module using Kibo's remote manipulator arm, as shown in Fig. 7. HICO was activated on September 24, and after a brief checkout, began imaging coastal sites worldwide. An example product of the new HICO capability to produce environmental maps from spaceborne imagery is shown in Fig. 8. The left image in Fig. 8 is a conventional color image of Andros Island and adjacent ocean in the Bahamas, acquired by HICO on the Space Station and constructed using three HICO wavelength bands. The false-color image on the right is a preliminary bathymetry map of the ocean surrounding the island, retrieved from the fully spectral HICO image.

**Summary:** The Hyperspectral Imager for the Coastal Ocean demonstrates a new capability for environmental characterization of the coastal ocean from space. Environmental maps produced from HICO data for coastal types worldwide will be compared to in situ



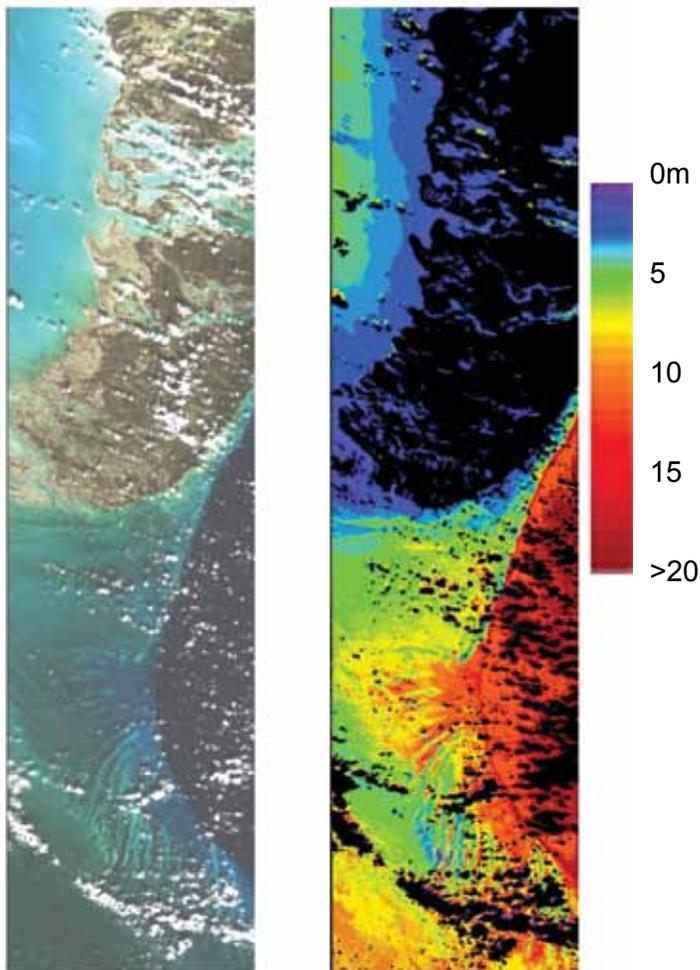
**FIGURE 7**  
The payload module containing HICO is positioned by the Japanese remote manipulator arm prior to attachment to the Exposed Facility (NASA photograph).

measurements to understand and validate the accuracy of the HICO products. The HICO program is the first step in providing a valuable new tool for Naval operations in the coastal zone.

[Sponsored by ONR]

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**FIGURE 8**  
Left: Color image of Andros Island, Bahamas, constructed using three HICO wavelength bands. Right: False-color bathymetry map retrieved from the fully spectral HICO data. Land and clouds are masked black. Imaged area is approximately 42 by 190 km.