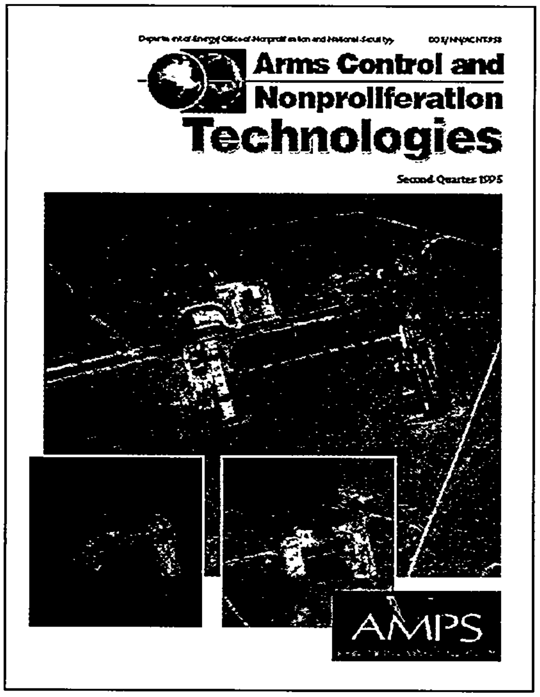
Department of Energy/Office of Nonproliferation and National Security DOE/NN/ACNT-95B

Arms Control and Nonproliferation Technologies

Second Quarter 1995

AMPS

AIRBORNE MULTISENSOR POD SYSTEM



About the cover

Our cover illustrates the central concept of the AMPS Program—that data from many sensors combined together create a more precise and complete image of a particular area. The large photo is an aerial view of the Arid Land Ecology (ALE) site at Hanford. The black-and-white photo on the bottom left-hand side is a Synthetic Aperture Radar image of the same site, taken by the SAR pod. And the photo on the bottom right-hand side is an integration of data from multispectral and hyperspectral sensors, taken by the Multisensor Imaging pod.

Focus on the AMPS Program

During the past few years, many individuals from the DOE national laboratories have collaborated on the Airborne Multisensor Pod System (AMPS) Program. Its primary mission is to provide a scientific environment to research multiple sensors and the new information that can be derived from them. The bulk of this research has been directed at nonproliferation applications, but it has also proven useful in environmental monitoring and assessment, and land/water management.

Many people provided their time and expertise to help produce this issue of *Arms Control and Nonproliferation Technologies*, and we would like to give credit where credit is due:

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Karen Steinmaus, Pacific Northwest Laboratory
Bruce Roberts, Pacific Northwest Laboratory
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Robert Huelskamp, Sandia National Laboratories
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Chief Warrant Officer Spiegel, U.S.M.C., Camp Lejuene

The purpose of *Arms Control and Nonproliferation Technologies* is to enhance communication between the technologists in the DOE community who develop means to verify compliance with agreements and the policy makers who negotiate agreements.

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Focus on the AMPS program

Using AMPS technology to detect proliferation and monitor resources

As part of its active mission to research and develop more effective solutions to problems in arms control and nonproliferation, the U.S. Department of Energy established a program for the aerial collection, integration, and exploitation of data—the Airborne Multisensor Pod System (AMPS). Managed through the Office of Nonproliferation and National Security, the AMPS program is shared through the cooperative efforts of the Sandia National Laboratories (SNL), the Pacific Northwest Laboratory (PNL), the Lawrence Livermore National Laboratory (LLNL), the DOE Remote Sensing Laboratory (RSL), the Savannah River Technology Center (SRTC), and the U.S. Navy. A modified U.S. Navy plane is the aerial platform and test bed of wing-mounted pods that contain a suite of sensors. This method of flying over the same area and collecting data with multiple sensors will advance data-integration techniques. The design of two AMPS pods began in early 1992. Designated Pods 1 and 2, they were completed and approved by the Navy to fly in April 1994. AMPS Pod 1 contains a Synthetic Aperture Radar (SAR) configured by SNL. AMPS Pod 2 is a Multisensor Imaging (MSI) pod configured by RSL. A new pod, AMPS Pod 3, planned for completion and flight certification by December 1995, is called the Effluent Species Identification (ESI) pod. Amps Pod 3 is a collaboration between LLNL, PNL, and SRTC.

Although the sensors in the pods are

1994 AMPS Missions

Mission 1: Kirtland Air Force Base, New Mexico
Maricopa Agricultural Center
Albuquerque, New Mexico

Mission 2: Nellis Air Force Base, Nevada
Hoover Dam, Nevada
Moapa Power Plant, Nevada
Las Vegas, Nevada area

Mission 3: Andrews Air Force Base, Maryland
Washington, D.C. area
Boston Massachusetts area
Beltsville Agriculture Center, Maryland
Norfolk Naval Base, Virginia
Georgia Floods

Mission 4: Hanford, Washington area
Idaho National Engineering Lab, Idaho

Mission 5: Coastal North Carolina
Coastal Florida
Chesapeake Bay area

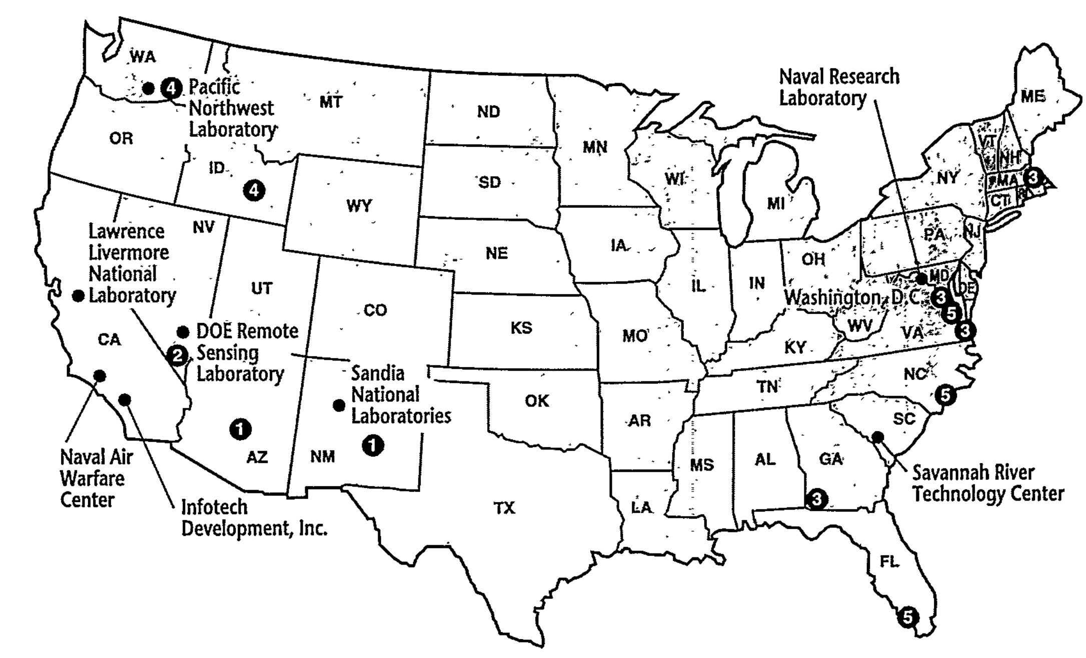


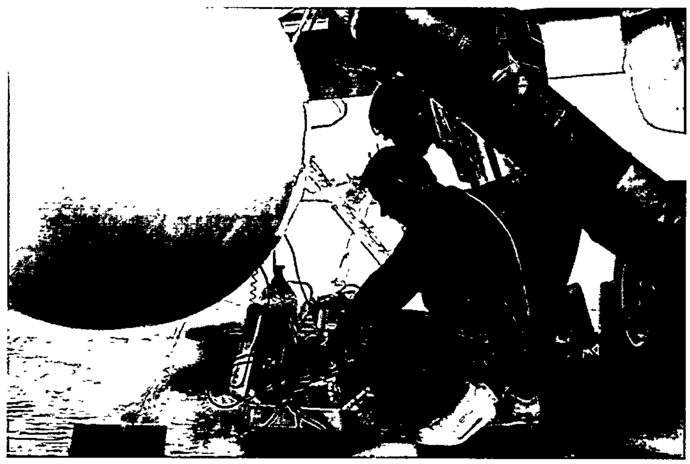
Figure 1. DOE's participants in the AMPS Program. Circled numbers refer to the AMPS missions (see box) flown in 1994.

ultimately intended for autonomous operation, during initial development, control stations on-board allow technical personnel to control and adjust sensors as necessary. Imaging media include digital and analog videotapes, photos, and digital data tapes. Digital files are generated by an array of non-imaging sensors.

While the AMPS program can accommodate numerous inter-related objectives, its primary mission is to provide a scientific environment for researching multisensor data exploitation and developing information products superior to those produced by a single sensor. Although this research has been directed toward nonproliferation applications, it has also been useful in environmental monitoring and in the assessment of natural resources. AMPS data can play a major role in establishing environmental priorities, serving as a valuable information resource.

Each AMPS pod is unique. The Synthetic Aperture Radar system is derived from another program, substantially modified to operate in a pod mounted underneath the plane. The Multisensor Imaging pod contains six commercially available imaging systems. The uniqueness of this pod comes from its ability to simultaneously collect data co-registered with time and location. The Effluent Species Identification pod is truly leading-edge technology, containing four sensors that have been designed and built from the ground up by the DOE national laboratories. In this issue, we focus on some of the data the AMPS pods collected during the past year. Also, we briefly describe the pods and sensors themselves, and finally show how to access AMPS data on the Internet. •

▲ **Figure 2.** MSI (left) and SAR (right) pods mounted and ready for pre-flight ground checks at the DOE Remote Sensing Laboratory, Nellis AFB, Las Vegas, Nevada.



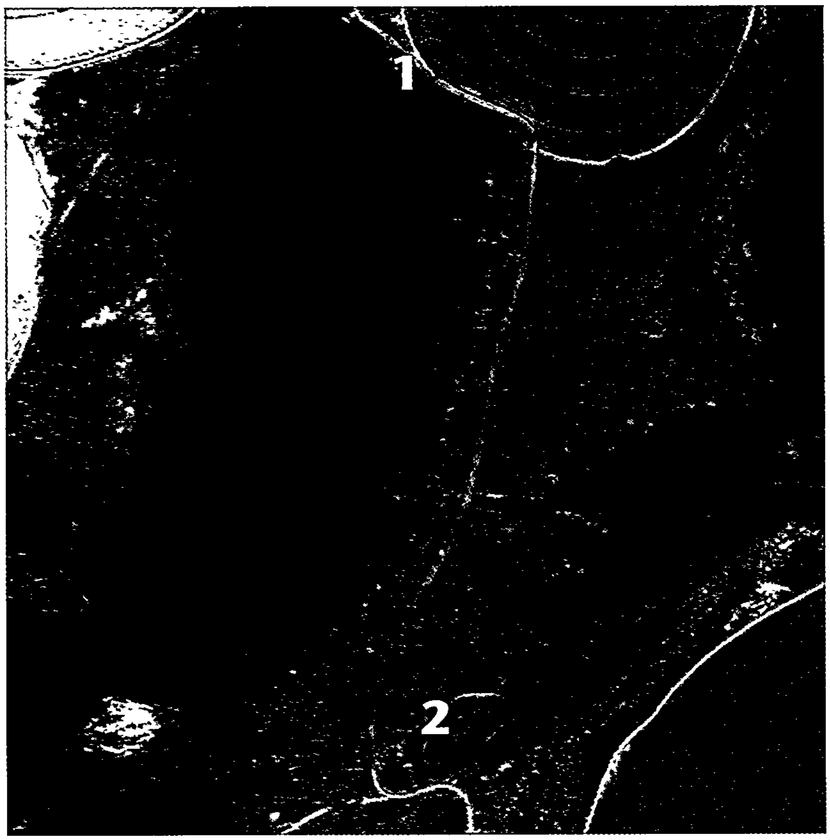
▲ **Figure 3.** MSI pod ground checks at Andrews AFB prior to AMPS Mission 3.

Combining multisensor data to monitor facilities and natural resources

One of the primary objectives of the AMPS Program is to conduct multisensor data fusion research for DOE's nonproliferation and national security communities. Data fusion is an often-used buzz word in this information technology age. In this context, data fusion refers to data combined and integrated from different sensors that results in more information from the combined sensors—or from the results of the integration—than would be available from each individual sensor. The phrase "the whole is greater than the sum of its parts" perfectly illustrates the objectives of multisensor data fusion research.

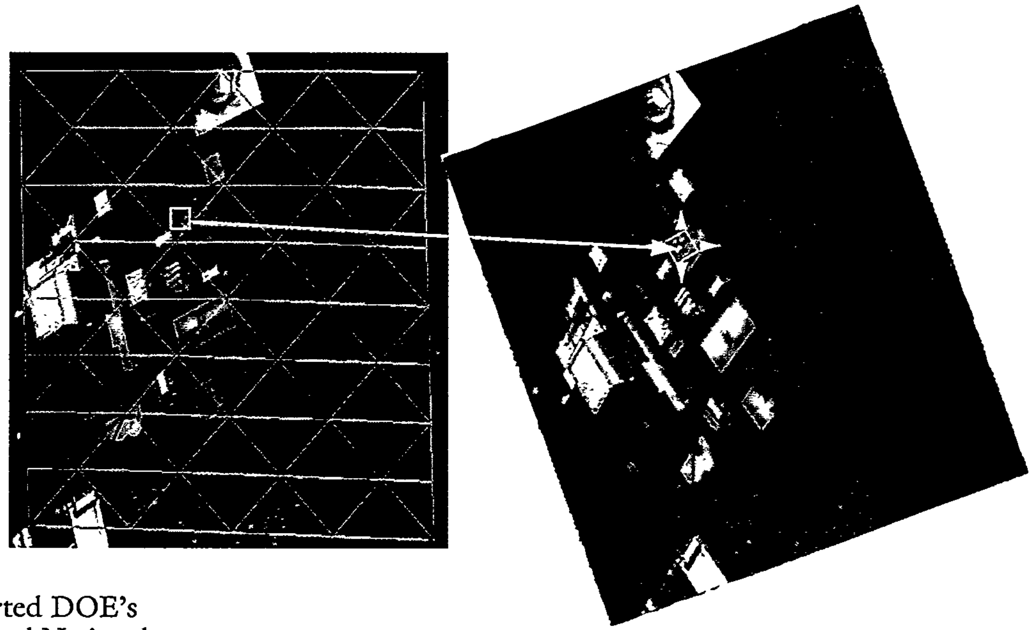
Accordingly, DOE's Office of Nonproliferation and National Security (NN-20) supports research at the national laboratories to advance the state-of-the-art in data processing, data analysis, interpretation, and multisensor data-detection algorithms. The program manager for Multisensor Systems Research (MSR) is Steve E. Herrick of NN-20's Advanced Systems Program.

The processing, analysis, and interpretation techniques as applied to multisensor data will enable scientists to detect and characterize nuclear-proliferation activities. The data-collection missions flown to date have not only tested the flight platform and sensor pods, but have also validated the techniques developed under the MSR program. For example, one mission flew over a moth-balled nuclear processing facility at DOE's Hanford Site in Washington and a nuclear-waste management complex at the Idaho National Engineering Laboratory. In conjunction with the flight, researchers collected data from the ground and conducted experiments to validate the detection and identification algorithms for the sensors in the pods. The lessons learned from these comparisons of data from known sites with the AMPS sensors help to enhance and refine our capabilities for nonproliferation detection and monitoring.

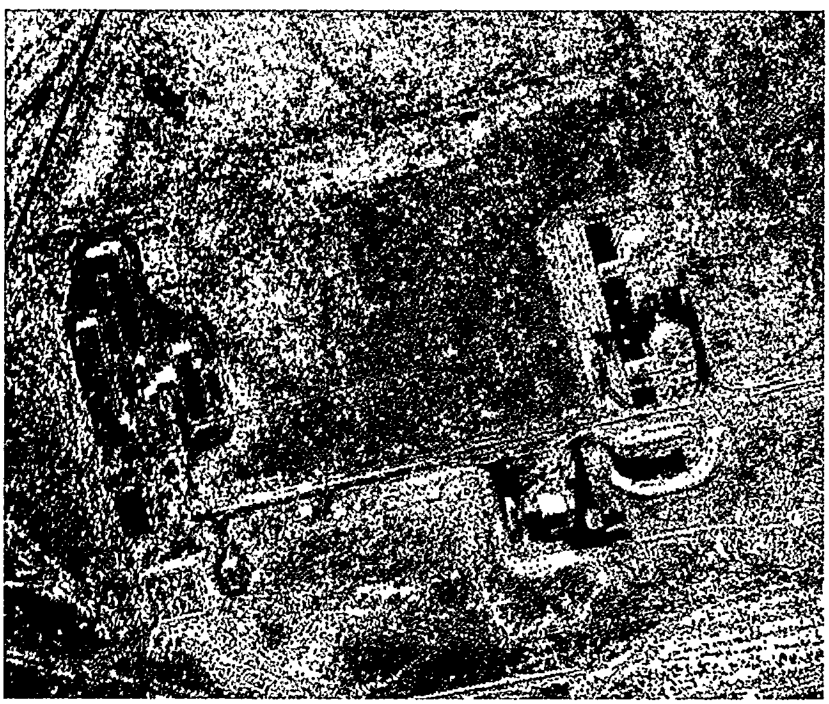


▲ **Figure 1.** Multispectral scanner data from an AMPS mission in September, 1994. This false-color composite of the McNary Wildlife Refuge shows areas invaded by the purple loosestrife plant (see 1) and by the purple loosestrife and Russian olive (see 2). Pacific Northwest Laboratory will apply data fusion methods developed under NN-20 to delineate riparian zones, identify alien species, and evaluate the wetlands.

This research is applicable not only to nuclear proliferation but also to a wide variety of areas important to federal, state, and local interests—wetlands mapping, agricultural monitoring, environmental damage assessment, land use management, just to name a few. The AMPS Program supports the agendas of other agencies interested in evaluating AMPS and fosters collaboration in the area of multisensor data fusion research. The first AMPS missions have supported DOE's Office of Nonproliferation and National Security and also the U.S. Army, the U.S. Navy, the U.S.D.A., and the National Oceanic and Atmospheric Administration (NOAA), and several universities. Numerous other government agencies and universities have shown interest in AMPS data because it is now available on the Internet. The rest of this article illustrates some of the AMPS data-collection and analysis efforts for a variety of applications and we follow with three specific examples from the 1994 missions.



▲ **Figure 2.** Accurate image registration is a critical first step toward data fusion. Pacific Northwest Laboratory is developing semi-automated image registration to improve the registration accuracy and shorten the time required. Multisensor data fusion is especially challenging. In this image, an "image patch" around a selected control point (right) is transformed into the source image (left).



◀ **Figure 3.** Multisensor data can be used to identify and characterize treaty-monitoring targets of interest. In this image, an aerial photograph was combined with SAR data and multispectral scanner data (taken at pre-dawn and day). Textural differences help distinguish man-made items such as roads and buildings (dark pink and red) from vegetation and soil (greens and yellows).

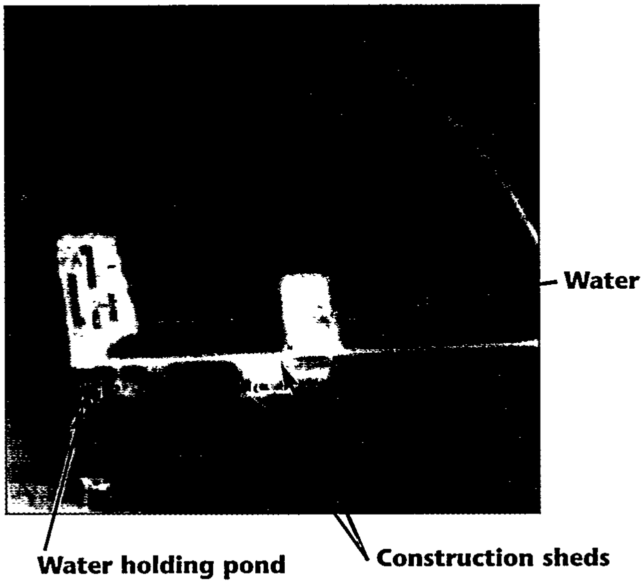


Figure 4. This image of the ALE Facilities at Hanford taken in September, 1994 on two different days shows the detection of thermal changes across time. Red represents warmer temperatures, and blue, cooler. The large red rectangle is a water-holding pond that warmed up between the two dates. The red–blue pair in the middle represents activities at a new construction site. The red square on the right represents thermal changes in the contents of a water truck.

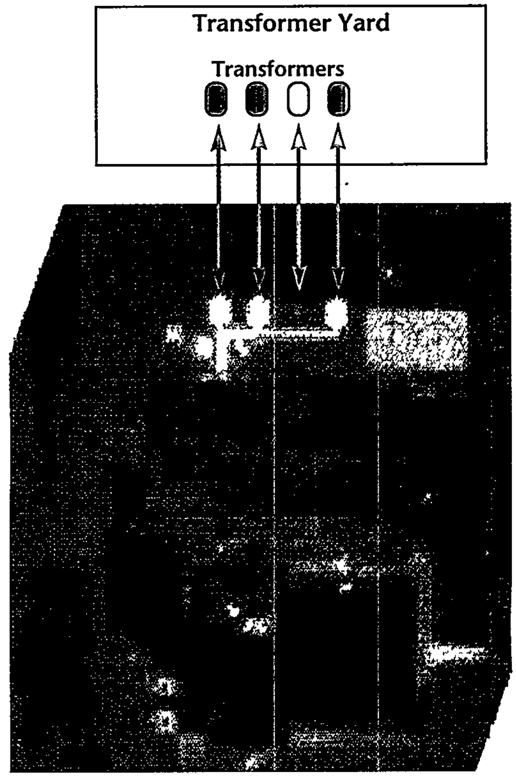
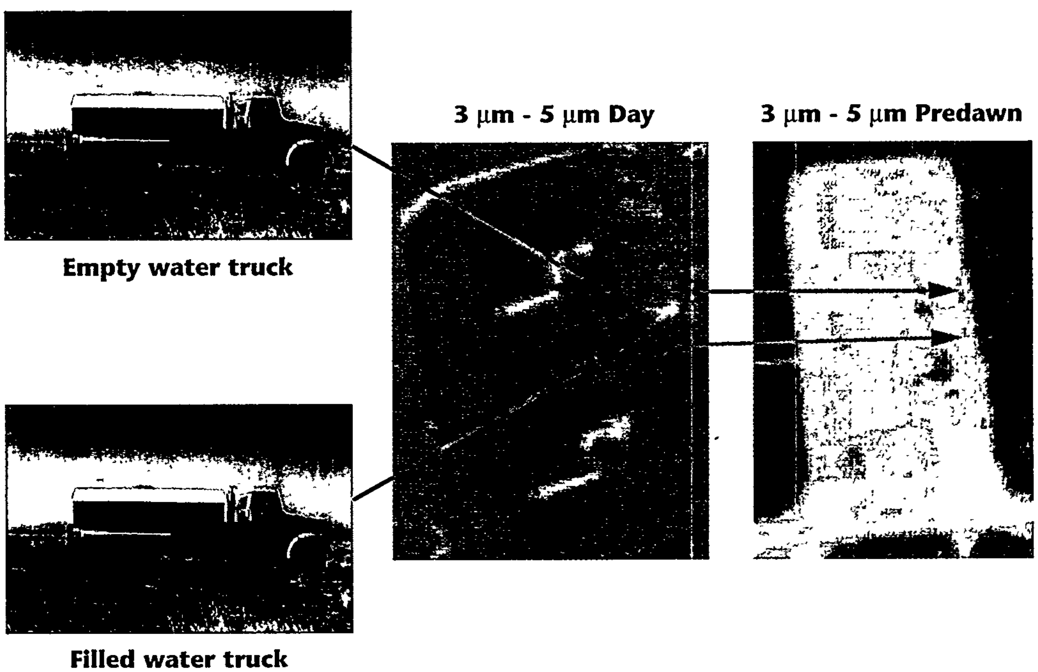
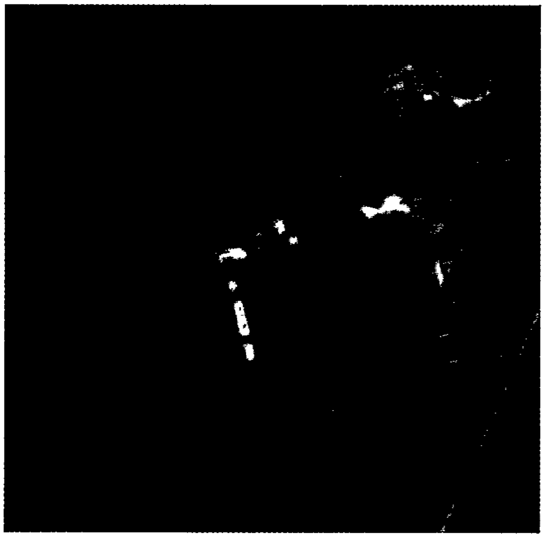


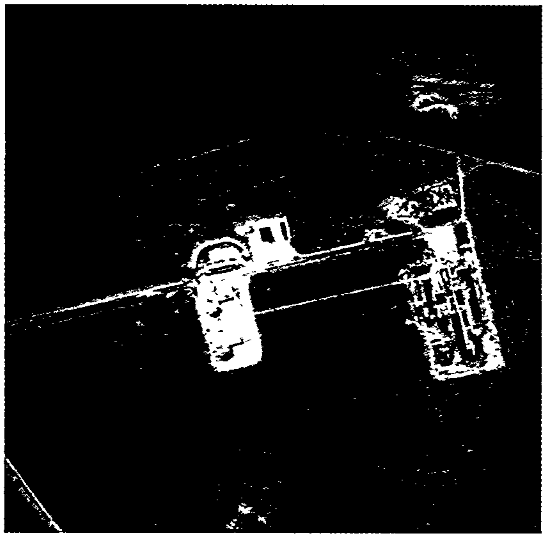
Figure 5. A commercial nuclear reactor on the Hanford site, the Washington Public Power Supply System, was imaged with the multispectral scanner. The aerial photograph did not show the transformers, which were in the shadow of the building. However, in the thermal band, 8–12 mm, it is easy to pick out three operating transformers (red indicates operating transformers, green the reserve).

Figure 6. Pacific Northwest Laboratory had a unique opportunity to experiment with thermal inertia. Two identical trucks, one filled with water, the other empty, were parked. Multispectral scanner data was collected at pre-dawn and during the day. In the pre-dawn image (right), the filled truck, having greater thermal inertia, remains warmer (whiter) than the empty truck. Experiments such as these can help determine the detectability of heat capacity by the AMPS sensors.



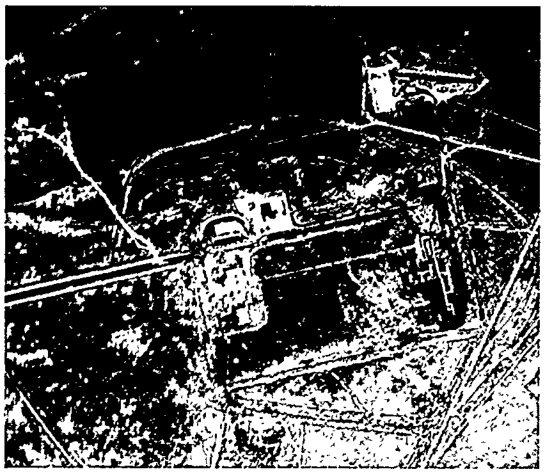


Aerial Photo 10,000 feet AGL 19 Nov 93

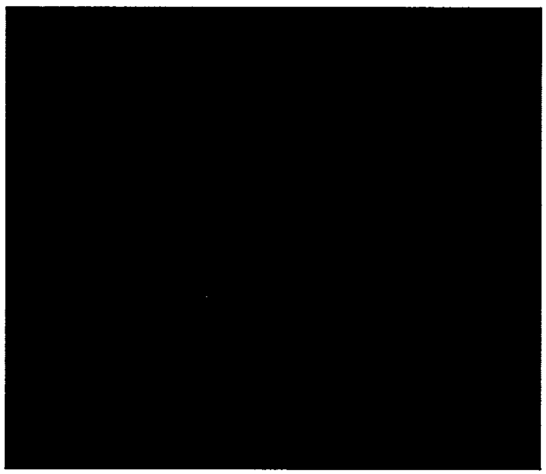


Color Infrared Aerial Photo (R) 2,500 feet AGL 22 Sep 94
Thermal Infrared - Predawn (G) 2,500 feet AGL 22 Sep 94
Synthetic Aperture Radar (B) 1,500 feet AGL 28 Sep 94

Figure 7. The aerial photograph on the left, taken with a large-format aerial camera at 10,000 feet in November, 1993, is a natural color photograph without digital enhancement and as it would appear to the human eye. For comparison, the photograph has been rectified and re-scaled to match the false-color image on the right that was derived from three different AMPS data sources: an aerial photograph, thermal infrared, and SAR.

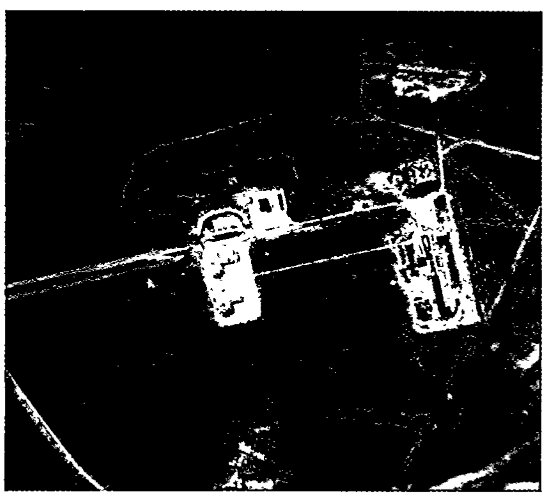


Color Infrared Aerial Photo 2,500 feet AGL 22 Sep 94
(First Principal Component)



Thermal Infrared - Predawn 2,500 feet AGL 22 Sep 94

Synthetic Aperture Radar 15,000 feet AGL 28 Sep 94



Color Infrared Aerial Photo (R), Thermal Infrared - Predawn (G),
Synthetic Aperture Radar (B)

Figure 8. Each AMPS data source is displayed as individual red, green, and blue components comprising the false-color composite. The red display color is the first principal component of a color infrared aerial photograph; the green display color is a pre-dawn thermal infrared image; and, the blue display color is SAR data. The integration of these data sources greatly benefits analysts by providing more interpretable information than what is available on the aerial photograph alone.

Automatic Target Recognition (ATR) of Cooling Towers

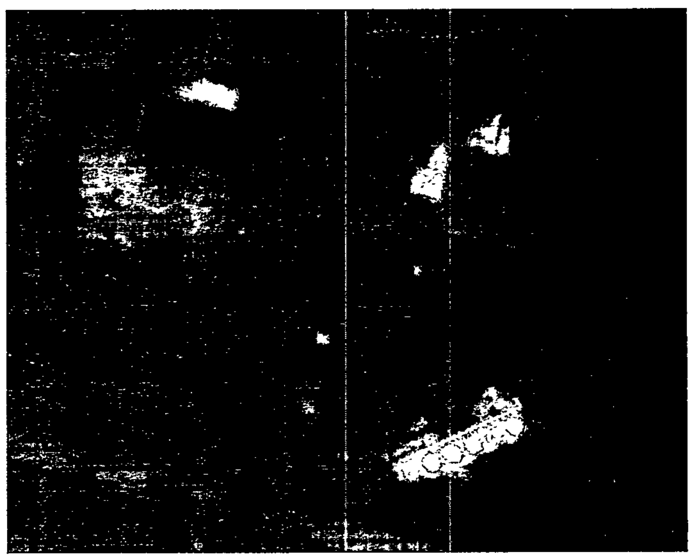
Just as important as developing new sensor technologies to monitor proliferation activities is developing systems that aid in the interpretation of the vast amounts of data collected by such sensors. Idaho National Engineering Laboratory (INEL) developed a system to identify targets of interest as part of INEL's contribution to the AMPS Program.

The automatic target recognition (ATR) system is designed to find targets in digitized images in a very general sense. The ATR system is presented with one or more images and it identifies whether or not there is a target and where the target is. Targets could be trucks and airplanes, traditional military targets. In the ATR system, "target" encompasses a broader meaning—a target is anything recognizable in the image data. For example, a target could be a golf ball or a river, a crack in a structure that emits heat, or an area of chemical contamination on the ground.

Initial experiments with AMPS data examined the idea of identifying nuclear reactors through detectable indicators such as cooling towers and gas effluent stacks. Data sets were acquired flying over INEL's test reactors, a chemical processing plant, a radioactive-waste management complex, and cooling towers and effluent stacks at sites near Richland, Washington. The data collected at Richland confirmed the ATR system's ability to handle real-world data with large, multiband images and to find cooling-tower targets.

Besides algorithms and software, INEL has also developed two prototype hardware systems. This was necessary because of the large volumes of information that an AMPS flight provides (some of the AMPS images comprise more than 10 million pixels) and also because of the need to process these large data sets in real time. Potential applications of the ATR system include locating underground structures via temperature variations on the surface or by detecting gas effluents, scanning for signatures characteristic of rocket emissions or of different types of explosions, and, of course, finding treaty-limited items in large amounts of surveillance data.

▲ **Figure 1.** A near-infrared image (1 micron) of part of the Test Reactor Area at Idaho National Engineering Laboratory shows some discharge from six towers (dark cir-



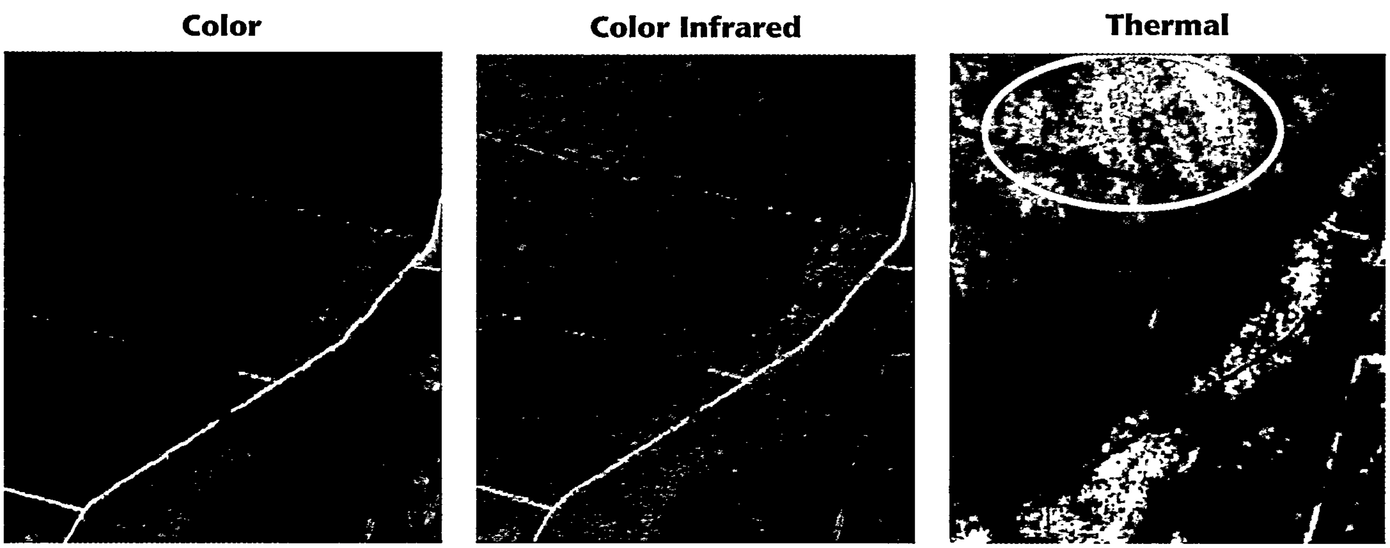
▲ **Figure 2.** Comparing the first image with a thermal infrared image (~10 microns) reveals additional information. The warm areas appear bright, including the now-whitened cooling towers and part of the nuclear reactor building itself.

Identifying Features in a Littoral Zone

The U.S. Marine Corps requested AMPS images of various sites within the U.S.M.C. base at Camp Lejuene, North Carolina and at an aircraft graveyard at Cherry Point, North Carolina. The Marines were interested in creating a data set to train image analysts. One relatively new training issue is the handling of data sent via modem. The AMPS infrared images are also useful in training photo-interpreters. Another area where multisensor data can augment existing information is battlefield intelligence, filling gaps in the database of a particular area. The AMPS sensors can also determine the effectiveness of camouflage and cover deception.

In addition to these tasks, the Marine Corps is becomingly increasingly interested in using multispectral images to detect and monitor enemy activities in the littoral zone (where land meets the sea). The large-format photographs can identify difficult landing spots and potential hazards. Color, infrared, and thermal data can further distinguish land and coastal features between those made by people.

▲ **Figure 1.** An aerial photograph of the Marine base at Camp Lejuene, North Carolina, clearly shows the base outline, sand movement, and current flow, all factors to be considered in landing military personnel on a beach.

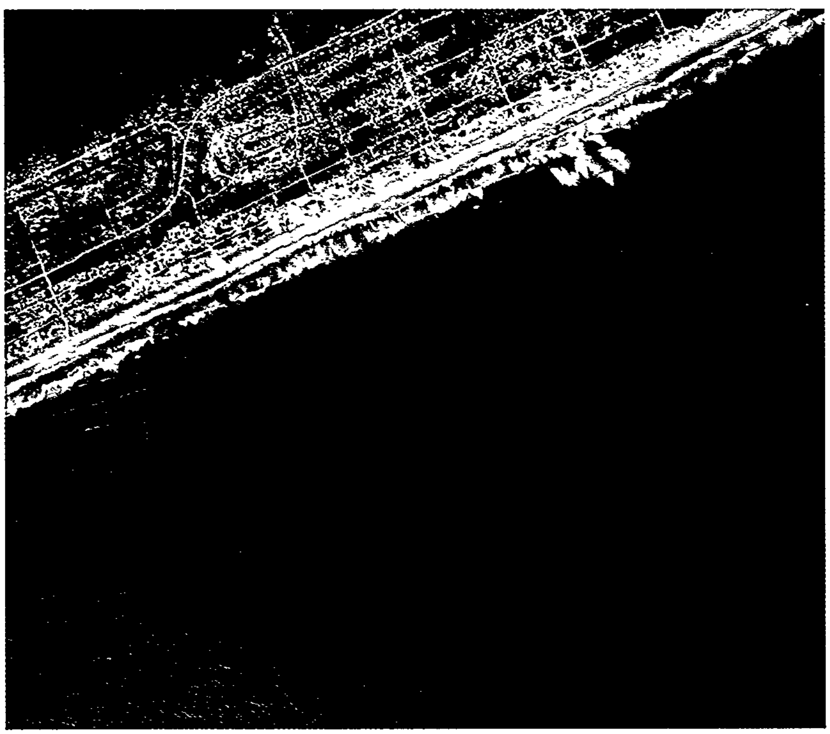


▲ **Figure 2.** These three multispectral images depict three different themes. The image on the far left shows what the landscape looks like to the human eye. The center color-infrared composite can distinguish vegetation types. The black-and-white thermal image on the far right adds information about soil moisture. Also, we can see differences between natural and man-made features: a natural drainage pattern (blue arrow), man-made dikes (red arrows), and splayed thermal patterns usually associated with all-terrain vehicle traffic (yellow circle).

Studying Nearshore and Coastal Oceanography

Two oceanographic field experiments in the nearshore coastal waters off North Carolina provided an excellent opportunity to apply the AMPS sensors to a variety of oceanographic processes. The DUCK '94 nearshore experiment involved 100 scientists and technicians from 15 different North American and European universities and 3 U.S. government agencies, with funding provided by the Office of Naval Research, Army Corps of Engineers, U.S. Geological Survey, and the Naval Research Laboratory. During August and October, 1994, these teams converged on the Army Corps of Engineers Field Research Facility at Duck, North Carolina. In fact, 35 distinct experiments took place simultaneously and in one location during DUCK '94. Nearly 500 instruments were deployed, many collecting data around the clock, making this the largest nearshore field experiment in history.

▼ **Figure 1.** Large-format aerial photo of Duck, North Carolina shows the sediment drifting off the beach, defining wave action near the surf zone.



The relatively straight, uninterrupted coastline and broad continental shelf is an excellent location to study wave-transformation processes, sediment transport, and surfzone hydrodynamics. Coupled with the DUCK '94 was the Coastal Ocean Processes (CoOP) experiment, funded by the National Science Foundation, that examined compelling research questions on the biology, physical oceanography, and geology of the inner continental shelf. Remote sensing, and in particular the diversity of the AMPS sensors, was extremely well-suited to all these experiments, providing expanded spatial coverage, interconnectivity between dispersed instrument locations, and the ability to examine a broad variety of variables measured simultaneously.

It is essential to understand the role of waves in nearshore hydrodynamic processes. As a distantly generated swell crosses the continental shelf and ultimately gives up its energy within the surfzone, a variety of processes such as refraction, diffraction, and non-linear energy transfer may take place. The AMPS SAR (Pod 1) offers a means of studying these transformation processes over a large area. Wave buoys, moored pressure gauges, and current meters supply continuous temporal information at fixed locations only. SAR, however, supplies information essentially continuous in space but representative of only a single point in time. Thus, moored oceanographic instruments and AMPS sensors are distinctly complementary. Continued applications of combined SAR and *in situ* sensors should greatly enhance understanding of wave-transformation processes.

A similar coupling of *in situ* point measurements and remote sensing is useful to understanding sediment transport. Instruments placed within the surfzone measure the concentration of sediment particles, and when linked to water motion, can study the transport of sand and the associated changes to the shoreline. As in wave studies, a limitation of such instruments—which make precise measurements over a small sample volume—is the assumption that conditions between sensors are similar or at least predictable. Variability in bathymetry and wave conditions may sometimes lead to inhomogeneity in sediment transport, as in the case of narrow, seaward-directed sediment plumes. Detection of such plumes by relying solely on *in situ* sensors would require an extremely dense instrument network. Thus, the single large-format camera photograph taken with the AMPS MSI pod (see Fig. 1), combined with proper geo-referencing, is a great asset in interpreting the complex point measurements.

The Coastal Ocean Processes (CoOP) experiment investigated the transport and settlement of invertebrate larvae (the planktonic juvenile stages of animals that live on the bottom as adults) along the inner shelf. Understanding the distributions of these larvae requires knowledge both of the responses of the organisms to water properties (temperature, salinity, etc.) within their environment and of the hydrodynamics and sediment transport. Complex oceanographic events, such as upwelling and water-mass intrusion, make such studies vastly more complicated. One such example is the southward extrusion of the Chesapeake Bay outflow. High rainfalls in the Bays' drainage basins produce a strong flow of reduced-salinity water that moves into coastal regions. Shipboard-surveying techniques to distinguish between this water mass and the more typical coastal water mass are time-consuming and costly. Geo-referenced AMPS sensors, however, such as the multispectral CASI and, to a surprising degree, the large-format camera, provide a clear depiction of this boundary (see Fig. 2).

Analysis of the data collected both in the water and overhead during the DUCK '94 and CoOP experiments is ongoing. Planning for the next nearshore experiment, SANDYDUCK, to take place in 1997, is underway. The partnership between *in situ* measurements and remote sensing provides significant promise in advancing our understanding of many important oceanographic processes within the coastal region. •

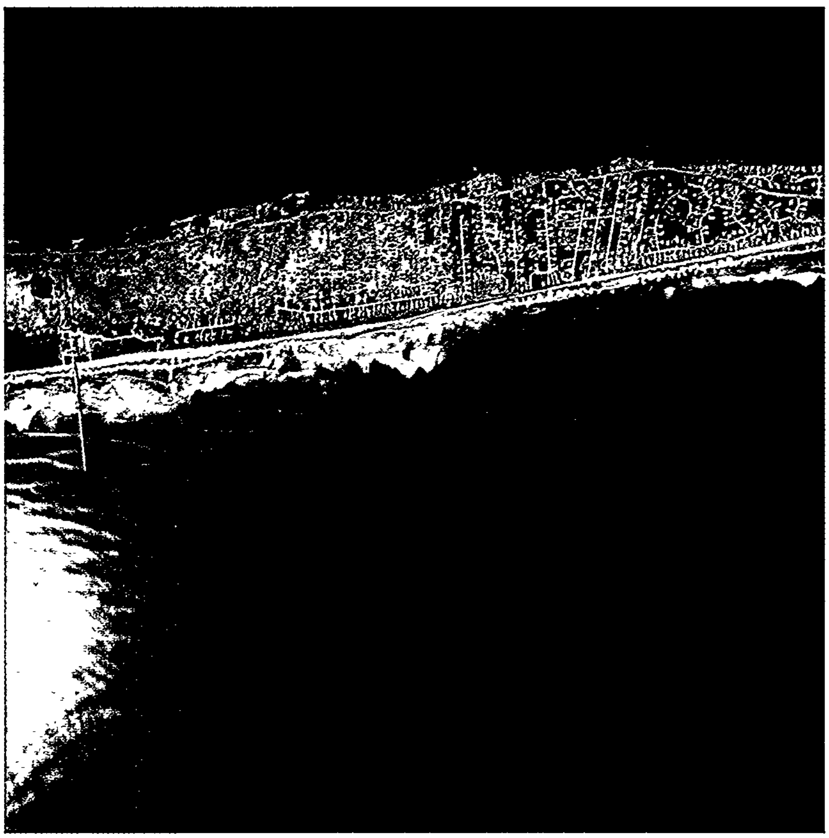


Figure 2. Large-format photo aerial above Duck, North Carolina show the intersection of green and brown water, indicating reduced-salinity water mixing with coastal water and sediments.

Planning an AMPS mission

An AMPS Mission requires a great deal of coordination between many groups, involved in both the collection and the final use of the collected data. The person responsible for ensuring the success of the AMPS Mission, and the coordination that makes it possible, is the Chief Mission Scientist (CMS). The CMS is often one of the requesters of the AMPS data that will be collected during the mission. This is highly beneficial because one of the first requirements in planning any remote-sensing experiment—and especially a multisensor remote-sensing experiment—is a solid understanding of the data required by the ultimate users.

Once a good understanding of the users' requirements is developed, an iterative process is begun by the CMS, the data requesters, and the experts from the DOE national laboratories. These people develop a flight schedule that balances the desires of the data users, the

Figure 1. This image of the Rio Grande River shows the usefulness of combining several sensors and the resulting data that increases the understanding of a particular problem. The red color indicates water uptake by the vegetation in the area; recently irrigated fields are bright red. This type of information is helpful in determining water use. Also, shallow areas in the Rio Grande might indicate a need for dredging the channel to keep the river flowing freely.

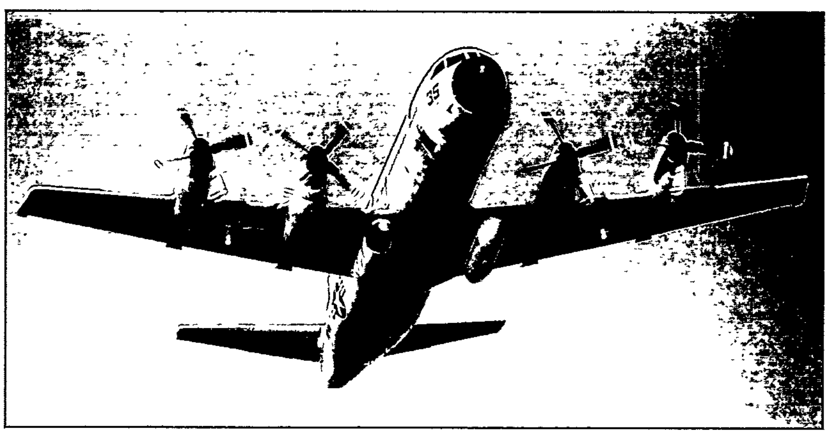
natural environment, and logistical limitations. This often involves a learning process for all involved. The data requesters know what problem needs to be solved—for example, whether it is detecting trace materials in the wastes leaving an industrial site or detecting changes in natural vegetation associated with buried materials. They also provide the real-world background against which the mission flight series must be developed. If a particular target is only found along ocean coasts, it is important to carry out the flight series in similar locations. The knowledge of the data requesters is shared with the AMPS Program through data request forms and clarifying meetings. This allows AMPS Program participants to learn more about emerging problems that may be addressed in the future with remote sensing.

The technical experts from the DOE national laboratories bring world-class expertise in remote sensing with their individual sensor pods. This expertise is shared with the data requesters during the development of the data requests and flight series schedule. The personnel at Sandia National Laboratories, DOE Remote Sensing Laboratory, Pacific Northwest Laboratory, Lawrence Livermore National Laboratory, and Savannah River Technology Center are a ready reference pool from which data requesters can learn important options inherent in the multiple sensors contained in the AMPS pods and the optimal methods for their use. This includes the important consideration of the natural environment. While some sensors, such as the Synthetic Aperture Radar, are fairly immune to meteorological conditions and time of day, others require specific conditions. Additionally, specific targets may require unique solar illumination angles or other environmental conditions. This education in basic, and more advanced remote sensing, can be invaluable to program managers who believe that remote sensing is essential to the success of their programs but do not have the same level of experience and expertise as the experts within the AMPS program.

The final group that interacts with the CMS in the development of the flight schedule includes all the logistical personnel. This mainly, but not exclusively, involves the U.S. Navy (and soon, NOAA) flight personnel who operate the P-3 aircraft that have been modified to carry the AMPS pods. These personnel are stationed at the Naval Air Weapons Command, Point Mugu, California, and at the Naval Research Laboratory in Washington, D.C. The flight crews get the clearances to operate the aircraft in the requested target areas and ensure that all flight operations are performed in a safe manner.

Once the flight schedule has been developed, a Mission Plan is prepared outlining the goals of the mission flight series, the targets that will be imaged during the series, the schedule by which those targets will be covered, and the agencies that have requested the data. The Mission Plan is reviewed by an interagency panel to ensure that the maximum benefit is derived from the use of the AMPS sensors and the Navy aircraft. The interagency panel is formed to match the location of the proposed flight series, for instance including NOAA for coastal areas and the Department of Agriculture for cultivated locations. The panel can request the addition of new targets, suggest changes in the targets already scheduled for imaging or can advise their own agencies of the opportunity to mount a cooperative ground-truth effort within one of the pre-arranged target areas. Once the interagency panel has reviewed the mission plan, the planning is completed and the AMPS Mission flight series can begin. •

Figure 2. Closeup view of the P-3 Orion in flight with the SAR and MSI pods mounted underneath.

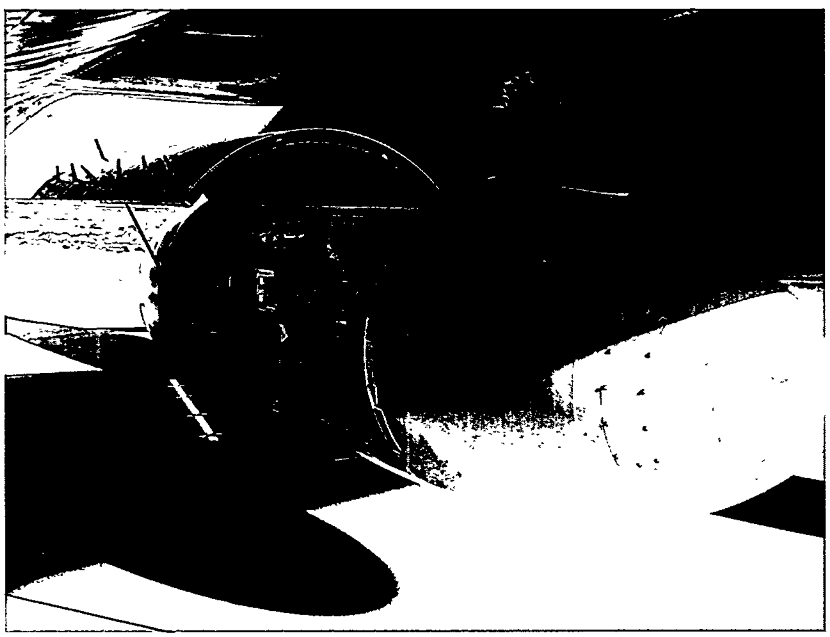


SAR pod produces images day or night, rain or shine

Pod 1 is dedicated to the Synthetic Aperture Radar (SAR), fielded by Sandia National Laboratories (SNL). The side-looking SAR is an airborne radar that forms images by sending electromagnetic energy to the ground and receiving echoes of that energy reflected back. As a result, the remote-sensing SAR produces high-resolution, two-dimensional images of the ground. The AMPS SAR operates in the Ku-band (15 gigahertz) portion of the electromagnetic spectrum, forming the images in real time. Images resulting from the computations are stored digitally within the pod.

The SAR uses the forward motion of the aircraft to produce the equivalent of a long antenna, resulting in better image resolution. The SAR transmits many pulses of electromagnetic energy along the flight path, gathers the target echoes, and stores them in digital form. An on-board digital signal processor performs a complex set of computations on these signals to create images with a resolution of 1–3 meters, regardless of the range to the target area. SNL's unique processing algorithms allow image formation to occur in real time. The imagery, as well as the raw digitized radar echoes, are stored on tape in the pod for additional ground processing if desired. However, with only a brightness and contrast adjustment, the SAR imagery is ready for use as soon as it exits the signal processor.

Figure 1. SAR pod.



The AMPS SAR can operate in two modes. In the strip-map mode, the system forms a continuous strip of images as the aircraft moves along its flight track. Adjacent strip-maps can be blended together into a seamless mosaic, thus forming a complete picture of a given area. In the spotlight mode, the antenna is pointed at a specific area on the ground for a long period of time, resulting in precise target images with very high resolution.

The SAR uses a complete global-positioning-satellite-aided inertial navigation system, providing GPS information to the pilot via a display mounted in the cockpit panel.

The SAR can produce images day or night, even through cloud cover and precipitation. Therefore, radar images can be produced when conventional film photography, videography, and other optical sensors cannot be used. SAR images can precisely locate objects on the ground or monitor a wide variety of parameters—for example, verifying ground features to facilitate land use, or surveying coastal erosion and soil moisture, or tracking the boundaries of oil spills.

Development of the AMPS SAR will continue in 1996. Completing work begun this year, the AMPS SAR will be able to collect high-resolution, *three-dimensional images.* This new SAR, being developed by SNL, is called Interferometric SAR (IFSAR) and will use two radar antennas co-located in the front of the pod. The images resulting from IFSAR will include high-quality terrain elevation maps in addition to current strip-map and spotlight imagery. The sample image in Fig. 3 demonstrates the IFSAR, showing an actual image of Interstate 25 crossing the Black Mesa area just south of Albuquerque, New Mexico. •

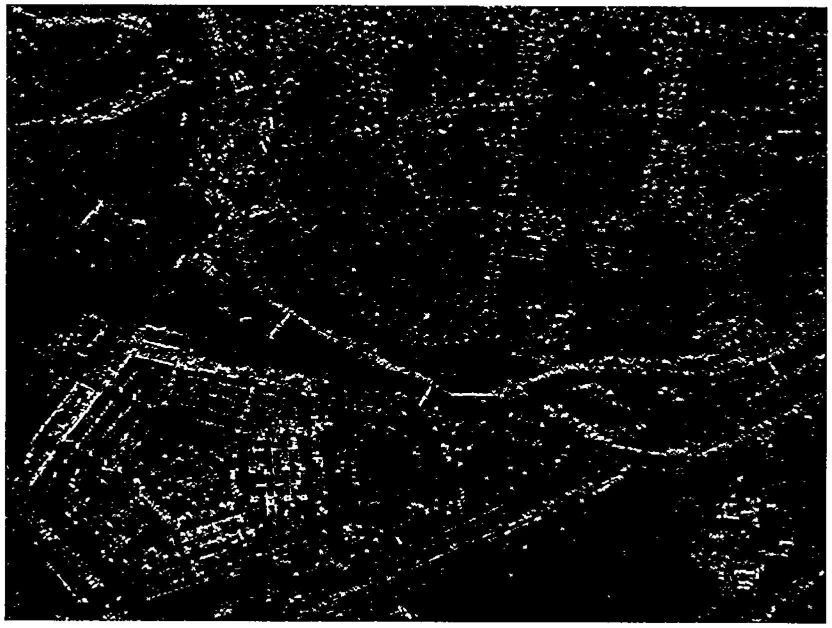


Figure 2. This aerial view of the Pentagon and Arlington National Cemetery was created by the Synthetic Aperture Radar (SAR) pod.

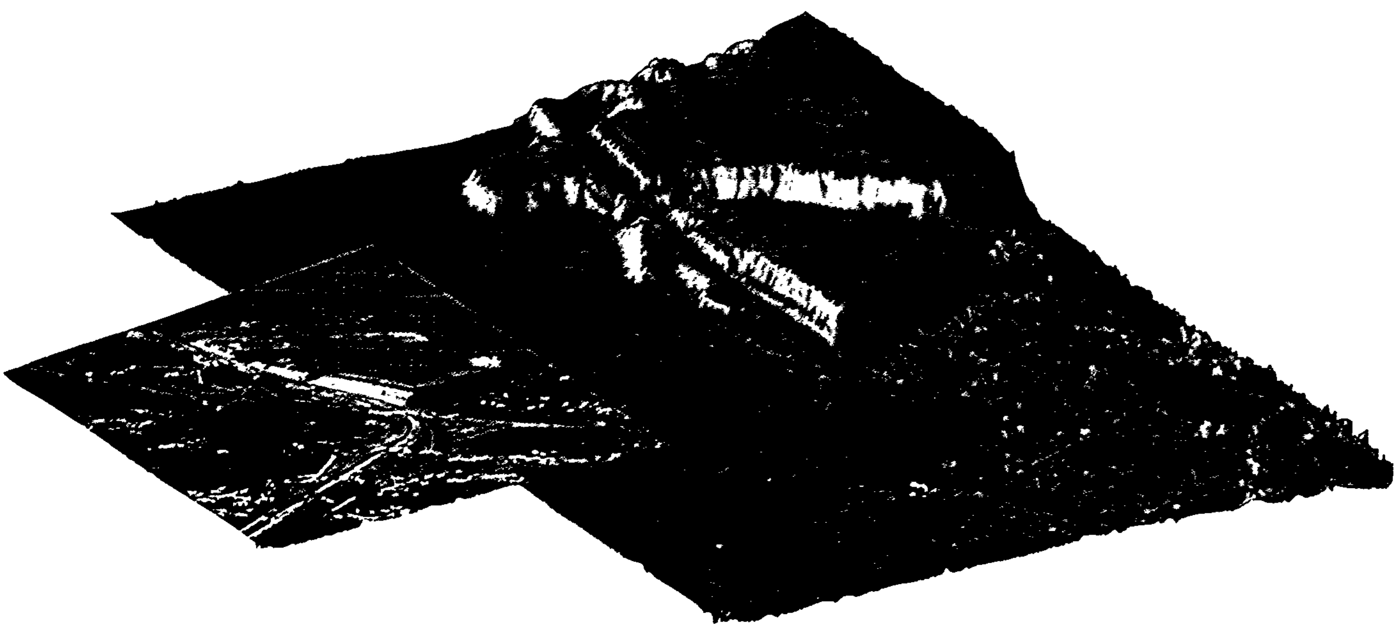
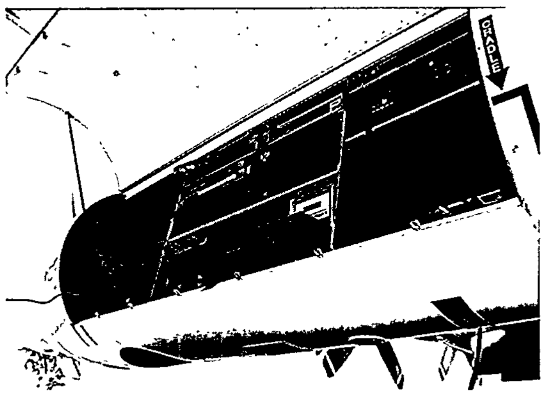


Figure 3. A sample image from Sandia National Laboratories' next AMPS development project (slated for completion in 1996) demonstrates the three-dimensional potential of Interferometric SAR (IFSAR). Shown in the image is the Black Mesa alongside Interstate I-25 and U.S.-85, south of Albuquerque, New Mexico, 22 December 1994.

MSI pod combines data from multiple sensors

Six imaging sensors are housed in RSL's Multisensor Imaging (MSI) pod: a large-format film camera, a thermal imager, a multispectral scanner, a hyperspectral imager, a low-light video camera, and a high-resolution video camera. All of the instruments face the ground through ports and windows. An operator in the aircraft controls each instrument. All data collected by the six imaging sensors is calibrated to the same time and geographic location.

Figure 1. MSI POD.



Data from the six sensors in the MSI pod are combined with the images from the Synthetic Aperture Radar (SAR) pod to create a data mosaic, giving us a greater amount of information than would be obtained from each sensor individually.

In Fig. 2, from left to middle, we see an aerial picture from a Wild Heerbrugg RC-30 camera, an image from a Daedalus 3000 multispectral scanner, and a hyperspectral image from a Compact Airborne Spectrographic Imager (CASI).

Directly below the CASI image are frames from the Sony DXC-750 video camera and a thermal image from the Barr & Stroud thermal imager.

To the left of the CASI/Sony/Barr & Stroud strip in the middle of the figure is another multispectral scanner image from the Daedalus. And the final strip in the mosaic is an image from the SAR pod. All data was collected during the same flight at the same time.

The geographic location of the data mosaic is the area around the Memorial Bridge in Washington, D.C.

The four black-and-white images in Fig. 3 demonstrate the effect of pixel resolution on interpreting an image. The same image acquired with the same scanner at four increasing altitudes would yield data with decreasing image content. It is relatively easy with 1- and 2.5-meter data to identify, recognize, and inventory the

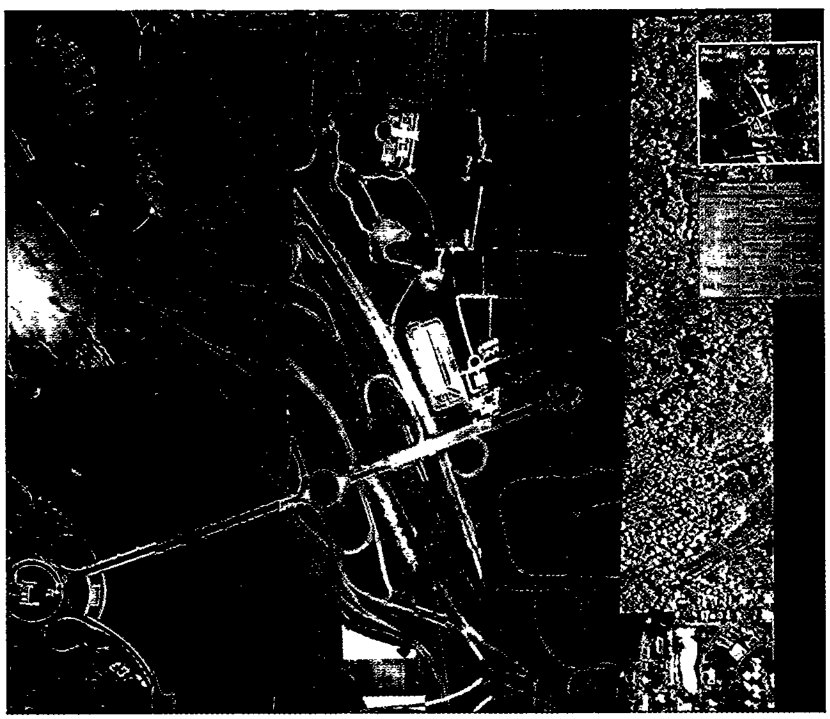


Figure 2. Mosaic image of data from the sensors in RSL's MSI Pod 2 and SNL's SAR Pod 1.

ships at the Norfolk Naval Shipyard. However, at the 5-meter resolution, the two ships in the middle of the image merge and are indistinguishable as separate ships. In the 10-meter data set, the features become amorphous blobs and are impossible to identify. For these data sets, image analysts would identify 7 ships in the 1- and 2.5-meter data, 5 in the 5-meter data, and 3 in the 10-meter data, at most.

The three-image mosaic in Fig. 4 was created by digitizing two aerial photographs, co-registering them, and merging them

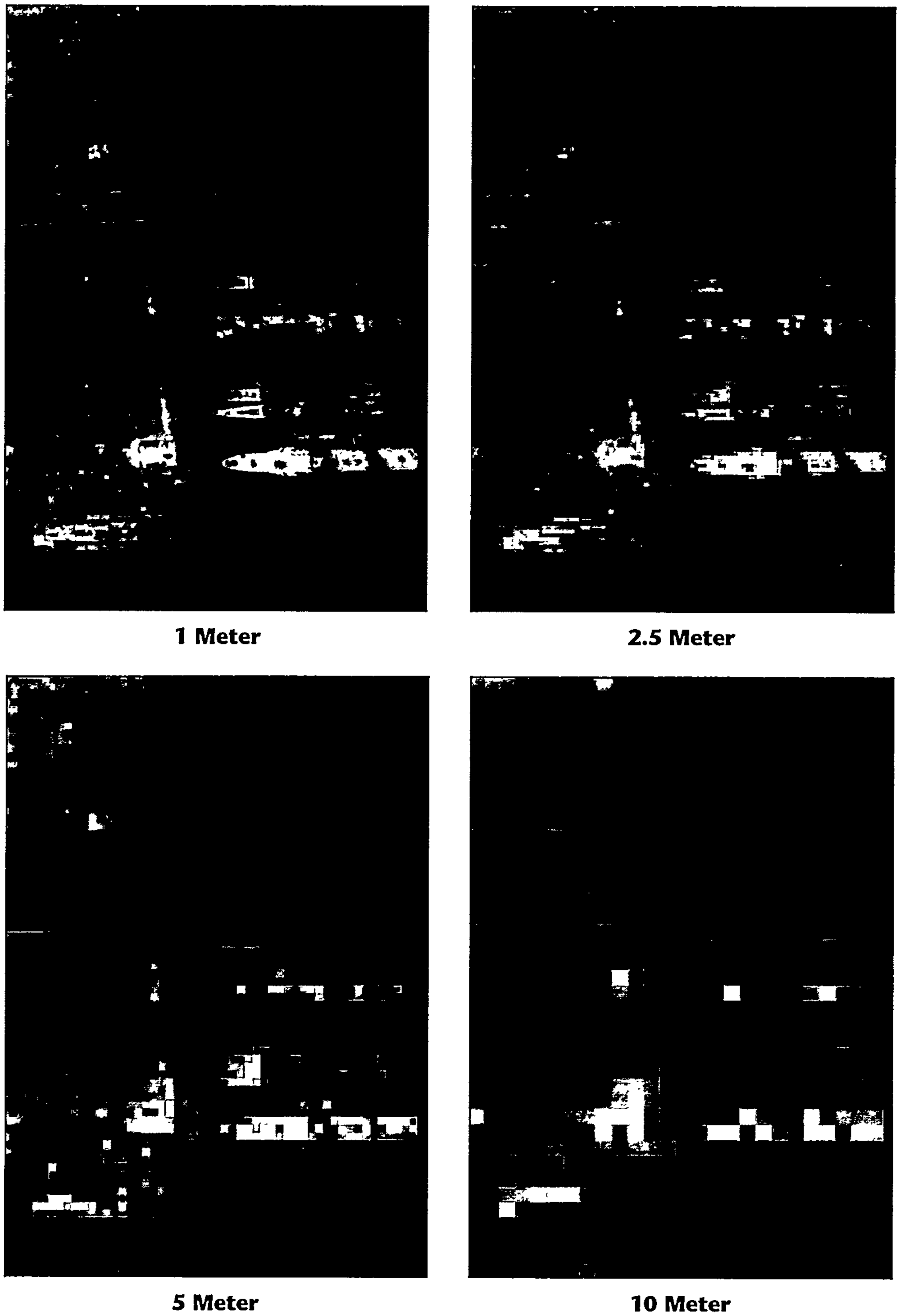
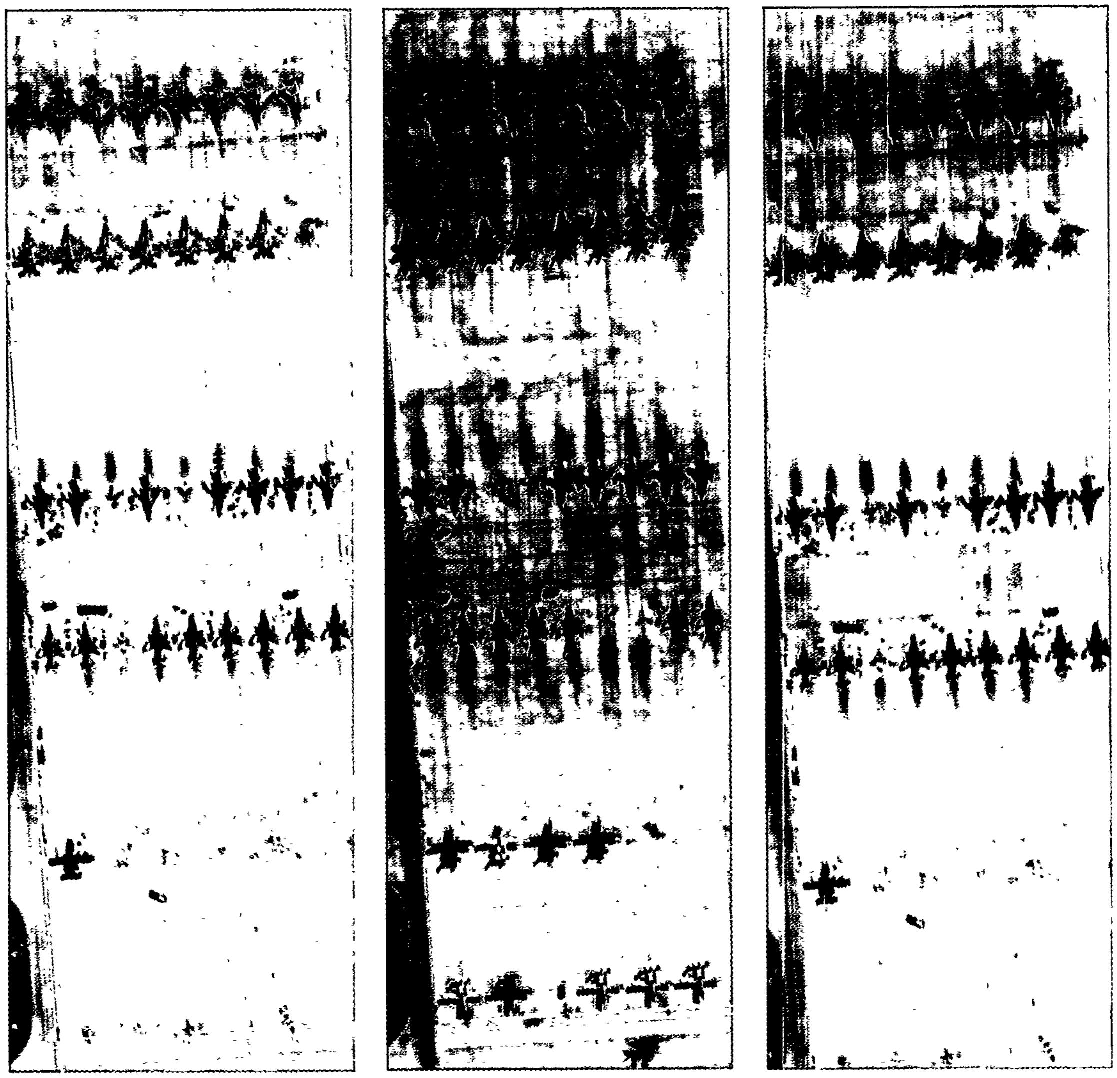


Figure 3. Norfolk Naval Shipyard, taken with the thermal imager.

into the third image (far right). In the merged photo, planes that were present on June 22 but had left by June 24 are shaded purple. Planes that were not present on June 22 but had been parked by June 24 are shaded yellow. Unfortunately, shadows cast by some of the planes added a "halo" effect that is quite noticeable. ●

Figure 4. Images of the aircraft area at Nellis AFB in Nevada taken with the large-format film camera and merged together in the far right picture.



ESI pod will analyze emissions and effluents

The Effluent Species Identification (ESI) pod is currently undergoing aerodynamic and flight-qualification tests. This third pod in the series is designed to identify the chemicals present in samples taken from the air. The aircraft will fly over a target site—for example, a chemical production plant—and collect emissions from the stacks. The effluent samples are then analyzed in mini-laboratories inside the pod or are captured and preserved for later analysis.

The ESI pod consists of a target tracking system, a radionuclide analyzer, a mass spectrometer, an Echelle grating spectrometer, and an aerial atmosphere sampler. The pod is designed with modularity in mind for future upgrades and easy changes to new equipment. This limits the modifications required for the aircraft. In addition, position data and time references from a global positioning satellite (GPS) receiver in the aircraft are provided to the sensors to key the data geographically.

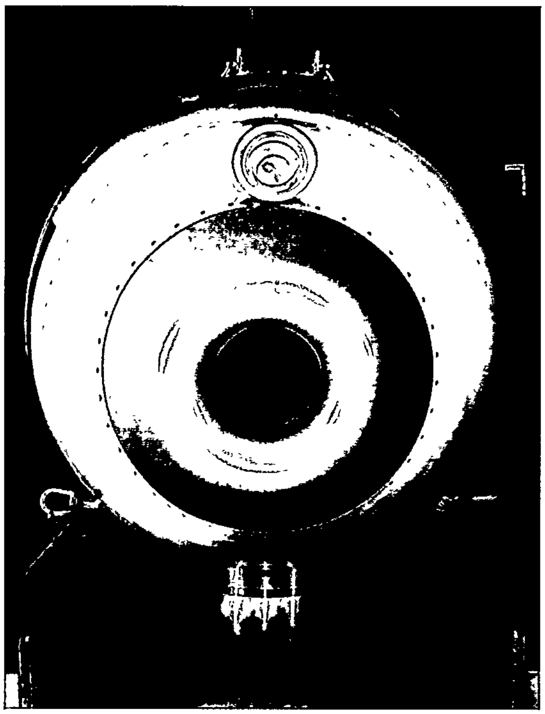


Figure 1. A look at the forward end of Pod 3, down the air intake tubes. Also seen is the placeholder for the target tracking system.

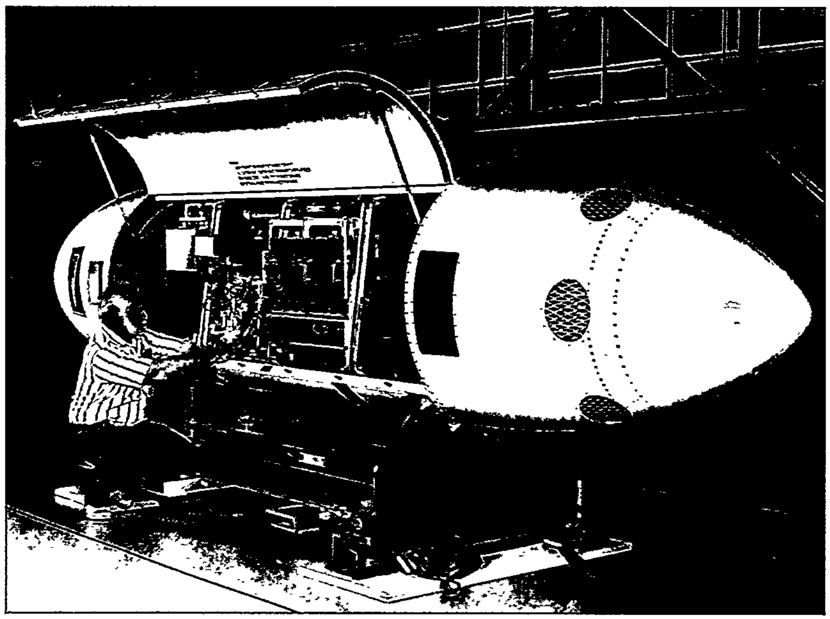
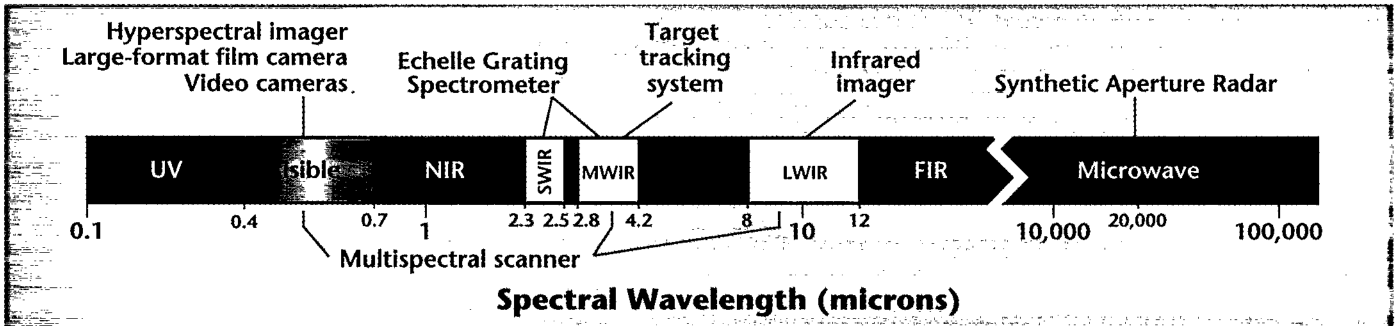
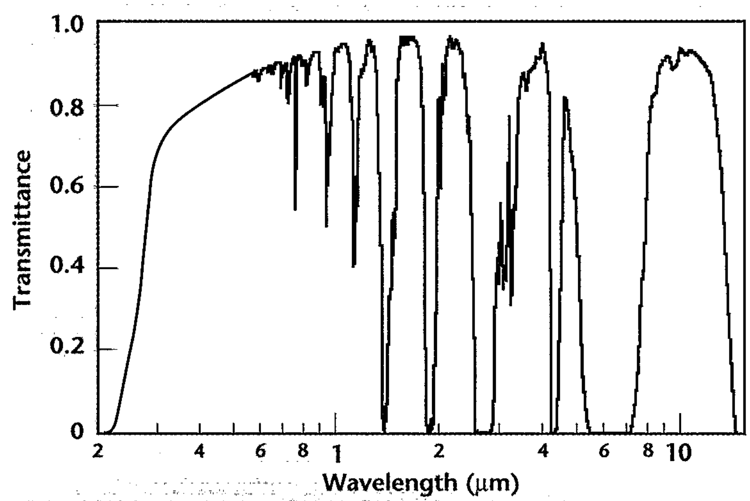


Figure 2. The Effluent Species Identification pod, currently under construction, with the ion trap mass spectrometer, radionuclide analyzer, and aerial atmosphere sampler in place.



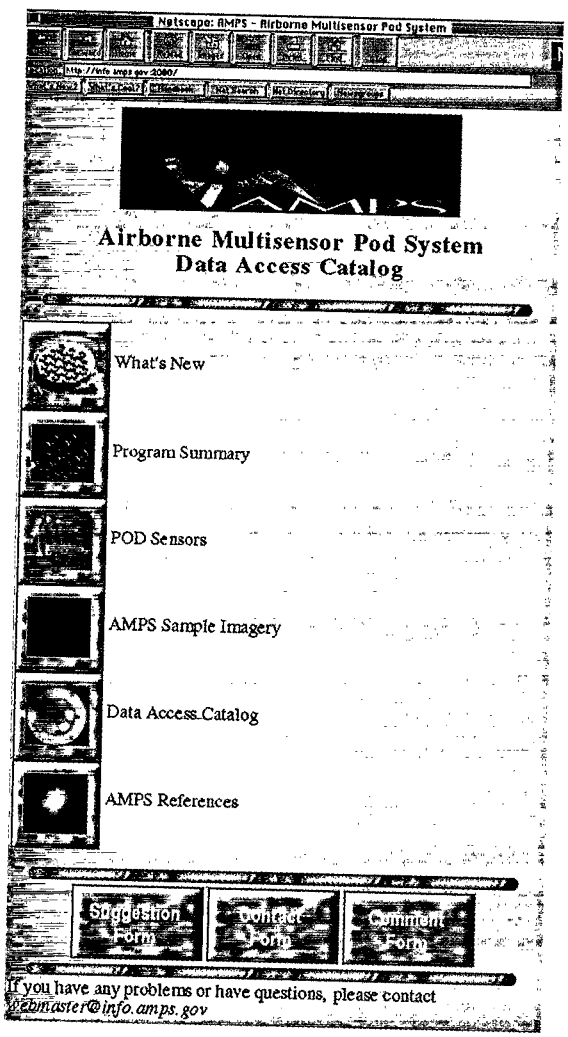
The spectral ranges of the various instruments in Pods 1, 2, and 3 are illustrated here. From visible light to the long-wave infrared and into the microwave region, the AMPS sensors cover a broad range of wavelengths. The covered bands correspond to "transmission windows"—wavelength regions in which the atmosphere is transparent, thus permitting remote monitoring to be made from an airborne platform. The ability to combine imagery from such a broad range of wavelengths is one of the major strengths of AMPS.



Accessing AMPS Information on the Internet

Current AMPS information, data specifications, actual data, and a data catalog are directly available through the Internet using the AMPS DATA Access Catalog (ADAC). ADAC is accessed using Internet browsers such as Mosaic™ or Netscape™ referencing the home page. Internet address: *http://www.amps.gov/.*

The AMPS home page is the first step to AMPS information, presenting a list of the basic AMPS features available through the network. A brief summary of each major feature is shown along with some examples.



The **What's New** page presents information on the release of AMPS data, software, and upcoming missions. The information usually includes a description and schedule. **Program Summary** contains information related to the objectives and background of AMPS, and a list of acronyms.

Pod Sensors contains descriptions of all sensor systems to date for all three pods. **Sample Imagery** lists the images according to geographic location and the mission number.

The **Data Access Catalog** allows users to preview data and order copies. Data may be transferred electronically on-line over the Internet, or through the mail on 8mm tape or CD-ROM. Video data is provided on S-VHS or standard VHS tape.

AMPS References contains several AMPS-related fields that tie in Internet statistics, instrument specifications, data formats, and personnel and facilities involved in the AMPS Program.

The **Suggestion Form** allows users to recommend improvements of the ADAC or to propose data collections of specific interest. The **Contact Form** places users' names on the mailing list. And the **Comment Form** is for comments, complaints, or requests by any AMPS participant. •

For more information on accessing AMPS information and data on the Internet, contact—

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