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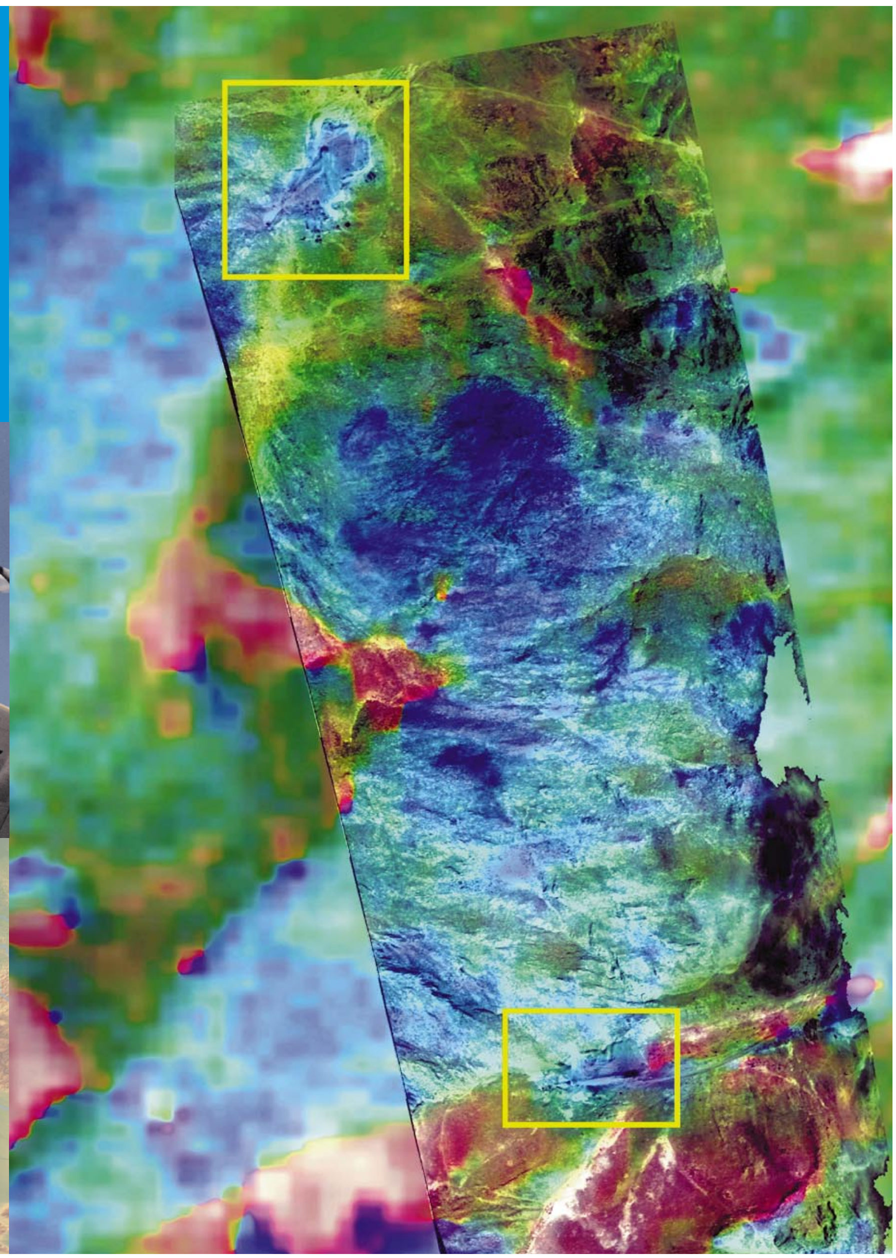
Arms Control and Nonproliferation Technologies

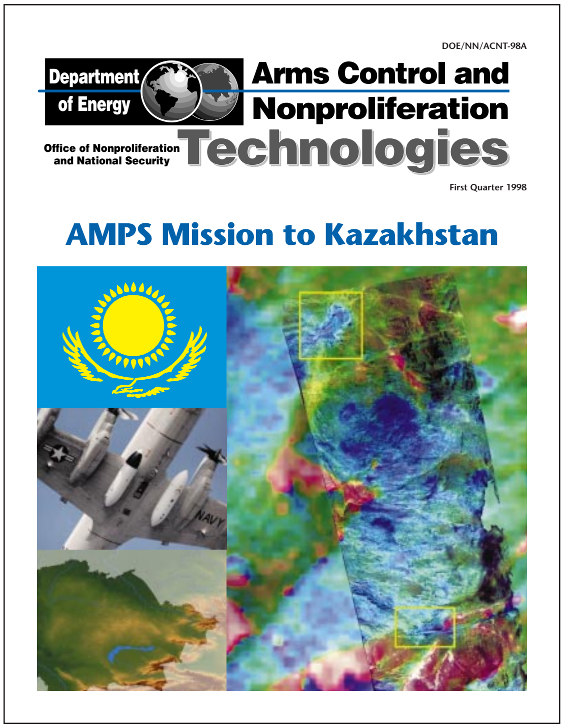
Department of Energy

Office of Nonproliferation and National Security

First Quarter 1998

AMPS Mission to Kazakhstan





About the cover

The first use of DOE remote-sensing technology, the Airborne Multisensor Pod System (AMPS) outside the U.S. occurred in July 1997 in the Republic of Kazakhstan (top left), one of many former Soviet provinces interested in developing its own natural resources. The AMPS pods mounted underneath the plane (middle left) contain the sensors. As the plane flies over the Kazakhstani terrain (lower left), data are collected from the various sensors. These data are then analyzed to create a detailed image (right), in this case showing the distribution of vegetation in Semipalatinsk.

About This Issue–Science and Technology Agreement

On July 12, 1996, the United States Department of Energy, in partnership with Earth Search Sciences, Inc., signed an accord with the Kazakhstan Ministry of Science to use remote-sensing technology developed by the U.S. in the Republic of Kazakhstan. This mutually beneficial agreement supported U.S. goals for nuclear nonproliferation and Kazakhstan's goals for infrastructure and economic development. This issue of Arms Control and Nonproliferation Technologies highlights this cooperative venture, providing examples of the data collected during the June–July 1997 mission.

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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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Arms Control and Nonproliferation Technologies

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Airborne Multisensor Pod System (AMPS)

The Airborne Multisensor Pod System (AMPS) was profiled in the second quarter 1995 issue of *Arms Control and Nonproliferation Technologies*, outlining its development to date. At that time, the collaboration between several DOE national laboratories had produced three pods containing prototype remote sensors. These pods were flown over various parts of the U.S. gathering data and exploring ways in which remote-sensing technology could be used beyond the original military mission of the development program.

The Office of Nonproliferation and National Security, which supports U.S. nonproliferation policies, had the design, development, and implementation of AMPS as one of its projects. The AMPS program's primary objective is the collection of data from multiple sensors for multisensor data fusion research. Secondary objectives include sensor development and technology demonstrations.

AMPS comprises three DOE-owned, wing-mounted sensor pods flown on modified U.S. Navy P-3 Orion aircraft. To date, a total of nine missions have flown over the U.S. and Kazakhstan. Although mainly directed at nonproliferation applications, these missions have also supported environmental monitoring, agricultural assessment, infrastructure analysis and development, and land–water management.

Pictured above: Closeup view of the P-3 Orion in flight with the Synthetic Aperture Radar and Multisensor Identification pods mounted underneath. (inset) VIP tour of the mission's plane at Almaty airport, Kazakhstan.

Mission to Kazakhstan (June–July 1997)

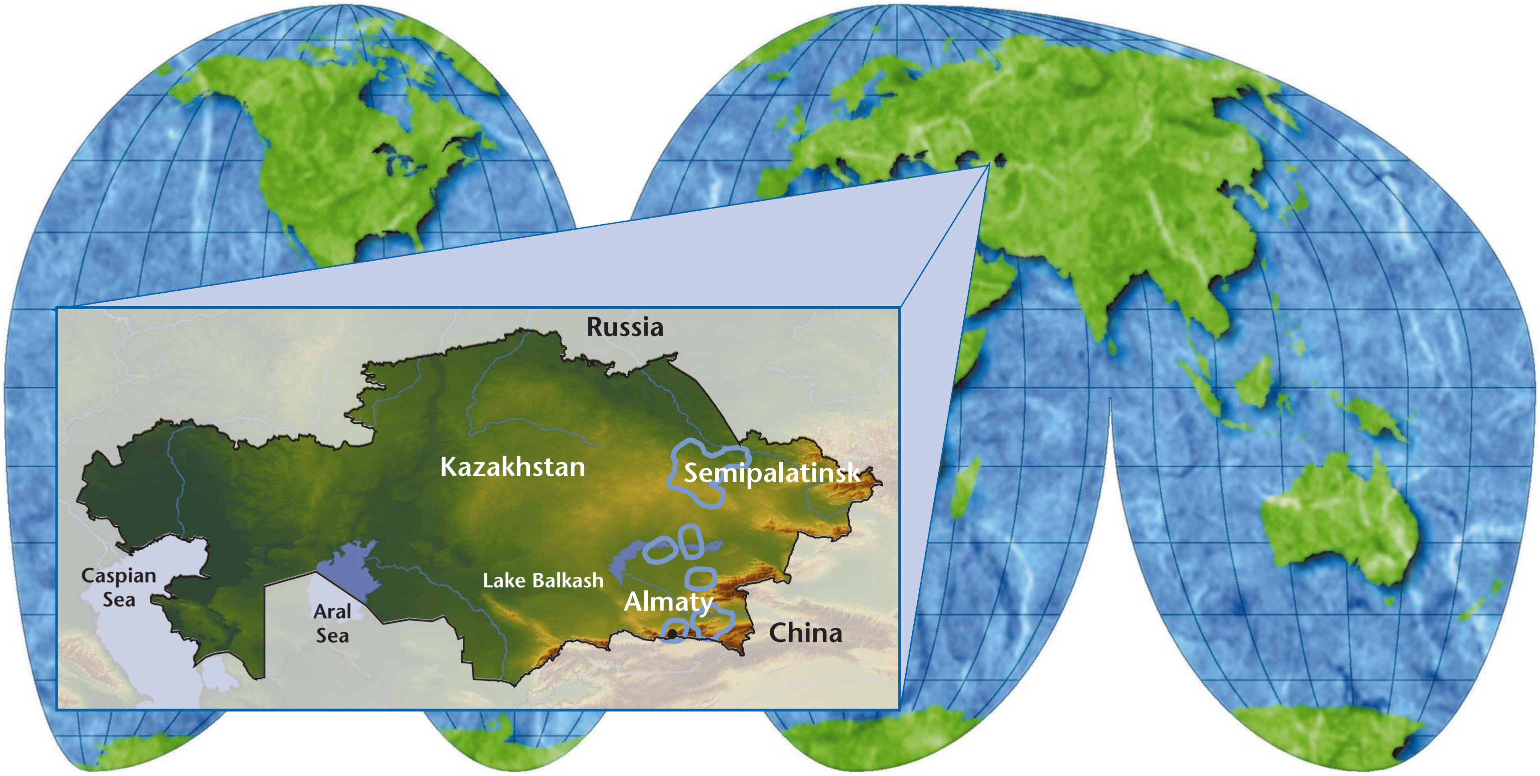
AMPS technology has been used for research within the U.S. for the last five years, further refining the suite of sensors carried by the pods. AMPS was offered for the first time outside the U.S. for a series of flights in the Republic of Kazakhstan. In addition to the AMPS sensors, Earth Search Sciences, Inc. (a mineral exploration company in McCall, Idaho) flew the Probe 1 hyperspectral sensor, and the Boeing Company (Seattle, Washington) fielded a georectification system. The primary objective of the mission to Kazakhstan was demonstrating the capabilities of state-of-the-art, remote-sensing technologies.

The basis of this collaboration between the U.S. and Kazakhstan is an intergovernmental agreement on the development of science and technology, dated February 14, 1994, and an agreement on programs of scientific research and engineering development, dated July 12, 1996, between the U.S. Department of Energy and Ministry of Science–Academy of Sciences of the Republic of Kazakhstan.

Prior to the 1997 mission, representatives from both countries met several times in Kazakhstan and the U.S. Kazakhstani and U.S. organizations were chosen to participate in the AMPS mission. Several Kazakhstani specialists were trained in the U.S. In addition, representatives from the Ministry of Defense and Security Agency were trained in the U.S. on the Navy P-3 aircraft to observe the mission during the flights to and from Kazakhstan.

The mission had a limited timeframe, so the technology demonstration was conducted in two regions of Kazakhstan—Almaty, the previous capital of Kazakhstan, and Semipalatinsk, the former Soviet Union's nuclear test site. Routes and scientific objectives of the flights were selected according to the Kazakhstani scientific research organizations and commercial enterprises and the technical capabilities of the aircraft and scientific equipment. Routes, flight time, and location of the airports had to ensure safety of the flights. Routes of the flights had to be chosen with respect to the interests of third countries. The scientific interests of the Kazakhstanis were given priority.

Pictured above: Representatives from the U.S. and Kazakhstan met over several months to determine mission objectives.



Why Kazakhstan?

The Republic of Kazakhstan is a mineral-rich country with an emerging economy and a wealth of highly skilled personnel. Kazakhstan needs to evaluate the consequences of the nuclear tests in years past near Semipalatinsk and plan their cleanup. And because of its vast mineral resources, Kazakhstan is keenly interested in exploiting advanced mineral-exploration technologies to uncover these mineral deposits, reduce exploration costs, and grow its economy by developing products and creating new jobs. Kazakhstan recognized that foreign experience and technologies would further its economic goals.

The Republic of Kazakhstan has been very open to the international community, inviting commercial investment and development. Kazakhstan provided a unique opportunity for the DOE national laboratories and U.S. private industry to demonstrate their remote-sensing technologies in a wide variety of applications. These applications covered city planning, infrastructure improvements, environmental monitoring, ecological assessments, and nonproliferation monitoring. In addition, the mission's objectives included building strong technical and political relationships, demonstrating advanced imaging technologies, and transferring remote-sensing experience and knowledge to Kazakhstani scientists.

The goodwill and cooperation between the U.S. and Kazakhstan serve both countries in achieving their policy and economic goals. The remote-sensing data from the mission to Kazakhstan will be used to improve infrastructure by helping to site new roads and railroads. Other experiments demonstrated the utility of advanced remote-sensing technology for mineral exploration, land-use planning, and environmental characterization. The mission provided valuable data for multisensor data fusion research and supports nonproliferation monitoring. DOE continues to support cooperative data analysis, train Kazakhstani scientists, and transfer computer capabilities to Kazakhstan.

Pictured above: The pods were flown over two main regions in Kazakhstan. Blue lines indicate experiment sites.

▲ The team watched the C-130 cargo unloading in Almaty.

◀ (top) The Semipalatinsk mountain range and a view (middle) from the plane of the Irtysh River and portions of the city of Semipalatinsk. (bottom) Hyperspectral image of the same river and city. Lush vegetation appears green.

Pod 1—SAR Pod. Housed in its own pod under the right wing of the aircraft, the Synthetic Aperture Radar (SAR) forms images by transmitting electromagnetic energy from the airborne pod and receiving echoes of that energy reflected from the ground. This procedure produces high-resolution, two-dimensional images, similar to conventional photographs. SAR can produce images day or night and in adverse weather, including heavy cloud cover and rain. SAR images have a number of applications, including verification, surveillance, navigation, and exploration and inventory of the earth's resources.

Pod 2—Multisensor Pod

The sensors described to the right are housed in this pod.

Large-Format Camera: The Wild Heerbrugg RC-30 is a large-format aerial camera for mapping and aerial reconnaissance. It uses a 9-1/2-inch-square film in a roll 400 feet long, resulting in a 9-x-9-inch image area per frame and 420 high-resolution images per roll. Photos are shot at 3-second intervals during the flight, permitting overlapping coverage of the ground at aircraft speeds of 250 knots or slower and at 1,000 feet above ground level. Ground coverage can be as small as a 750-foot square at a 1,000 feet up or as wide as a 21-mile square area at 43,000 feet.

Thermal Imager: The Agema forms pictures from heat-generating objects. Operating much like a video camera, the Agema is sensitive to only thermal infrared energy. Its lens is a dual-focus germanium telescope offering two sizes of magnification, 2.5x or 9X.

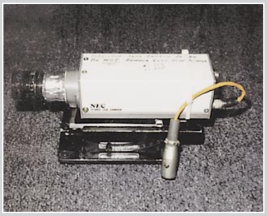
◀ Sensors located in special pods underneath the wings of a modified P-3 Orion collect information while flying over an area of interest.

Color Video Camera: The Sony DXC-750 CCD video camera is a high-resolution color video camera used to record in daylight. The video can be reviewed and duplicated immediately after each flight. This camera is particularly well suited for aircraft operations because it is capable of shutter speeds of up to 1/10,000 of a second.

Hyperspectral Imager: The Compact Airborne Spectrographic Imager (CASI) is a passive, electro-optical imaging spectrometer, designed to detect and digitally record reflected visible and near-infrared electromagnetic energy in narrow wave bands. Sometimes referred to as an hyperspectral imager, this instrument can acquire data over spectral bands as narrow as 1.8 nanometers.

Daedalus Airborne Multispectral Scanner: The Airborne Multispectral Scanner (AMS) is a dual-optical-port multispectral scanner that simultaneously records up to six spectral channels directly onto 8mm digital tape. The AMS calibrates thermal information for determining radiometric temperature relationships between various remote-sensing applications.

Probe 1 Hyperspectral Imager: Probe 1 hyperspectral imager is an active, optical-scanning system that generates a raster scan image of the path below the aircraft, resulting in higher resolution images than CASI. The instrument functions as an imaging spectrometer for reflected sunlight (in the middle and thermal infrared regions) and has 128 spectral channels.



Autonomous Georectrification System: Boeing's Autonomous Georectification System, used with the Probe 1 hyperspectral imager, correlates motion vectors with the roll, pitch, and yaw of the plane, correcting pointing errors.

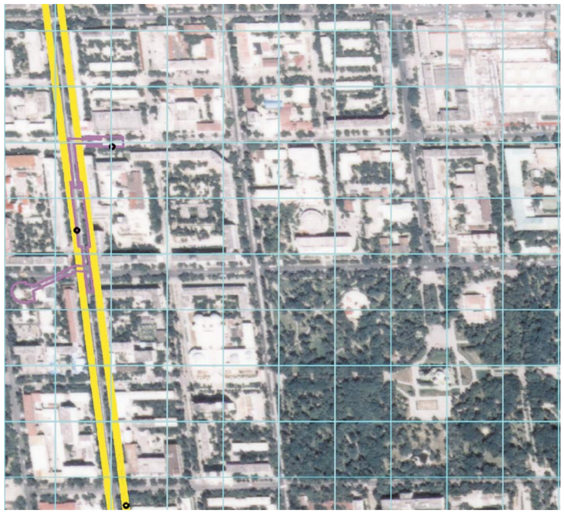
Underground Detection in the City of Almaty

The Ministry of Science–Academy of Science of Kazakhstan requested a flight over the largest city in Kazakhstan, Almaty, with the AMPS pods. The objective of the flight was two-fold: it provided an opportunity for the Kazakhstanis to see the types of sensors in action and to request the collection of data useful to their city planning efforts. The Kazakhstanis viewed the AMPS sensors and on-board processing capabilities to better understand the collection regime. The imagery collected during this flight is being used for infrastructure mapping (roads, railroads, and subway systems).

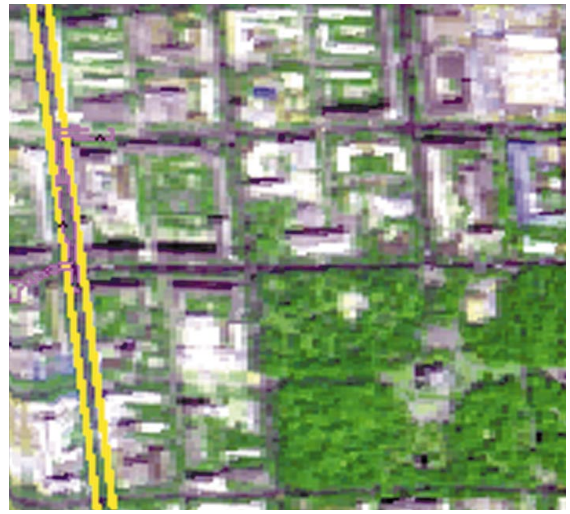
The Kazakhstan mission provided a unique opportunity to combine known engineering data and ground photography with multisensor collections taken over the Almaty subway system, currently under construction. Scientists are using image processing and remote-monitoring techniques to identify distinct spectral signatures associated with underground features in an urban environment.

Pictured above: Ground photo of an elevator shaft under construction.

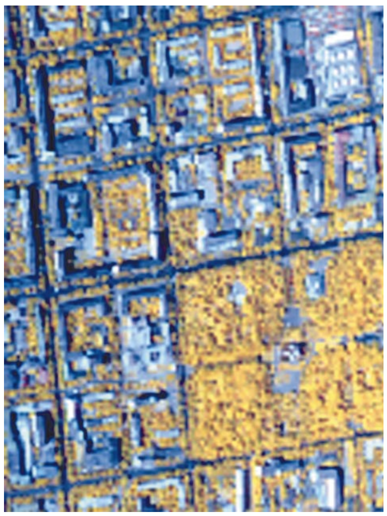
High-resolution aerial photography of Almaty shows a section of the city where a subway is being built. The line indicates the path of one subway segment.



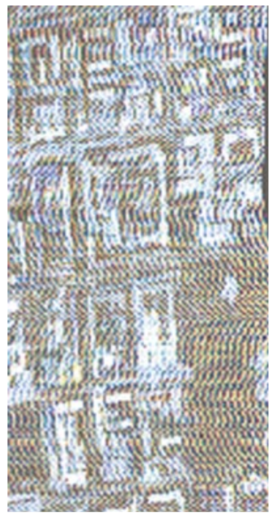
High-resolution aerial photo



Hyperspectral image from the Probe 1



Multispectral image from Daedalus



Hyperspectral image from CASI

Representative imagery from various AMPS sensors is being used to define surface expressions of the subway construction. For example, the high-resolution photography provides needed spatial detail, while Daedalus, CASI, and Probe 1 multispectral and hyperspectral images provide details on the material properties.

Ground photo of subway construction at the surface of the street.

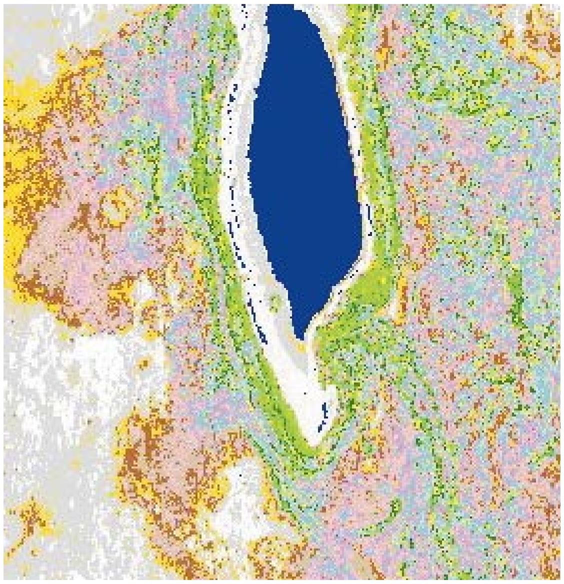
Resource Monitoring of the Ilishyi Region

The Ministry of Science–Academy of Sciences' Institute of Cosmic Research requested this study to characterize the natural environmental conditions of the Ilishyi region. This study focused on spectral analysis of the imagery and correlation with existing and coincident ground and satellite data.

Ongoing research at the Institute of Cosmic Research involves a three-tiered, resource-monitoring study to evaluate imagery from the ground, air, and space (from the Almaz radar and MIR space station). The Institute is very interested in evaluating AMPS data in regards to mapping and characterizing soil, water, vegetation, and the terrain of the area, to better understand and document people's effects on the environment. Data collected during this flight provided baseline information and will subsequently be used for land-use planning.

Pictured above: Lake Beskol, Ilishyi Region: the field team included staff from the Institute of Cosmic Research, Almaty, and Pacific Northwest National Laboratory.

▲ Lake Beskol: the high-resolution photograph shows depth variation in the lake, dense riparian vegetation, desert sand, dirt roads, and abandoned buildings. Ground data were accurately located using Global Positioning System (GPS) technology.



▲ Lake Beskol (top): Multispectral image shows vegetation in red and blue-grey to white. (bottom): the same image with an analysis program applied to the data, actually quantifying the biomass coverage in and around the lake.

Ecological Studies of the Charyn River Valley

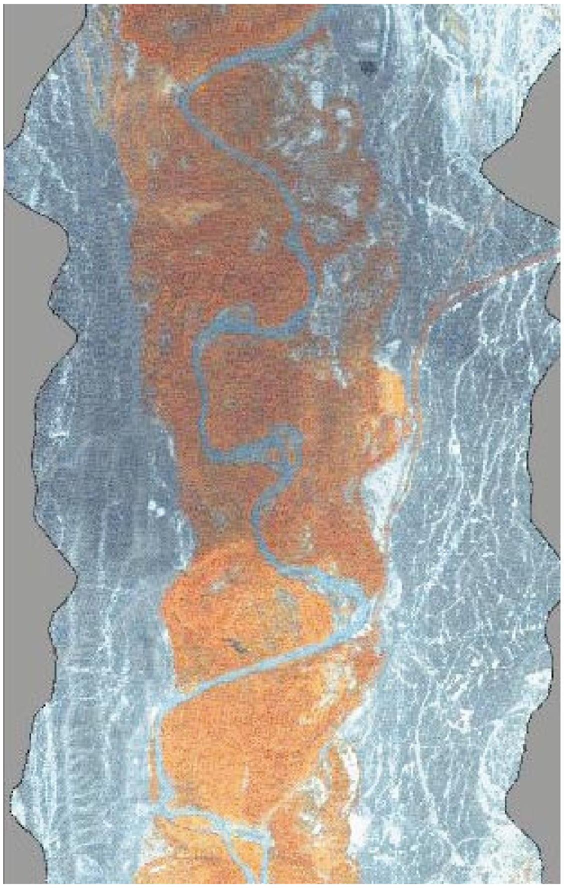
Ministry of Science–Academy of Sciences' Laboratory of Geobotany is collaborating with the U.S. Department of Agriculture to characterize five different ecological sites in the Charyn River Valley: (1) the river valley itself; (2) irrigated fields; (3) forest and adjacent areas of desert vegetation; (4) sub-montane desert and steppes; and (5) mountain forest, meadows, and steppes.

Vegetation, both the types of and changes in, is the best indicator of ecosystem change. Field data on the vegetation in the different ecosystems listed above significantly enhanced by adding remote-sensing data. Remote sensing is powerfull enough to cope with large-area surveys over inaccessable terrain in a short time frame.

The spectral data is being correlated to geobotanical maps that the Laboratory of Geobotany is producing. These data also provide baseline information for land-use practices in this natural preserve of Kazakhstan. Ecological challenges in this part of Kazakhstan include desertification, salination, and erosion.

Pictured above: Charyn River Valley: A yurt, the traditional dwelling of the Kazakhstani nomads, is common in the more remote regions of the country.

▲ Charyn River Valley, Southeast Kazakhstan: high-resolution aerial photography shows vegetation (dark grey-green), surrounding desert (light browns, greys), and linear irrigation canals.



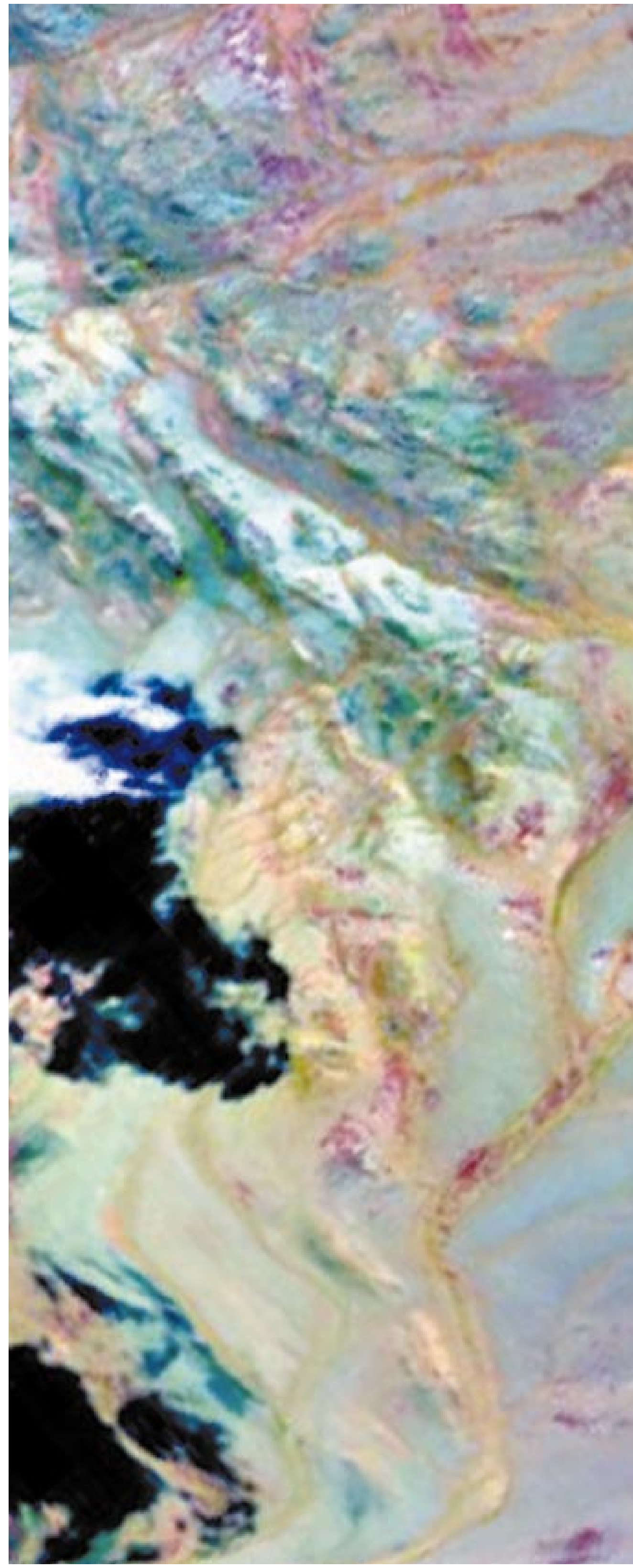
▲ Charyn River Valley (top): Multispectral image shows the desert in red, the river in blue, and surrounding riparian vegetation in green. (bottom): hyperspectral image of same portion of the valley shows vegetation in red and desert in blue.

Mineral Exploration of the Semipalatinsk Test Site

Kazakhstan's Institute of Geophysical Research collaborated with Earth Search Sciences, Inc. (ESSI), a private company in McCall, Idaho, and Semtech, a U.S.-Kazakhstan joint stock company to demonstrate the use of multisensor imagery for mineral exploration and mapping. Multisensor data from AMPS are being processed and analyzed for ESSI-identified targets to examine how multisensor data—specifically hyperspectral imagery—can contribute to the search for minerals.

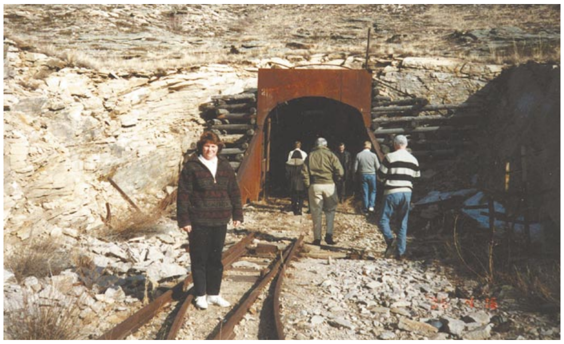
The Semipalatinsk Nuclear Test Site, recently opened to mineral exploration, is geologically complex. Modern remote-sensing techniques offer great potential for monitoring resources and identifying viable prospects. This AMPS collection provided an opportunity to evaluate the technology and demonstrate its effectiveness.

Pictured above: Two private companies, Earth Search Sciences, Inc. and Boeing, had sensors included in the mission. The Probe1 is a hyperspectral sensor developed specifically for mineral exploration.



Semipalatinsk Test Site: the Probe 1 hyperspectral image shows high variability in geology and vegetation. Scientists can use this variability to map geologic features and differentiate between mineral types.

Semipalatinsk Test Site: (top) multispectral image from the Daedalus sensor shows the same area at the photo to the left. (bottom): also the same area, this hyperspectral image is from the CASI. The apparent size reflect the different aspect ratios of the pixels collected by each sensor.



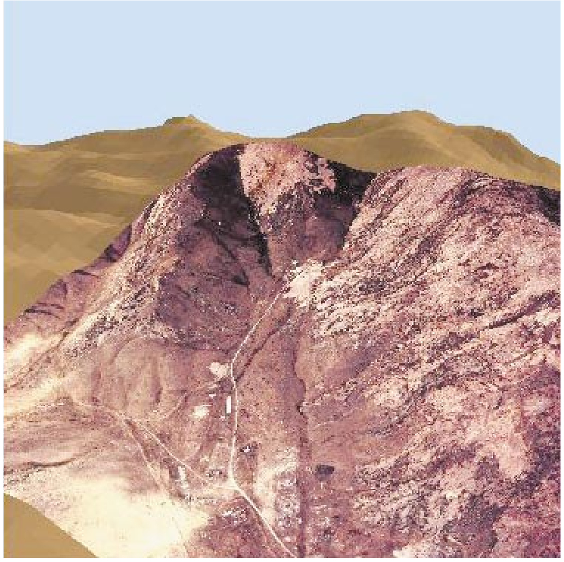
Nonproliferation Monitoring of Tunnel Closures

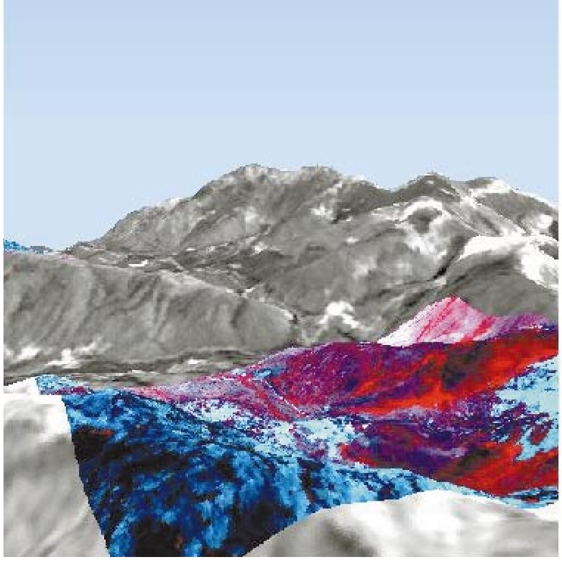
DOE collaborated with Kazakhstan's National Nuclear Center to remotely monitor indicators of nuclear testing at Degelen Mountain, the site of 186 underground tunnels used by the former Soviet Union. This experiment took advantage of a Defense Threat Reduction program to destroy the underground tunnels at Degelen Mountain—prohibiting their use in future weapons testing. Research scientists at the Pacific Northwest National Laboratory are analyzing AMPS multisensor data from this site and testing algorithms that detect, identify, and monitor underground facilities.

Underground detection is a very challenging problem for remote sensing. Subtle indicators—new roads, support equipment, changes in vegetation, the existence of spoils or excavation materials—can identify suspect sites. At Degelen Mountain, a "change detection" experiment was conducted. AMPS data were collected before and after one of the tunnels was destroyed. This provided a unique opportunity to test and evaluate how remotely sensed data can be used to identify a tunnel's existence and also monitor changes (e.g., the destruction or construction) of underground tunnels.

Pictured above: (top) a ground photograph of the Degelen Mountain's tunnel 22 site. The tunnel entrance (not visible in this photo) is just over the crest of the hill in the foreground, by the trailer and tank. (bottom): A closeup view of another tunnel entrance.

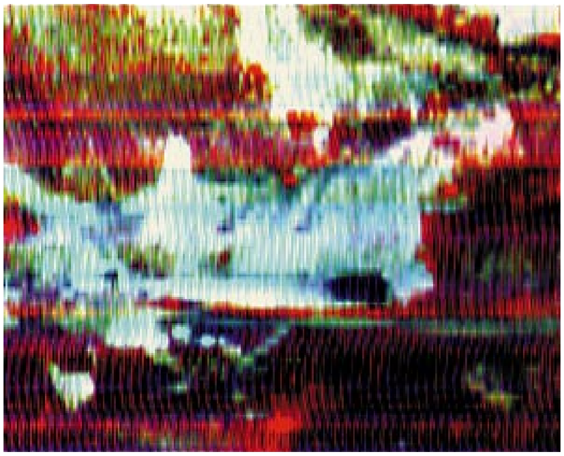
Degelen Mountain: high-resolution aerial photograph of the tunnel 22 site. Note the roads, spoils (or excavation materials from the tunnel), tanks, trucks, equipment sheds—all of which are subtle indicators of the existence of a tunnel.

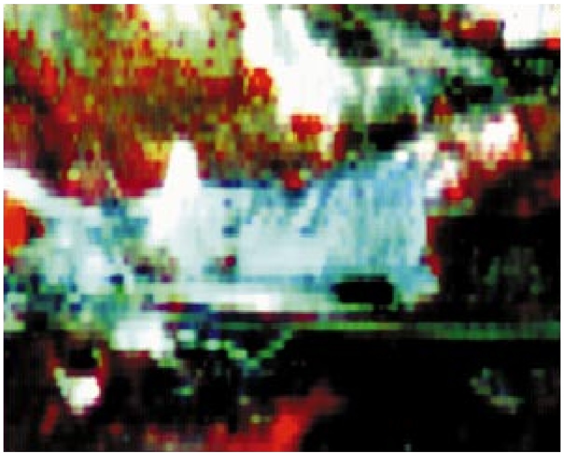




Simulated image: (top) 3D view of Degelen Mountain, looking west, up the valley toward tunnel 22. This image was created by draping high-resolution aerial photography over a digital terrain model. (bottom): 3D image, looking east. This image was created by draping multispectral data of the tunnel and a SPOT satellite image over a digital terrain model.

▶ A CASI hyperspectral image (right) shows more subtle detail after signal noise is removed (left).





Nonproliferation is fundamentally defined as detecting and identifying facilities and activities associated with weapons of mass destruction. Supported by DOE's Office of Nonproliferation and National Security, R&D focuses on techniques that address the inherent difficulties in detection and identification.

No individual sensor system can provide more than a partial answer to any one question about a site. The Pacific Northwest National Laboratory has the primary task of evaluating and refining sensor technologies and their data, pooling AMPS information from a suite of sensors, analyzing it, and adding data collected from the ground, satellites, and other sources to build a more complete picture.

IPP

In addition to nonproliferation monitoring research being conducted at the national laboratories, DOE's Initiatives for Proliferation Prevention (IPP) funds activities in the Newly Independent States (NIS) that include engaging scientists and engineers non-defense work; assisting in stabilizing the technical and scientific infrastructure; encouraging commercialization of NIS technologies through U.S. industry; and promoting the development of a market-oriented economy.

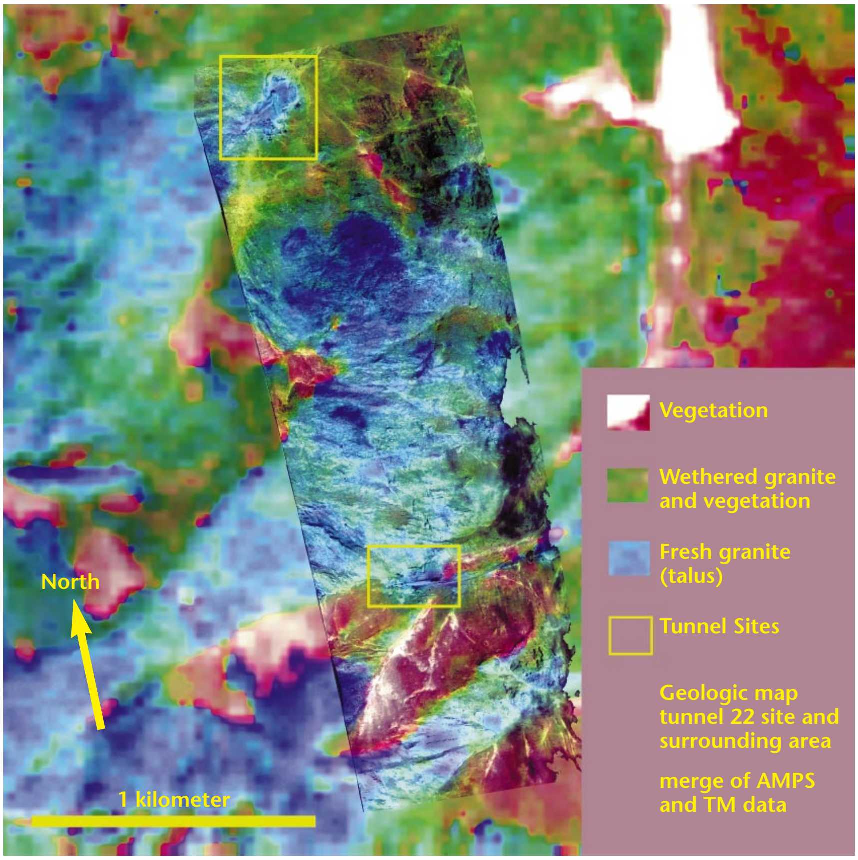
Under this program, Pacific Northwest National Laboratory has contracted with Kazakhstan to analyze the data collected during the mission in three ongoing tasks:

Institute of Geophysical Research—using AMPS data to explore for minerals, from a target identified by Earth Search Science, Inc.

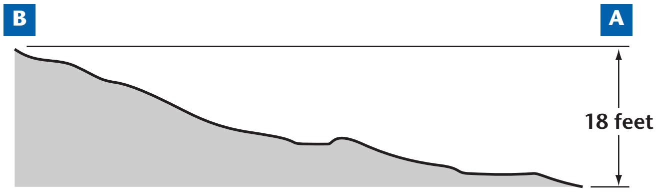
Laboratory of Geobotany—using AMPS data to generate maps of the Charyn River Valley in central Kazakhstan.

Institute of Cosmic Research—using AMPS data to generate maps that will contribute to land-use planning in Kazakhstan.

A follow-on effort, being proposed under this program, will establish a remote sensing and geochemical analytical laboratory in Kazakhstan. Kazakhstani scientists, formerly involved with the production of weapons of mass destruction, will be employed to foster the creation of a technically and economically viable facility supporting the mineral and mining industries in Central Asia. The team members on this effort will include Pacific Northwest National Laboratory, Kazakhstan's National Nuclear Center, and BHP Minerals, a Delaware-based mineral exploration company.



◀ DOE is funding data fusion research at the University of Wisconsin, whose objective is improving characterization and mapping of the vegetation covering any site. The commercial applications include mineral exploration and natural resource monitoring.



◀ Stereographic analysis when combined with high-resolution aerial photography can be used to calculate the volume of the spoils pile at Degelen Mountain. Volume information helps to characterize the size, shape, and orientation of the tunnel.

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