The Future of Space Reconnaissance

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Source: *Scientific American*, Vol. 264, No. 1 (JANUARY 1991), pp. 38-45

Published by: Scientific American, a division of Nature America, Inc.

Stable URL: https://www.jstor.org/stable/10.2307/24936752

SCIENTIFIC AMERICAN January 1991 Volume 264 Number 1

The Future of Space Reconnaissance

As the superpowers continue to launch spy satellites, many nations are planning to orbit their own. Such extensive proliferation will complicate international politics into the next century

by Jeffrey T. Richelson

During the past three decades the U.S. and the Soviet Union have exploited successive advances in launch capability, materials science and electronics to develop fleets of reconnaissance satellites. At present, some 20 of these spacecraft swarm in low or geosynchronous orbits around the earth. One might reasonably expect that the waning tension between the superpowers, the reunification of Germany and the crumbling Warsaw Pact would presage a thinning out. Yet there are indications that the number of intelligence satellites in orbit will proliferate—perhaps dramatically so—in the next decade.

Part of the explanation lies in the fact that despite the warming of U.S.-Soviet relations, the U.S. will still need to conduct extensive satellite reconnaissance, as will the Soviets. Besides monitoring advances in military technology and compliance with arms-control treaties, satellites have additional targets to examine. As demonstrated by recent events in the Persian Gulf, regional hot spots present constant threats. Targeting weaponry or listening in on an enemy's military communications from space is feasible for any nation operating a spy satellite. But, at the same time, satellites will also enable nations to gauge threats accurately and thus possibly circumvent potential hostilities. In any event, a multitude of orbiting eyes and ears from various countries—hostile, friendly and neutral—will affect international affairs for some time to come.

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Much of the surveillance technology other countries will use, however, will not match that of the U.S. Unclassified documents, military experts and former intelligence officials reveal that U.S. satellite reconnaissance, having been an established and accepted component of intelligence operations for more than 30 years, has now reached a pinnacle of high technology. Indeed, analysts think the U.S. may budget as much as $5 billion on space reconnaissance each year; the Department of Defense has already spent an estimated $100 billion since 1960, when the U.S. began launching its photoreconnaissance satellites.

These early satellites produced photographic images. After photographing the target, the satellite ejected the capsule containing the film. Equipped with a parachute, the capsule descended until it reached the earth or until Air Force transport aircraft such as the C-130 snatched them out of midair. Intelligence agencies then developed and analyzed the film.

Although film-return satellites provided excellent information on Soviet and Chinese strategic forces, such as military installations and missile silos, delays in recovery and processing hampered their usefulness in fast-breaking crises. For example, a film pack returned shortly before the August 20, 1968, invasion of Czechoslovakia by the Soviet Union showed no signs of the upcoming battle. A second film pack returned after the invasion that carried images taken just before the attack showed unmistakable signs of Soviet troops massing along the border. Few in the photoreconnaissance program forgot that experience.

The inability of the film-return satellites to provide immediate data led the U.S. to phase them out—the last operated in 1984—in favor of a more sophisticated kind. These satellites, which the U.S. began launching in 1976, are designated KH-11. They use charge-coupled devices. Such devices transform the varying light levels in a scene into digital signals, which are transmitted to a receiving station at Fort Belvoir, Va., via a relay spacecraft. Fort Belvoir then sends the real-time imagery data to the Central Intelligence Agency's National Photographic Interpretation Center in Washington, D.C., as well as to other U.S. intelligence agencies for analysis.

The KH-11's electro-optical capability has had a dramatic impact on intelligence. The speed with which the digital signals are returned to the earth allows

RADAR IMAGE of San Diego Bay, taken from an aircraft, simulates the ability of Lacrosse spy satellites to form images that resemble visible-light photographs.

a picture to be in the hands of an interpreter within minutes of a KH-11's pass over a target. The president or secretary of defense no longer has to wait days or weeks to obtain photographic evidence of events. Instead the image can be obtained, analyzed and set on a desk within an hour.

In addition, the KH-11 made it possible for the U.S. to increase dramatically the number of targets. Twenty years ago, when the U.S. used only film-return satellites, the supply of film limited the target base to about 20,000 (about 80 percent of which lay in the Soviet bloc and China). Charge-coupled device technology and rapid signal processing enable the KH-11 to behave like a television camera. The U.S. can now monitor 42,000 targets (fully half of which lie outside the Eastern bloc countries and China).

Currently the U.S. operates two KH-11s, whose orbits range from 150 to 250 miles above the earth. The satellites have expected lifetimes of three to four years. One will probably cease operating soon (it was launched in October 1987). The other is expected to last until late this year. Many experts believe that, under ideal conditions, these two satellites can probably resolve objects six inches across; exact performance statistics remain classified.

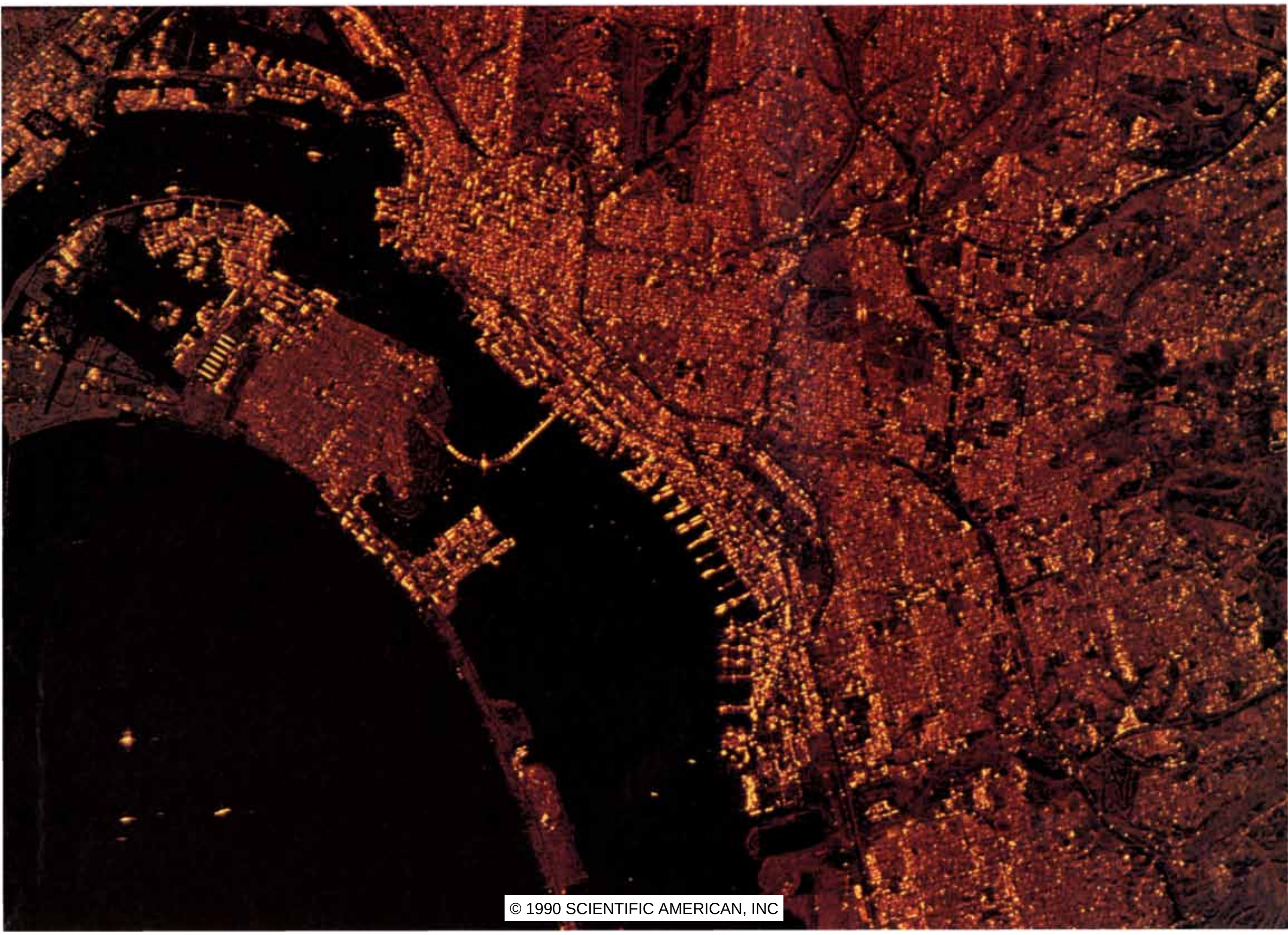
Since they began operating, the KH-11s have monitored the Soviet Union's construction of a nuclear-powered aircraft carrier, the Abalakova early-warning radar system and the testing of the Blackjack bomber. The satellites have also been used to identify landing and departure sites for the attempted hostage-rescue mission in Iran, to detect Libya's chemical warfare plant at Rabta and to examine nuclear weapon facilities across the globe.

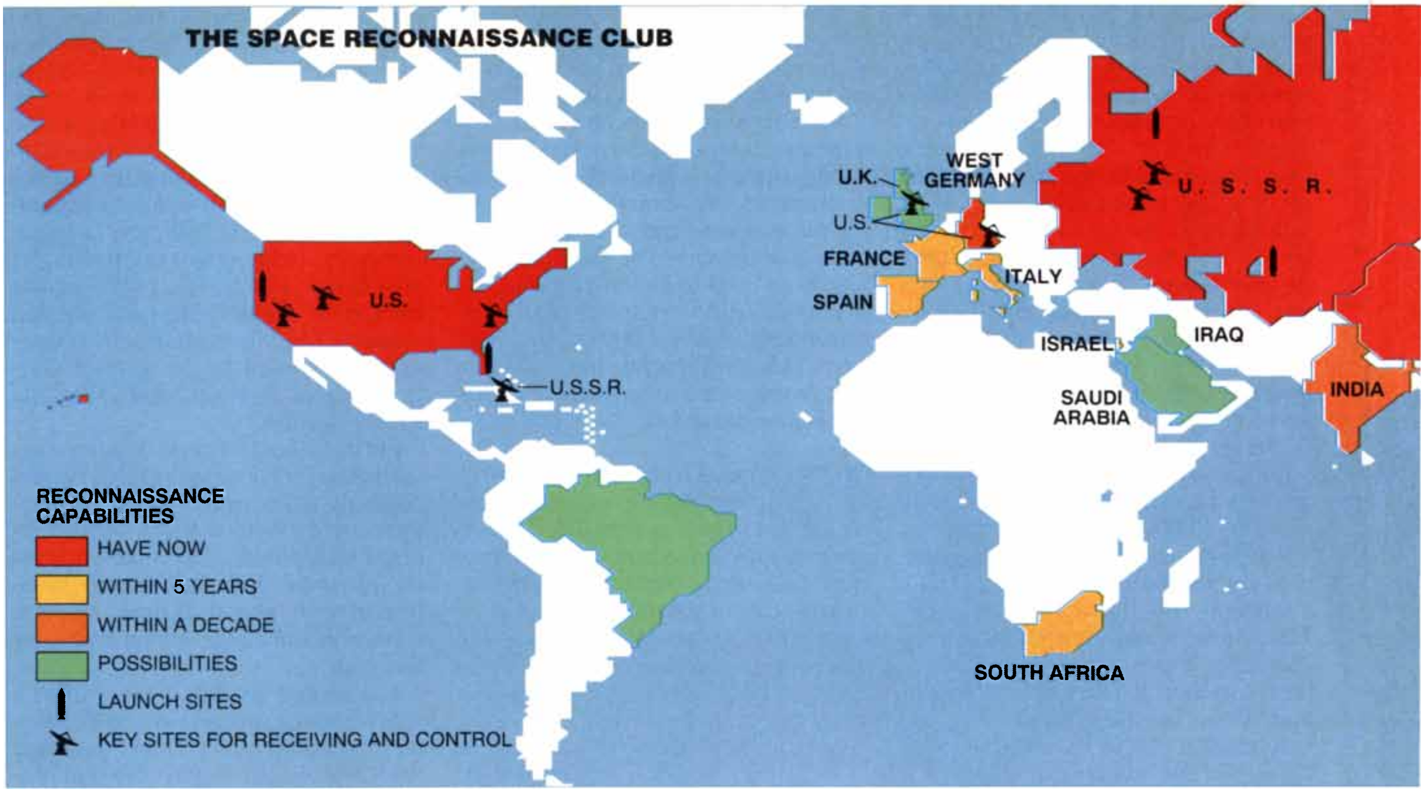
Despite its capabilities the KH-11 has two significant limitations. The optical system functions efficiently only in daylight. It cannot produce detailed photographs at night, nor can its sensors penetrate cloud cover—a particular problem with regard to the Soviet Union and Eastern Europe, where clouds blanket many regions as much as 70 percent of the time.

One solution was implemented in December 1988, when the space shuttle *Atlantis* deployed a satellite first called Indigo, later code-named Lacrosse. (The U.S. alters the designations to confuse the Soviets or to restore cover when a code name leaks to the public.) The Lacrosse operates in the same way *Magellan* does, the interplanetary probe now mapping the surface of Venus. Rather than producing images from existing light, the Lacrosse transmits radio waves to the target area below, which reflects the signals back to the satellite. The Lacrosse then converts the information into images and relays them in the form of electronic signals to White Sands, N.M., via a relay satellite.

Close reading of news reports suggests that such a radar-imaging system probably has a resolution of between three and 10 feet—as much as 10 times better than *Magellan*'s resolution. Present plans call for two Lacrosse satellites to be in orbit at all times. The U.S. expects to launch the second craft later this year.

The second solution to the KH-11's shortcomings was implemented when the space shuttle *Columbia* launched the world's most sophisticated photoreconnaissance satellite in August of





1989. Known as the Advanced KH-11 in intelligence circles, the craft has a larger fuel capacity, which enhances its ability to avoid antisatellite weapons and enables it to change orbits and thus examine new targets.

The Advanced KH-11, mistakenly referred to as KH-12 in early accounts, also reportedly has an infrared-imaging capability. This technology enables the satellite to provide some night photography. The device can also render images in false color to reveal hidden details. For example, cut vegetation used for camouflage differs in false color from healthy, uncut flora. The system's resolution, however, is probably similar to or just slightly better than that of the previous KH-11.

In February 1990 the space shuttle *Atlantis* orbited a second Advanced KH-11. The satellite, augmented with antennas that can intercept communications and electronic signals, apparently malfunctioned. A Titan IV rocket reportedly launched a replacement last June.

Currently the U.S. uses two KH-11s, two Advanced KH-11s and one Lacrosse. According to a former CIA official, future plans call for at least three Advanced KH-11s and two Lacrosse satellites to make up the imaging portion of the U.S. space reconnaissance program. Complementing this surveillance capability will be signals intelligence satellites, designed to intercept a wide variety of foreign signals, including military communications and telemetry data.

The U.S. began its signals intelligence satellite program in 1962 when it launched into low earth orbit the first "ferret" satellites. Reportedly, the exclusive mission of these satellites was the interception of radar signals from the Soviet Union, China and other potentially hostile countries. Among other advantages, the interception enabled the U.S. to locate the radar stations and target them for destruction or disruption (by jamming) during war.

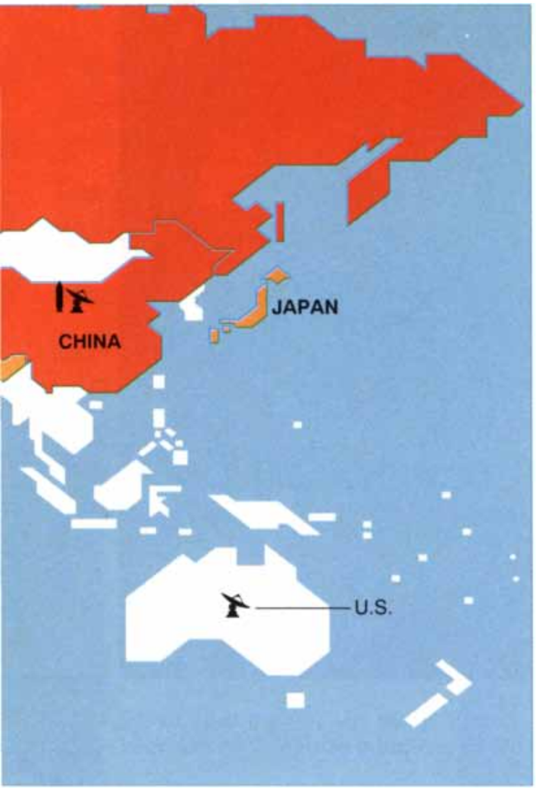
Of far greater utility to peacetime reconnaissance are signals intelligence satellites that occupy geosynchronous orbits. At 22,300 miles above any point over the Equator, the speed of the satellite orbiting around the earth matches the speed of the earth's rotation. The satellite effectively hovers above a single point.

From such a vantage, the satellite's listening antennas can intercept signals from well over a third of the earth's surface and monitor a given set of frequencies or communications links continuously. Through such constant vigilance, geosynchronous satellites can witness brief, unexpected events such as missile tests, which last only 20 or 30 minutes.

In 1970 the U.S. launched its first signals intelligence satellite, code-named Rhyolite (subsequently renamed Aquacade), that operated in geosynchronous orbit. Since then the U.S. has launched four more Rhyolites, four or five Vortexes (another kind of signals intelligence satellite, previously code-named Chalet) and two Magnums (advanced versions of the Rhyolite).

Ground stations at Pine Gap in Australia, Menwith Hill in Britain and Bad Aibling in Germany have enabled the U.S. geosynchronous satellites to monitor the signals from many nations. The information includes walkie-talkie traffic from military exercises, telemetry signals from missile tests and military, government and economic communications. Currently one or two Vortexes and two Magnums monitor the globe at all times.

The combination of photoreconnaissance and signals intelligence satellites provides the U.S. with formidable surveillance capabilities. During the cold war, the satellites have helped the U.S. determine the size of Soviet weaponry, to monitor treaty compliance and to detect swift military moves. More recently news reports indicate that U.S. photoreconnaissance satellites have been monitoring Iraq's troop strength in the Persian Gulf and have shown the movement of military hardware, such as chemical munitions and mobile missile launchers. The sig-



nals intelligence satellites have been monitoring Iraq's air defense systems and military communications. In fact, newspaper accounts stated that satellite photography helped to convince King Fahd of Saudi Arabia to allow U.S. troops onto Saudi soil.

The U.S. has also used satellites to monitor nonmilitary operations, such as disaster relief. During the Chernobyl incident the Vortex satellite monitoring the western Soviet Union intercepted the two-way radio and telephone communications of the military, government and security forces within several hundred miles of the incident. Combining the intercepted communications with photography obtained by a KH-11 of the damaged reactor and clean-up operations, the U.S. made detailed assessments of the catastrophe as it was unfolding.

The U.S. consequently determined the extent of the damage, including the burning of the graphite reactor, well before the Soviets admitted the severity of the accident. The data also reassured the U.S. that only one reactor melted down, not two as some early reports indicated.

Reconnaissance satellites have also monitored domestic upheaval in other nations, including secessionist activity and ethnic conflict in the Soviet Union. They recorded events in Beijing during the days and weeks surrounding the Tianamen Square demonstrations and thus circumvented the news blackout imposed by China's leaders.

Since the beginning of satellite surveillance the Soviet Union has trailed the U.S. in space reconnaissance capabilities. In recent years, however, the Soviets have made significant advances that have narrowed the technology gap between the two countries. Until late 1982, the Soviet Union relied solely on film-return spacecraft for their photoreconnaissance activities. These included satellites that provide a wide field of view as well as high-resolution satellites for close-look reconnaissance.

Since December 1982 the Soviets have been launching a limited number of satellites that could provide real-time data. Like the KH-11s, these satellites, part of the Cosmos series, transmit their digital signals to the earth via a relay satellite in geosynchronous orbit. The Soviets launched the latest versions in 1989: the *Cosmos 2007* in March and the *Cosmos 2049* in November. The main receiving station may be in Vatutinki, 50 kilometers southwest of Moscow, at a site belonging to the Soviet General Staff's chief intelligence directorate (GRU).

Experts in Soviet satellite operations believe the GRU has used the satellites to monitor military conflicts throughout the world, including the Indo-Pakistani War, the Yom Kippur War and the U.S. invasion of Grenada. In addition, based on its orbital changes, a third-generation, high-resolution spacecraft called *Cosmos 1343* apparently monitored the White Sands, N.M., shuttle landing site just before the touchdown of the third shuttle mission in 1982. The Soviets have offered for sale to the general public some medium-resolution photographs, including those of the U.S. army base at Fort Riley in Kansas, the Strategic Air Command in Omaha and a U.S. intercontinental ballistic missile field.

The Soviets usually maintain three photoreconnaissance satellites (primarily film-return types) in orbit during most of the year. During the summer months, two or three more craft may join the fleet to enable the Soviets to take advantage of the long summer light. Soviet satellite engineers, who prefer many cheap satellites to a few, highly sophisticated ones, designed their film-return satellites to last from 14 to 44 days. Their real-time imaging satellites have much longer lifetimes (more than six months).

Thus, to maintain year-round coverage, the GRU must launch a greater number of satellites than does the U.S. In 1988 the GRU launched 32 photoreconnaissance spacecraft (only one of which provided real-time images); in 1989 it launched 31 satellites.

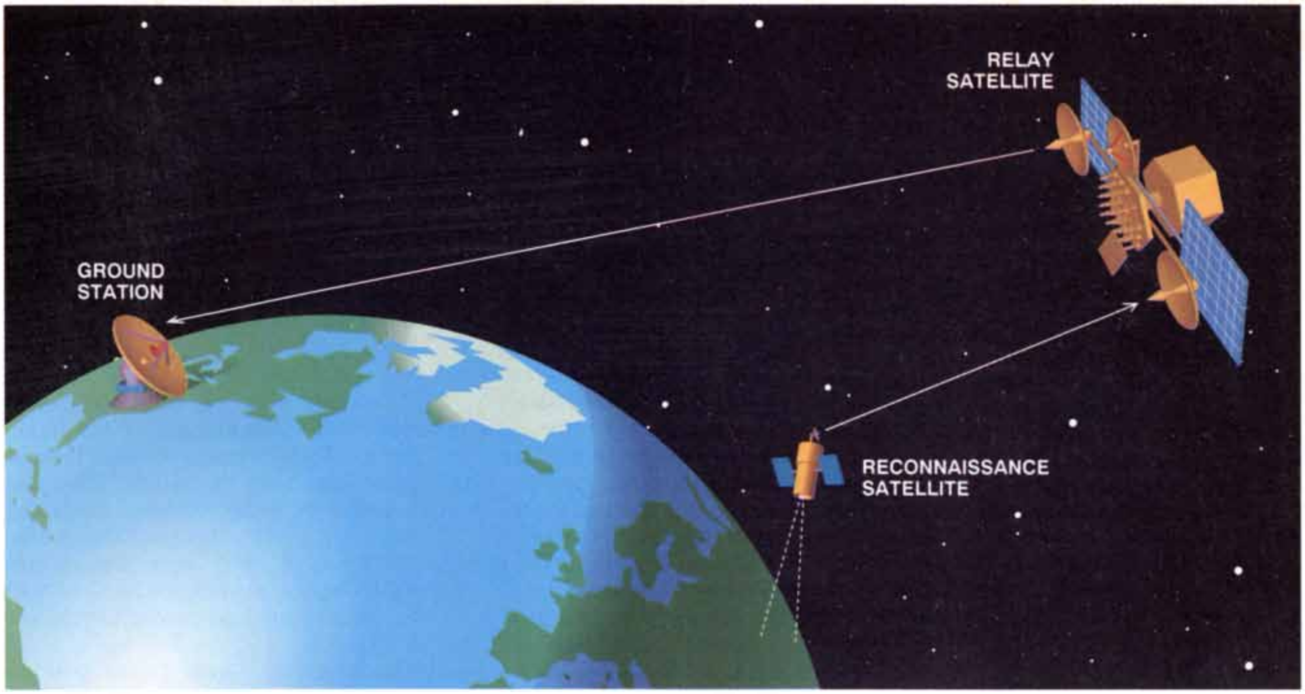
Although the Soviet Union has almost matched the photoreconnaissance technology of the U.S., a dramatic gap exists in signals intelligence satellite capability. In 1967, five years after the U.S. began launching its ferret satellites, the Soviets began placing their signals intelligence satellites in low earth orbit, at altitudes of approximately 400 to 500 miles. In such low orbits, the satellites remained in range over a given target for a brief period and thus could play only a limited role in communications and missile-test monitoring. Their primary mission instead must have been the identification and location of radar systems, including those covered by the Antiballistic Missile Treaty of 1972. The Soviets are currently operating one constellation of six signals intelligence satellites in low earth orbit.

In 1985 the Soviet Union sent up *Cosmos 1738,* its first geosynchronous-orbiting signals intelligence satellite, fully 15 years after the U.S. launched its own. The U.S. found that the Soviet satellite, along with its two successors, *Cosmos 1961* and *Cosmos 2054*, orbit over the Western Hemisphere at 14 degrees west longitude. Apparently, the Soviets' signals intelligence complex in Lourdes, Cuba, serves as the ground control station, which ultimately relays the signals to the GRU.

The data these satellites can obtain originate throughout most of the U.S. and South America. The satellites probably pick up telemetry data from tests conducted in the Carribbean of the new Trident D-5 submarine-launched ballistic missile as well as military signals related to the Brazilian and Argentine ballistic missile and nuclear power programs.

Despite the changing world situation, both superpowers will continue to photograph each other's missile silos, bomber fields, submarine facilities and military test sites, bases and installations. The signals intelligence satellites will keep monitoring radar signals, missile-test telemetry and political, military and economic communications. Such ongoing reconnaissance should reveal major advances in military technology as well as any treaty violations that may elude on-site inspectors.

Both superpowers can be expected to devote increased attention to the growing problem of weapon proliferation. The more frequently known military facilities are monitored, the greater the chance is of detecting an interesting



RELAY SATELLITES, such as the Tracking and Data Relay Satellite System, act as the intermediaries between satellites and ground stations. Relays speed the flow of data to the earth and complicate the interception of signals by enemies.

event. Such persistence was rewarded when a KH-11 spotted Argentina's Condor II missile on its launch pad, awaiting testing.

Satellite sensors can also spend more time searching for new facilities. U.S. satellites discovered, for instance, the chemical weapon plant near Rabta, Libya. Frequent reconnoitering will help detect such installations before they become operational.

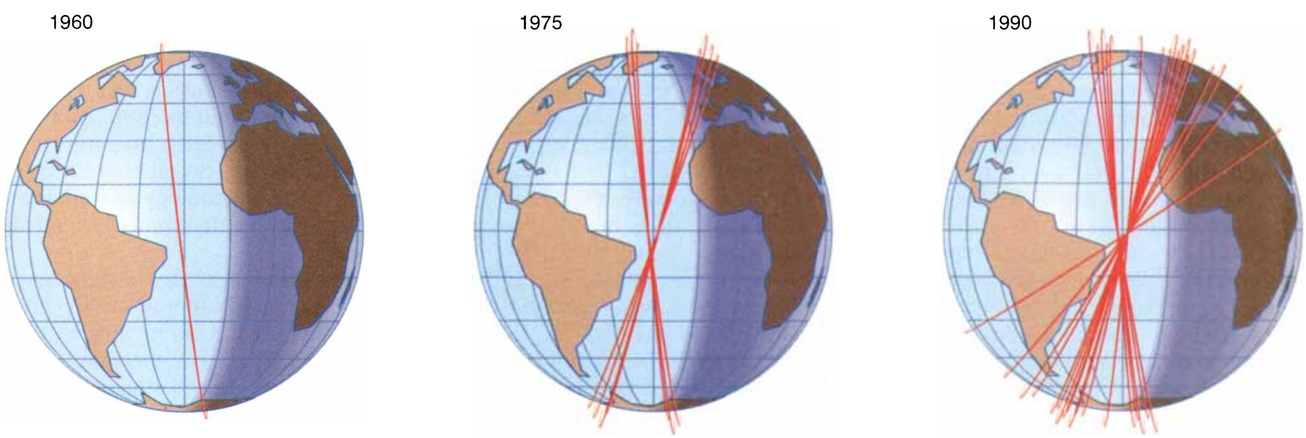
As tensions have ebbed, the U.S. and Soviet Union have begun sharing some of the information produced by their reconnaissance systems. For example, in 1989 the U.S. informed the Soviets that KH-11 photography had turned up evidence of a new nuclear reactor outside Pyongyang, North Korea, and even specified the exact geographic coordinates of the plant, enabling Soviet satellites to photograph it.

Such national assets can serve another facet of international security: monitoring the continuing degradation of the earth's environment. The U.S. and Soviet satellites will be able to devote an increasing amount of time to producing images of oil slicks, sources of pollution and damage from natural disasters such as earthquakes.

Although the U.S. and Soviet Union have been the dominant players in the space reconnaissance arena, they have not been alone. Since 1970 the People's Republic of China has been a participant. Progress there has been uneven. China has yet to orbit a signals intelligence satellite. Its photoreconnaissance systems have made slow but steady gains. China began producing images from space on April 24, 1970, when it placed a 354-pound imaging satellite in low earth orbit. By the mid-1970s China could launch photoreconnaissance satellites weighing almost 10,000 pounds. Although this payload equals about a third of the weight of a KH-11, it gives engineers considerable opportunity to construct a fairly large and sophisticated optical system.

Between 1970 and December 31, 1989, China orbited 12 satellites associated with military photoreconnaissance. It usually launched a satellite no

PROLIFERATION OF SATELLITE RECONNAISSANCE



more than once a year and only during the late summer or early winter. From their orbits the satellites covered the entire world except for the most northerly parts of the Soviet Union, Canada and Scandinavia.

The satellites primarily returned the film to the earth for development and analysis. On one occasion, instruments in the satellite developed the film on board. A scanner read the images and then transmitted them to the earth via radio signals. U.S. intelligence agencies believe China is currently developing a more advanced system, which will apparently be similar to France's SPOT commercial observation satellite. Scheduled for launch in the early 1990s, the satellite will use charge-coupled devices to form images.

The Soviet Union, particularly its border with China, has been and will continue to be a high-priority target of the latter country's satellites. Vietnam and India have been adversaries in the past. As potential future enemies, they will undoubtedly remain prime targets. China also will probably survey Cambodia and Afghanistan, two countries whose antigovernment guerrilla groups it has supported.

MILESTONE LAUNCHES IN SPACE RECONNAISSANCE HISTORY

COUNTRY	YEAR	NAME	DESCRIPTION
U.S.	1960	*Corona/ Discoverer 14*	First operational photoreconnaissance satellite. Its film capsule was successfully recovered in midair.
U.S.S.R.	1962	*Cosmos 4*	First Soviet photoreconnaissance satellite. The Soviet Union began launching Cosmos satellites with near clocklike regularity in 1965 and currently operates three to six photoreconnaissance satellites at all times.
U.S.	1962	"Ferrets"	Signals intelligence satellites in low earth orbit to monitor foreign radar systems.
U.S.S.R.	1967	*Cosmos 148*	Signals intelligence satellite similar to U.S. ferrets.
U.S.	1970	Rhyolite	First geosynchronous-orbiting satellite for signals intelligence. From such an orbit, a satellite can monitor one third of the earth's surface.
CHINA	1970	*China 1*	First Chinese photoreconnaissance satellite.
U.S.	1976	KH-11	Satellite with charge-coupled device to form real-time images of objects as small as six inches on any dimension.
U.S.S.R.	1982	*Cosmos 1426*	Photoreconnaissance satellite similar to KH-11 but with lower resolution.
U.S.S.R.	1985	*Cosmos 1738*	Geosynchronous-orbiting satellite for signals intelligence.
U.S.	1988	Lacrosse	Radar-imaging satellite capable of resolving objects three to 10 feet across. It currently operates under a new code name.
ISRAEL	1988	*Offeq 1*	Experimental satellite built with the aid of South Africa.
FRANCE ITALY SPAIN	1993	Helios	System of four photoreconnaissance satellites to be launched over a period of 10 years.

Smaller powers seem inclined here as in other technological areas to follow the trails that the superpowers have blazed. Practical considerations as much as hubris supply motivation. Even nations aligned with one of the superpowers often do not wish to rely on a patron for satellite data. For instance, Israel's entrance into the satellite reconnaissance field stemmed from the dissatisfaction Israeli officials felt with being dependent on U.S. satellite data. Israel's cabinet minister and former Chief of Staff Mordechai Gur complained that the U.S. withheld satellite data immediately before the 1973 Yom Kippur War. Meir Amit, the former chief of the Mossad, the Israeli secret service, said his country was receiving the "crumbs" of satellite intelligence. Satellite reconnaissance would also help an aligned nation make more independent assessments of foreign affairs as well as provide it with a measure of prestige in the elite world of high technology.

Commercial satellites would not completely fulfill intelligence requirements, either. Besides the comparatively low resolution (ranging from 30 to 100 feet) of such satellites, the client could not exercise significant control over the operation. A client would also have to compete with other customers for use and could not directly prevent disclosure of areas of interest.

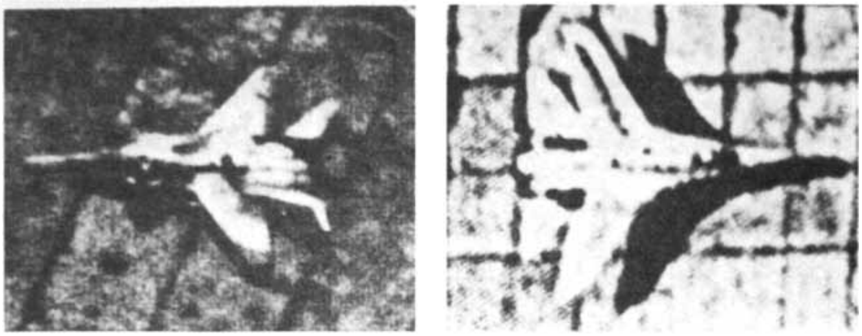
High-flying aircraft do not make a good alternative to satellites. Overflights tend to be a politically sensitive issue. They can also be decidedly dangerous. Many countries now have sophisticated tracking devices and effective ground-to-air weapons. Aircraft suffer technological deficiencies as well. They cover only limited areas, and fuel supply renders many target nations distant enough to make aerial reconnaissance risky. Israel's air force, for example, would have difficulty monitoring its enemies' movements deep in the Middle East.

Consequently, several countries have decided that the benefits outweigh the costs, which run into hundreds of millions of dollars for a single satellite. Many governments are on the verge of joining the space reconnaissance club or are actively considering it. France currently operates the SPOT system, which provides color images that have 66-foot resolution and black-and-white images of a 33-foot resolution. Although the system is designed for commercial purposes (geology, urban planning, agriculture), the French military exploits its abilities for intelligence. France, however, will soon have its own dedicated reconnaissance system, called Helios, to gather intelligence.

The Helios system calls for the launching of four satellites over 10 years, beginning in 1993. These high-resolution satellites, developed with the participation of Spain and Italy, will be able to resolve objects smaller than a baseball bat, according to intelligence analysts.

Jacques Bosquet, head of guided-weapon and space programs for the French Ministry of Defense, stated that the different needs of the three countries will severely tax the capabilities of Helios. France will undoubtedly reconnoiter the now unified Germany and parts of the Middle East and Africa, such as Chad, where France has had traditional interests. The system should also provide accurate targeting information for France's nuclear strategic missiles. In addition, Helios will independently verify arms-control treaties by the Soviet Union and the U.S. Italy, wary of terrorist attacks similar to the *Achille Lauro* incident, will probably monitor areas in the Middle East. For what purpose Spain will use Helios remains unclear.

Threatened by many of its Middle East neighbors and unhappy with U.S.-supplied data, Israel began its space reconnaissance program in 1988 by launching *Offeq 1*. Intelligence sources believe Israel probably developed the experimental satellite in conjunction



SATELLITE IMAGES used in 1984 congressional hearings show a Soviet MiG-29 (*left*) and an SU-27 (*right*). They were mistakenly published in the proceedings.

with South Africa. In early March of 1990 Israel lofted *Offeq 2* into an orbit that ranges from 125 miles at perigee to 923 miles at apogee.

Although Israeli officials deny that the 374-pound *Offeq 2* carries any kind of optical system, it is clear to space and intelligence experts that the satellite is at least the predecessor of a photoreconnaissance satellite. Israel would target activities throughout the Middle East, including Libya's construction of a chemical warfare complex and Saudi Arabia's deployment of CSS-2 missiles.

India, which has an active space program, will be ready to use its Polar Satellite Launch Vehicle in the next few years. This delivery vehicle will be able to place a 7,000-pound spacecraft in low earth orbit. Such a launch capability will be adequate to orbit a photoreconnaissance satellite. Satellite images should prove quite useful to India, which has long-standing disputes with two of its border antagonists, Pakistan and China.

For instance, in 1987 India engaged in a large-scale military exercise, called Operation Brass Tacks, near the Pakistani border. Pakistan, unsure of India's motives, then massed its own troops, threatening to turn the exercise into a full-scale war. Satellite data would have provided an early warning and an opportunity for diplomats to resolve the situation. Similarly, when Indian and Chinese troops faced off in the Sumdorong Valley in Arunachal Pradesh in 1986, satellite data would have given India's leaders the exact size, location and kind of units that Beijing had deployed.

If India orbits photoreconnaissance satellites, targets will include Pakistan's military bases, suspected terrorist training camps and undoubtedly the nuclear facility in Kahuta. India will also use satellite reconnaissance to provide targeting information for its intermediate-range ballistic missile, Agni [see "Third World Ballistic Missiles," by Janne E. Nolan and Albert D. Wheelon; SCIENTIFIC AMERICAN, August, 1990].

In 1988 Britain was reportedly developing a signals intelligence satellite, code-named Zircon, for launch in geosynchronous orbit over the Indian Ocean. A satellite in such an orbit will give Britain an electronic view of the eastern half of the Soviet Union. The Zircon would also be close enough to Soviet communications satellites to intercept some of their traffic.

Early in 1990, West Germany announced studies to determine the desirability of a space-based earth-observing system. West German officials indicated that they were primarily concerned with the role the satellites would play in arms-control verification. That role will probably not change significantly with the unification of the two Germanys.

Japan has reportedly just started development of a photoreconnaissance satellite for defense and environmental purposes. The craft may go up within the next 10 years. Iraq, Brazil and Saudi Arabia, all of which have ballistic missile programs, may also have space reconnaissance systems ready sometime after the year 2000.

The potentially massive explosion in reconnaissance systems will force nations to adjust their foreign policy. Military operations, including hostage-rescue missions and other actions considered justifiable, will be harder to keep secret from prying eyes—including hostile ones. If two nations have nonnegotiable differences, then reconnaissance may help increase the efficiency with which war is conducted. The Israeli attacks on the nuclear reactor in Osirak, Iraq, and on the headquarters of the Palestine Liberation Organization in Tunis were planned with the help of satellite images obtained (according to news reports), legally and illegally, from the U.S.

But a proliferation of space reconnaissance systems may have positive consequences as well. Military secrecy and undetected arms-control violations will become more difficult to achieve. As the number of satellite eyes increases, the harder it will become to hide weapon systems, radar installations and military production facilities.

For instance, when only a few reconnaissance satellites orbited the earth, a country could conceal its secret aircraft or suspend training exercises once or twice a day. With many satellites, however, such practices become costly and inconvenient. The U.S. alone, with five pairs of eyes in space at all times, imposes a heavy cost on any nation that would seek to keep targets out of view.

Such extensive surveillance will make it more difficult for nations to prepare for war or mount a surprise attack. Assuming that countries truly prefer to settle their differences peacefully, satellite reconnaissance can provide reassurance that another nation is not preparing to attack. Satellite data can also reveal the adversary's military capabilities. Intelligence officials can then decide whether to deploy new offensive weapons.

The continued improvement of space reconnaissance systems by the U.S. and Soviet Union and the development of new systems by other nations will have a significant impact on international affairs. Some countries may use satellites to wage war, others to avoid it. No one can accurately predict all the changes that proliferation will bring, and it is impossible to say whether spy satellites will prevent military conflicts. But history seems to testify that satellite reconnaissance has helped moderate the arms race and keep the peace between the U.S. and Soviet Union for 30 years. Perhaps space reconnaissance will limit hostilities between other nations as well.

FURTHER READING

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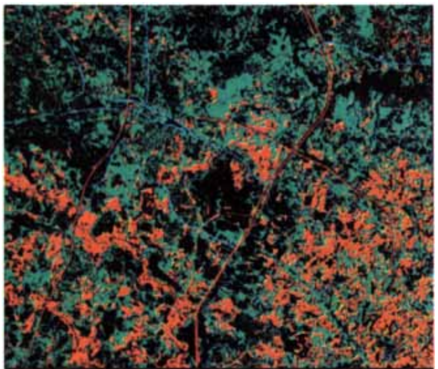
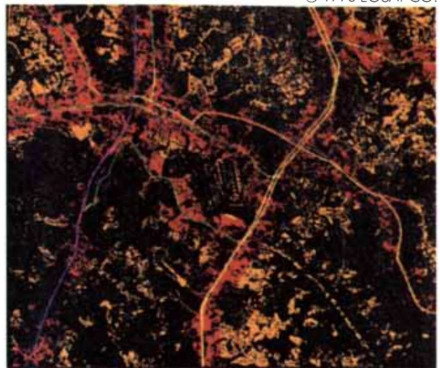
No two businesses see things alike.

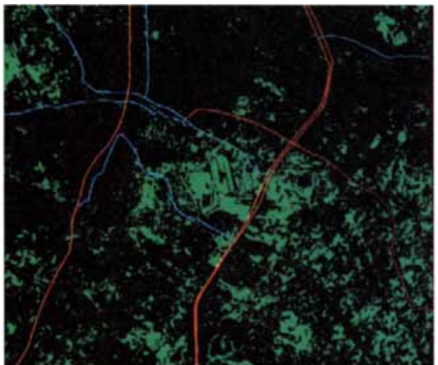
Millersville, Maryland as it would appear to the human eye.



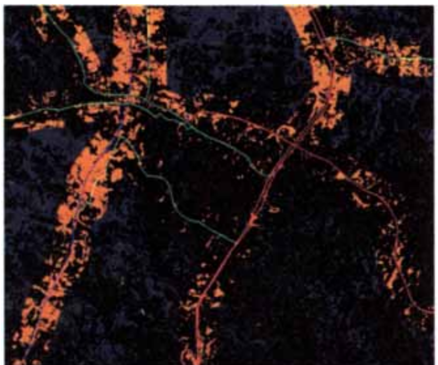
Coniferous trees are shown in orange. Deciduous in green.



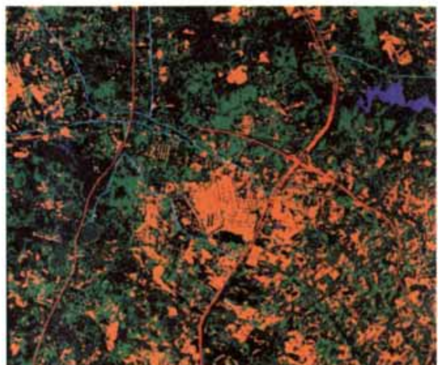
We've laid down a buffer-zone that highlights in red all developed regions within 570 meters of a road.



All 5,188 acres of crops and similar vegetation are highlighted in green.



This buffer-zone highlights in yellow all wetlands within 570 meters of a road.



Here, virtually everything is identified. Trees in green. Water in blue. Grasslands in orange. Wetlands in brown. Suburban development in black.

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