Spy Satellites: Entering a New Era

Intelligence agencies are launching a constellation of new reconnaissance satellites with broad military and arms control implications; but can the data be handled?

AFTER WAITING 2 YEARS for the return of the space shuttle, America's intelligence agencies have begun to launch a constellation of new and improved spy satellites. All three of the space shuttle launches since the Challenger accident, including last week's flight of the Discovery, have added important links in this surveillance network.

By the end of 1989, if all goes well, three new reconnaissance spacecraft will be in orbit, collecting unprecedented amounts of information on military targets around the globe. Together, they will mark a new era in the ability of the U.S. government to monitor arms control agreements, locate military targets precisely, and wage war in far-flung parts of the globe.

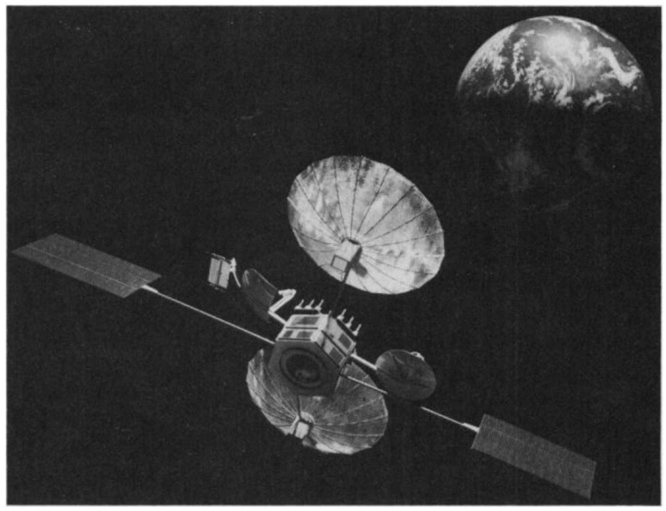
The first of the new satellites flew into orbit last December aboard the space shuttle Atlantis, according to an account in the industry magazine *Aviation Week* that has been confirmed privately by Administration sources. It is a radically new type of surveillance satellite that uses radar to produce high-quality images of the earth's surface. Although NASA has previously launched similar instruments, called synthetic aperture radars, to study geologic formations and ocean phenomena, this is the first imaging radar to be placed into orbit specifically for military surveillance. First known as Indigo, the satellite's code name later changed to Lacrosse, the name revealed by *Washington Post* reporter Bob Woodward in his book *Veil*.

Later this year, the first two KH-12 spy satellites are scheduled to fly into orbit aboard Titan IV rockets. The KH-12 is the latest and most advanced in a long line of photographic intelligence satellites, which use a powerful telescope aimed at the earth to take pictures using visible light and infrared radiation.

Equally important in this network are the Tracking and Data Relay Satellite System (TDRSS) satellites, the third of which was launched by Discovery last week. Although secrecy surrounds military use of the TDRSS, most observers believe that Indigo-Lacrosse is using the satellite to relay its data flow to earth. The KH-12's images probably will be relayed through TDRSS as well.

TDRSS, in fact, is where NASA's science missions and the secret world of military reconnaissance come into closest contact. Both the military and the space shuttle are "priority 1" users of TDRSS's communications channels, according to NASA officials. The satellite's capacity is scheduled by computer at the TDRSS ground station, located at White Sands Missile Range, New Mexico.

Lower priority users of TDRSS, such as the Hubble Space Telescope or the Landsat earth-imaging satellites, must submit their requests to use TDRSS without knowing which times are blocked out for the military's use. "You're in an absolutely crazy situation where you have to play guessing games," said Robert Bless, professor of astronomy at the University of Wisconsin, Madison. He is the principal investigator for the high-speed photometer on the Hubble telescope.



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The TDRSS satellites, *one of which was launched last week by the space shuttle, play a key role in relaying data from spy satellites.*

The peak rate at which Hubble's instruments will send data through TDRSS—1 million bits per second (Mbs)—is a mere trickle compared with the flood of data generated by the new spy satellites. Synthetic aperture radars like Indigo-Lacrosse, in particular, tend to swamp any available data relay, because transmission capacity and available computing power, not the radar itself, generally limit the quality and size of the images that the system can produce.

Robert Cooper, former head of the Defense Advanced Research Projects Agency, noted in an interview that a high-resolution radar system, with a resolution of perhaps 1 foot, can generate raw data at a rate of many billions of bits per second—far beyond the capacity of any existing communication links in space. Cooper is now president of Atlantic Aerospace Electronics Corporation.

Reducing the raw data instantly to images—a data stream small enough for TDRSS to handle—would require one of the world's largest supercomputers on board the spacecraft, said Cooper. A more likely way of getting around the data bottleneck is for Indigo-Lacrosse only to operate intermittently, storing bursts of data on recorders. These devices could then transmit the data at a slower rate through TDRSS to earth.

NASA plans to launch its own imaging radar as part of its Earth Observing System (EOS) sometime in the late 1990s. The instrument will detect objects roughly 30 meters across in a swath 50 kilometers wide, with less detail when the swath is expanded to its maximum width of 700 kilometers. The data rate of its transmissions is limited to 300 Mbs, the maximum capacity of one of TDRSS's two high-capacity channels. "The data rate limits everything. It limits resolution, gray scale accuracy, and field of view," said one of EOS's designers at NASA's Jet Propulsion Lab.

Because Indigo-Lacrosse's performance is limited by the capacity of TDRSS, the pictures it furnishes probably are less detailed than those from optical systems like the KH-12, which can detect objects only a few inches across. According to John Pike of the Federation of American Scientists (FAS), the new radar satellite probably can detect objects as small as 1 meter across, since that level of detail is necessary to identify important items such as mobile Soviet missiles.

The radar's crucial advantage, however, is its ability to see through the clouds that generally hide much of the Soviet Union and Europe from optical remote-sensing satellites such as Landsat and the KH-12. An all-weather capability "opens up entire new worlds," said Cooper, who, like other former government officials interviewed for this article, refused to confirm Indigo-Lacrosse's existence.

Compared to the novelty of Indigo-Lacrosse, the KH-12 is practically a known quantity. In fact, it probably bears a strong resemblance to the Hubble Space Telescope, since both were built to fit inside the shuttle bay. The primary mirror (and therefore the power) of the KH-12's telescope can be little larger than Hubble's.

As a comparison, a telescope with Hubble's power in an orbit 200 nautical miles above the earth could detect objects on the earth's surface 7 inches across. According to Pike and Jeffrey Richelson of the private National Security Archive, the KH-12 carries a large quantity of fuel that it can use to maneuver in space, so that it could dip down to a low 100-mile orbit in order to see details half as large. In order to counter the distortions caused by the earth's atmosphere, spy satellites use computer-controlled "adaptive optics" that vary the surface of its mirror minutely.

Detecting ever smaller objects, however, is no longer the key to more effective spying from space, according to reconnaissance specialists. The greatest technical challenges now lie in programming high-speed computers to unearth valuable information buried in the mountain of data.

"In the past, the problems have been mostly connected with sensing the data. Now, they are more in filtering and interpreting it," said Thomas Rona, who moved from the Department of Defense to be deputy director of the White House Science Office in 1986.

McDonnell Douglas Corp.

Edward Aldridge: *Better space-based surveillance capability is needed to target mobile Soviet missiles and command centers.*

"You have to filter it in terms of geography, but also in terms of targets that are interesting," said Rona. "Humans used to do this—photo interpreters. Now there are attempts to automate it."

Technical experts for the Central Intelligence Agency, the Pentagon, and the National Reconnaissance Office now are struggling to harness computers to the task of filtering out valuable information from the deluge of data sent down from space. Computers, says former Air Force Secretary Edward (Pete) Aldridge, eventually may help solve a typical dilemma confronting intelligence analysts: "Somewhere in that data there is a target. Now, how do you find it . . . unless you take the population of the United States and make them photo interpreters?" Aldridge is now president of McDonnell Douglas Electronics Corporation.

The sheer volume of data streaming down through TDRSS, threatening to overwhelm even armies of analysts, is one source of pressure to automate the interpretation of photographic intelligence. But skyrocketing demands on the reconnaissance system are even more important.

Rather than simply monitor known sites, such as missile silos and airfields, satellites now are required to find and track Soviet nuclear missiles that move about from day to day. This will be necessary to verify future arms control treaties, but the Air Force also has a more frankly military aim: targeting the missiles for destruction in wartime.

"As we see [Soviet] leadership and military forces becoming more mobile, it's putting more demands on us to detect, localize, and hold at risk those forces," said Aldridge. "The biggest difficulty is not searching the target area. Even if the sensor has flown over the target, and it is in the database, it still has to be found."

Computers can search the data from a wide area, looking for an electronic signal that matches the known return from a Soviet missile launcher. But while simple in concept, teaching computers to recognize an object—particularly when the Soviet Union is also trying to hide the targets under cover and behind trees—has proved difficult in practice. "We're still 5 years away from the point where some data comes in and rings a bell and says I've got a target X in location Y," said Aldridge.

The most valuable contribution of computer analysis, said Rona, may be in matching up information from various sensors, so that one instrument can correct the other's blind spots. While the KH-12 might be fooled by a plastic decoy built to look like a tank, for instance, the radar of Indigo-Lacrosse could immediately tell the difference. "All sensors lie a little," said Rona. "The reason that you coalesce information from all sorts of sensors is that you don't trust any of them." Attempts to write computer software capable of comparing and evaluating data from many different sources, however, have run into significant problems. Military sources estimate that working prototypes of these "data fusion" systems will not be available for several years.

Complicating the job even more is the growing demand for access to data from satellites. Not only the President, but every major U.S. military commander around the world can now request pictures from satellites to help plan military operations.

The trend began nearly 10 years ago, when the armed forces started a program called TENCAP (Tactical Exploitation of National Capabilities) aimed at making information from space reconnaissance available to military commanders. Although an Army spokesman refused to provide any information on TENCAP, calling the program "100% classified," it has been discussed frequently at congressional hearings.

In 1981, the Marines established a TENCAP elective at their staff college, said Lieutenant General Harry T. Hagaman (retired), former Director of Intelligence for the Marine Corps. "We opened that magic door . . . and many eyes were opened to what was actually out there," said Hagaman. "As you continue to educate people about what's available, you build up enthusiasm . . . and ways begin to be developed on how to break down some of the old national barriers [preventing] some of this very fine information [from being] sent lower down [the chain of command]."

The primary barrier to wider use of satellite data, said Hagaman, has been secrecy. But under the pressure of crises, such as the

Culliton Named to New Post

Barbara J. Culliton, News Editor of *Science* for the past 10 years, has decided to return to her first interest—reporting. She has accepted a newly created position at *Science* as Correspondent-at-Large, which will give her wide latitude in the choice and writing of news and features for the magazine. During her editorship, the News section has received many distinguished prizes, including the George Polk Award for the "lucidity and pertinence" of News and Comment.

military operations in Beirut and the Persian Gulf, decisions were made to distribute information that had been held very tightly by intelligence officials in Washington. "It takes a commander in the field screaming for more information to get things to change," said Hagaman.

"Most of the imagery is declassified down to the level where it's just handled as 'secret,'" said Donald Latham, former Assistant Secretary of Defense for Command, Control, Communications, and Intelligence. "We can move imagery today, worldwide, with our communications systems. We've even got suitcase versions of these systems, where you can look at [an image] and do things with it—all with soft copy, without film."

It now takes only hours, said several sources, for a picture of a particular scene to get from the satellite to the military commander who ordered it. In the future, said Aldridge, field commanders may be able to look at a scene at the very moment that the satellite is photographing it.

These technical marvels have their price. "Data fusion systems are not cheap," commented Aldridge. According to the industry newspaper *Defense News*, the Army has spent somewhere between $840 million and $1 billion during the past decade on a single system, called the All Source Analysis System, that is designed to distribute information from various intelligence sources to Army commanders. Primarily because of problems with software, "it's 2 or 3 years, and a couple of hundred million dollars away," said Hagaman.

According to published reports, the White House has agreed to a demand by the Senate Intelligence Committee that it spend $6 billion on improving surveillance systems during the next 5 or 6 years. The FAS's Pike estimates that each KH-12 satellite costs between $1.5 and $2 billion, not including the cost of launch.

The irony of spending this quantity of money on spy satellites while cutting off funds for Landsat, the civilian earth resources monitoring satellite, was noted by Congressman Dave McCurdy (D–OK), a member of the House Intelligence Committee, which approves all secret reconnaissance projects. At a hearing on Landsat on 8 March, McCurdy complained that "the green eyeshade guys down in a basement [at the White House Office of Management and Budget] are running national space policy. If [Landsat] were a special access program, we wouldn't be up here worrying about funding." ■ DANIEL CHARLES

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DOD Lists Critical Technologies

The Department of Defense (DOD) has submitted to Congress a list of 22 technologies that it considers critical to the long-term superiority of U.S. weapons systems. In every area except one, the United States holds a lead over the Soviet Union, and in most cases the lead is substantial, according to the Pentagon's analysis. But among U.S. allies, technological leadership in some key areas has gone to Japan.

The list was prepared in response to legislation authored last year by Senator Jeff Bingaman (D–NM), who says he has grown increasingly frustrated because "technologies that seemed to be on everybody's list of truly critical technologies were severely underfunded in DOD [budget] requests." That experience, says Bingaman, "left a real question in my mind as to whether we had a very well prioritized science and technology program in the DOD."

Bingaman therefore attempted to force the Pentagon to consider its technological priorities by asking DOD, together with the Department of Energy, to list 20 technologies deemed especially critical for future weapons systems. (The Pentagon came back with a list of 22.) He also asked for an assessment of where the United States stands in relation to other countries in the development and use of these technologies.

The Pentagon's report* could prove important in budget deliberations on Capitol Hill. It has already been the focus of hearings, held on 17 March, by the Senate Armed Services Committee's defense industry and technology subcommittee, which Bingaman chairs.

The report indicates that the United States holds a clear world lead in technologies that have primarily military applications, such as sensitive radars and "stealth" technology. But in most areas that also have civilian applications, the United States is losing ground to allied countries.

In the area of microelectronic circuitry and the fabrication of microelectronics devices, for example, the report states that "if current trends continue, the United States can be expected to become dependent on Japanese suppliers of many key materials and production equipment by the year 2000." The same holds true for gallium arsenide semiconductors, a technology in which "Japan is the undisputed leader," fiber optics, and some areas of materials science.

As for the Soviet Union, the report indicates that the United States is technologically superior in all the key areas except for high-power microwave oscillators. In most cases, the Soviet Union's relative backwardness in state-of-the-art computing is a severe handicap. "In the USSR, software continues to be an area of serious deficiency," the report says, and "there is no evidence that the Eastern bloc has achieved any success in high-performance computing. . . . The Soviets lag the U.S. and can be expected to fall further behind due to a lack of capability in the underlying microcircuitry." These deficiencies affect Soviet capabilities in areas as diverse as robotics and fluid dynamics, the report says.

The report estimates that DOD will spend a total of about $2 billion this year on R&D involving 21 of the 22 key technologies it identified. (The budget for one technology—suppressing the radar signature of weapons systems—is classified.) In some areas, such as the development of sensitive radars and computer modeling, the Strategic Defense Initiative (SDI) provides the bulk of the funding. This led Bingaman to suggest that perhaps Congress should move some of the programs out of the SDI budget in order to protect them when the SDI request is cut back by Congress.

The critical technologies identified by the Pentagon are: microelectronic circuits and their fabrication; the preparation of gallium arsenide and other compound semiconductors; software producibility; parallel computer architectures; machine intelligence/robotics; simulation and modeling; integrated optics; fiber optics; sensitive radars; passive sensors; automatic target recognition; phased arrays; data fusion; signature control (stealth technologies); computational fluid dynamics; air-breathing propulsion; high-power microwaves; pulsed power; hypervelocity projectiles; high-temperature, high-strength, lightweight composite materials; superconductivity; and biotechnology materials and processing. ■ COLIN NORMAN

**The Department of Defense Critical Technologies Plan*, 15 March 1989.