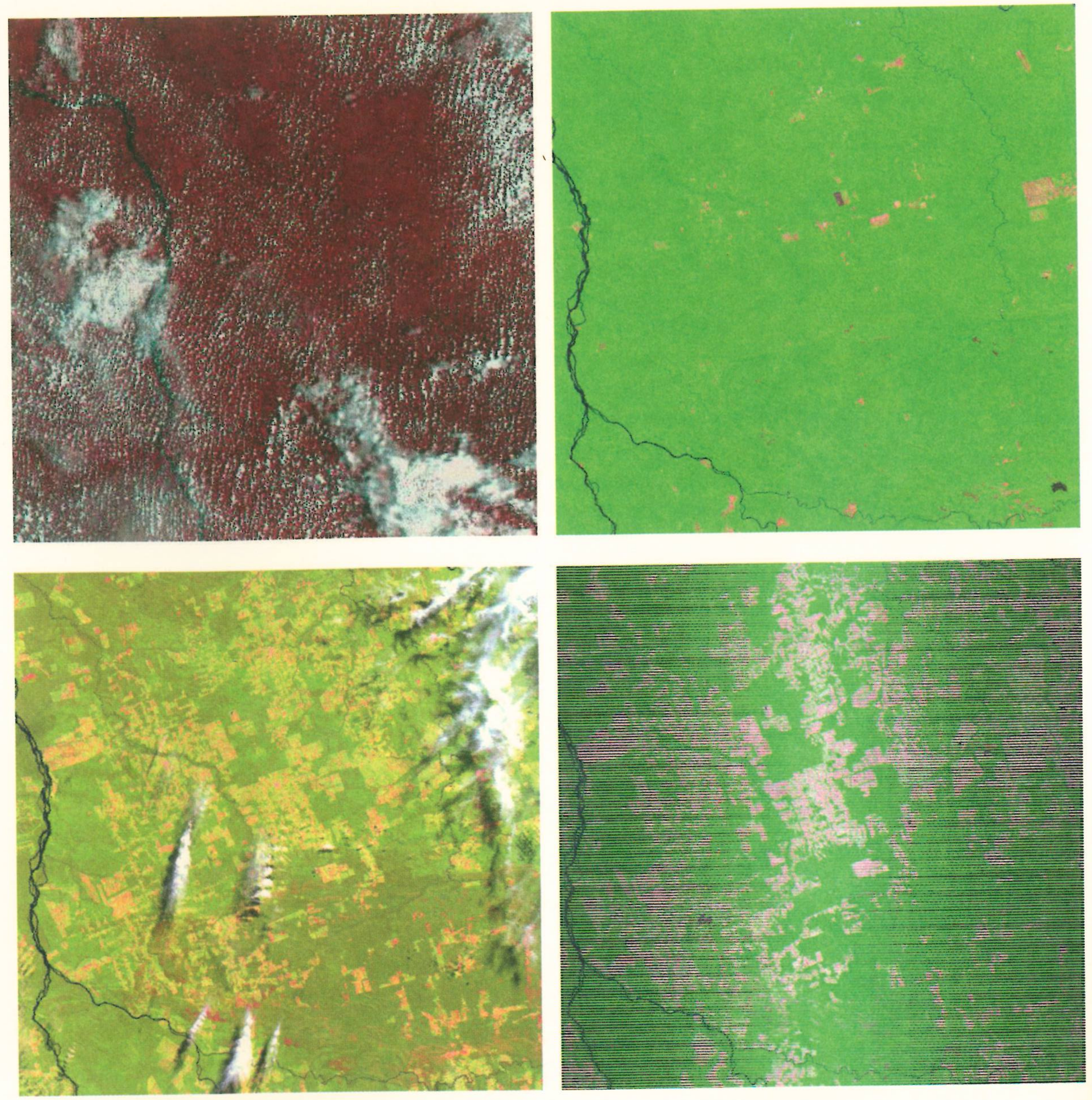


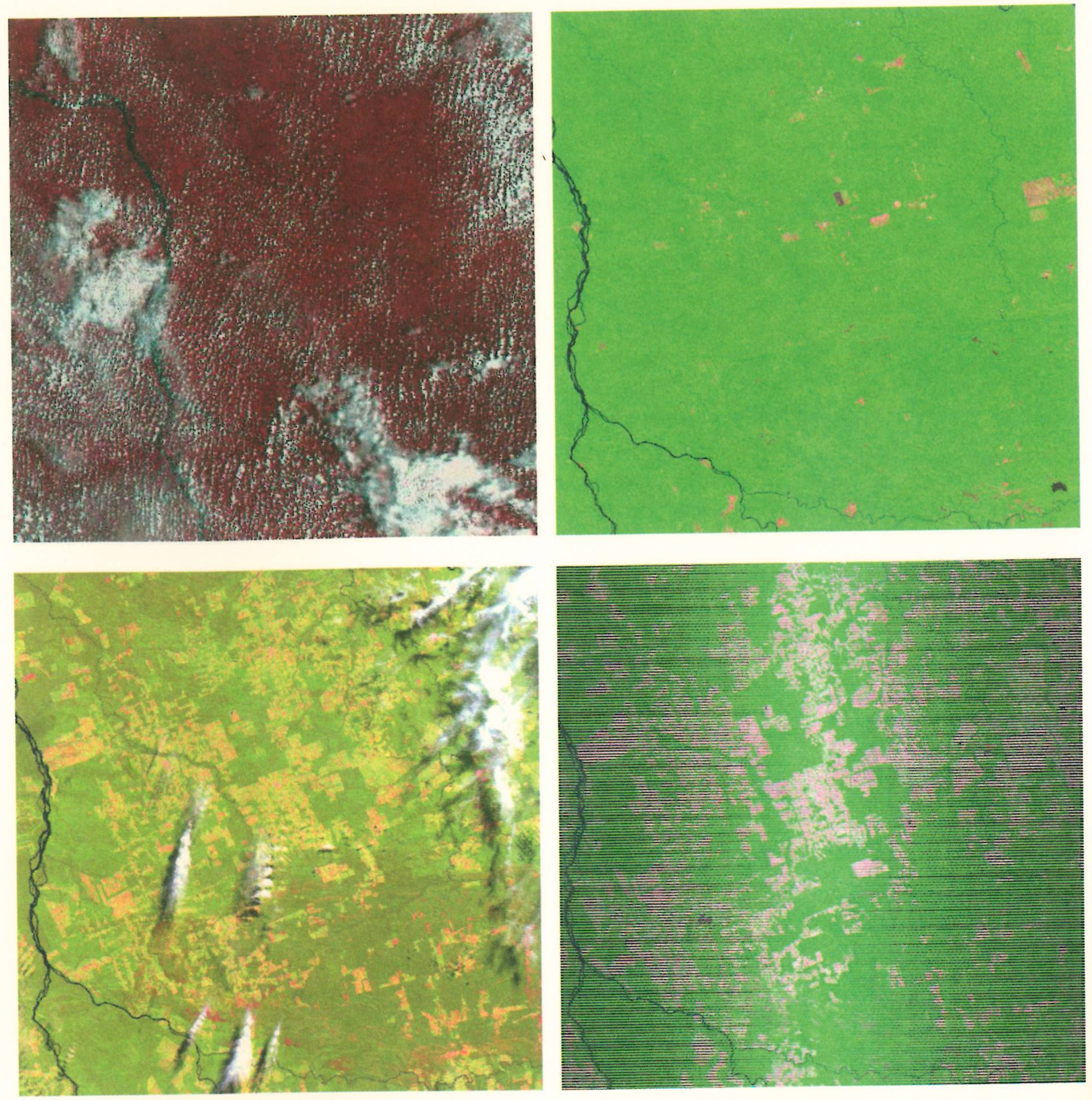
Landsat's forty-year archive gives researchers the ability to investigate changes at the same location over time. These images, acquired by Landsat 1, 4, 5, and 7, show an area near Nova Monte Verde, a municipality in the Brazilian state of Mato Grosso, just south of the Amazon, where rain forest is being replaced by ranching and monocropping. Top left: November 30, 1972; top right: August 5, 1986; bottom left: May 5, 2006; bottom right: August 4, 2012. The striping in the last image is due to failure of Landsat 7's scan line corrector.

## From Military Surveillance to the Public Sphere

The discussions of the projects in this book refer to a number of technologies used in the process of mapping—GPS, remote-sensing satellites, and GIS. The projects make use of them in order to create new images or repurpose existing ones. But the history and politics of these technologies are at once obscure and important for understanding what's at stake in working with them. The following lexicon attempts to sketch the stories of the development of these technologies, their technical language, and their political and historical contexts. This chapter, which largely eschews explicit theoretical reflection, is designed both to document the increasing public access to these technologies and to lay the groundwork for the discussions of how they have been put to use in the chapters that follow. The list is not a complete one, but touches on most of the technologies with which I have engaged.

### GLOBAL POSITIONING SYSTEM (GPS)

The GPS is a network of twenty-four satellites and five ground stations designed to provide to anyone carrying a portable receiver a highly specific determination of his or her location, anywhere, anytime, and in any weather.[1] The satellites, launched and operated by the U.S. military, are arranged in six circular orbits at an altitude of 11,000 miles, which makes it possible for at least four of them to be "seen" at one time by a receiver anywhere on Earth, and they constantly emit signals specifying their time and their own positions. A GPS receiver measures the time that the different signals take to reach it, and by comparing that with what it learns about where the satellite is, the receiver can calculate its own position. GPS location and time signals are freely available to anyone with a GPS receiver, including those embedded in other devices, such as mobile phones and cameras.



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The research and launch period for the Global Positioning System began in 1973 and ended in 1991, when the program became operational just in time for the first Gulf War. The first experimental satellite was launched in 1978, the first satellite in the system was launched in 1989, and the full constellation of twenty-four satellites, also known as NAVSTAR by the Department of Defense, was completed in 1993.[2] GPS is now not only a household word, but a ubiquitous technology—what the official GPS website calls a "U.S.-owned utility"—used for everything from directing missiles to their target, to tracking elephants, to locating mobile phones and their users, to everyday navigating on land and sea, to hiking in the mountains, to recording the precise time of a financial transaction, to playing urban games using geotagging devices, and beyond.

Originally designed to provide accurate measurements of positions to within 100 meters, GPS is now capable of locating a position within 5 meters of accuracy. Not everyone, however, has always been permitted to make use of this degree of accuracy. When the system was launched by the U.S. military, it was designated a "dual-use technology," which meant that its features were also available for civilian use—but in an intentionally downgraded way. Originally it was governed by a policy known as "Selective Availability," which intentionally scrambled the highly accurate signals so as to reduce accuracy readings to 100 meters for civilian users. It was possible for civilians to improve the accuracy using a technique called "differential correction," which involved gathering additional readings from base stations at known locations within roughly three hundred miles (the area covered by one group of four satellites) and correcting the errors by measuring against the location of the base stations. This allowed, even in the early days of the system, position readings between 2 and 5 meters of accuracy.

Over time, the accuracy and availability of the GPS system has been affected less by the limitations or capacities of the technology than by a series of U.S. government policy decisions.[4] The first was the decision to activate the system in a two-tier manner, with different quality readings available to military and civilian users.

Only five years later, in 1996, President Clinton committed the United States to the continued maintenance and upgrade of the system and announced that it was his "intention to discontinue the use of GPS Selective Availability (SA) within a decade, in a manner that allows adequate time and resources for our military forces to prepare fully for operations without SA."[5] In May 2000, the SA program was abandoned, and fully accurate GPS readings are now publicly and freely available.

Today, according to the U.S. government's online GPS information page:



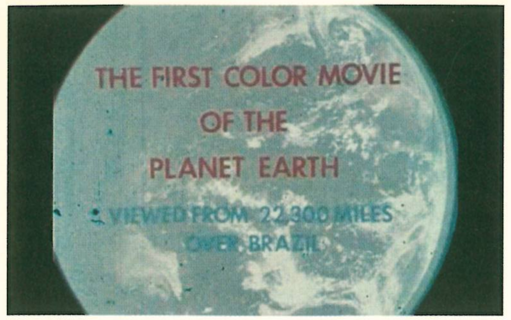
> The GPS signal in space will provide a "worst case" pseudorange accuracy of 7.8 meters at a 95% confidence level. The actual accuracy users attain depends on factors outside the government's control, including atmospheric effects and receiver quality. Real-world data collected by the FAA show that some high-quality GPS SPS receivers currently provide better than 3 meter horizontal accuracy. [FAA data from early 2011 shows GPS SPS was often accurate to ~1 meter.] Higher accuracy is available today by using GPS in combination with augmentation systems. These enable real-time positioning to within a few centimeters, and post-mission measurements at the millimeter level.... The accuracy of the GPS signal in space is actually the same for both the civilian GPS service (SPS) and the military GPS service (PPS). However, SPS broadcasts on only one frequency, while PPS uses two. This means military users can perform *ionospheric correction*, a technique that reduces radio degradation caused by the Earth's atmosphere. With less degradation, PPS provides better accuracy than the basic SPS. Many users enhance the basic SPS with local or regional augmentations. Such systems boost civilian GPS accuracy beyond that of PPS.[3]

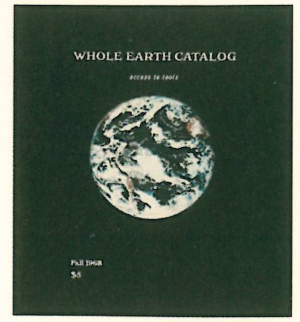
In 2004, President Bush created the National Executive Committee for Space-Based Positioning, Navigation, and Timing (PNT) and adopted a new national policy committed to modernization, sustainability, and maintenance of GPS as a free worldwide utility.

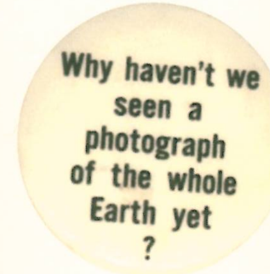
> Over the past decade, the Global Positioning System has grown into a global utility whose multi-use services are integral to U.S. national security, economic growth, transportation safety, and homeland security, and are an essential element of the worldwide economic infrastructure. In the year 2000, the United States recognized the increasing importance of the Global Positioning System to civil and commercial users by discontinuing the deliberate degradation of accuracy for non-military signals, known as Selective Availability.[6]

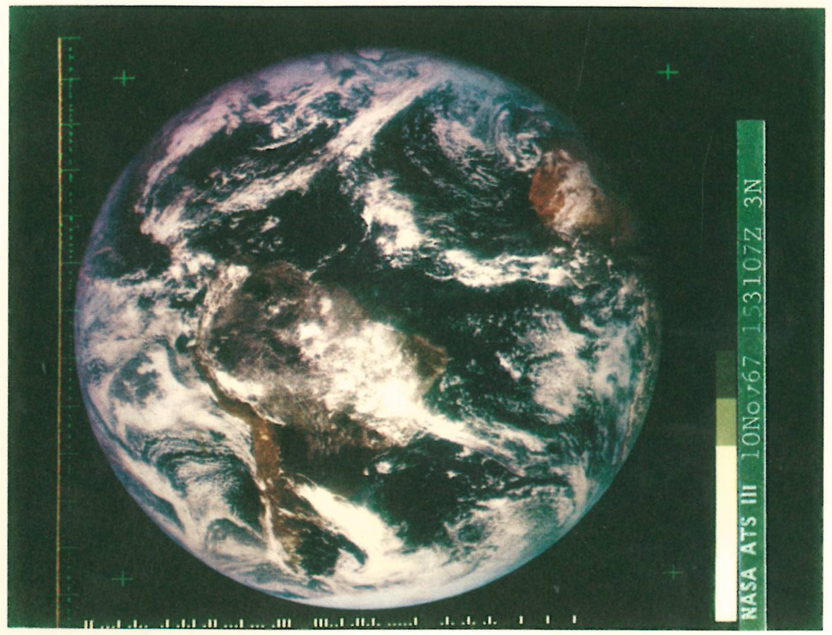
The policy acknowledges the development of European-based PNT systems and supports standards of interoperability and compatibility so that they might rely on each other's infrastructure. The policy also endorses a more accurate version of the system for military use, but without SA. In 2010, President Obama reaffirmed these policies.

Other nations have begun putting their own PNT systems into place. In Russia, the system is called GLONASS and has been in operation since 1995. Galileo is a system being developed by the European Union and other partner countries and is planned to be operational by 2014. There are other regional systems being planned by China, India, and Japan.




In 1966, Stewart Brand printed and sold buttons which asked the question, "Why haven't we seen a photograph of the whole Earth yet?" As his colleague Robert Horvitz wrote later, "Stewart wanted NASA to release a photo of the whole Earth because he believed it would have significant psychological impact: it would be visual proof of our unity and specialness, as our luminous blue ball-of-a-home contrasted dramatically with the dead black emptiness of space. Differences in skin color, religion, nationality and wealth, which can seem so important down here on Earth, shrink to nothing when viewed from afar." No spy satellite images were declassified. But a year later, NASA and a team of weather scientists at the universities of Wisconsin and Chicago released a film made of images taken by the newly launched ATS-III satellite in November 1967, titled "The First Color Movie of the Planet Earth: Viewed from 22,300 Miles over Brazil." And in the fall of 1968, the first issue of Brand's *Whole Earth Catalog* told readers how to buy a 16mm print of the film, and featured another image, also from the ATS-III spin-scan camera, taken over Brazil on November 10, 1967, on its cover. SATELLITE IMAGE: NASA

## REMOTE-SENSING SATELLITES

The *Oxford English Dictionary* defines "remote sensing" as the sensing "of something not immediately adjacent to the sensor; *spec.* the automatic acquisition of information about the surface of the earth or another planet from a distance, as carried out from satellites and high-flying aircraft." Remote sensing implies the collection of knowledge from an array of distances and methods, from human sight and sound to seeing and hearing from hundreds of miles in the sky or deep down in the ocean from the water's surface. What follows, however, focuses only on remote-sensing satellites and the technologies that allow us to see very closely from a distance.

Remote-sensing satellites have been launched since the 1960s, generally to an altitude of between 400 and 900 kilometers (249 and 559 miles) above the Earth, first by the United States and the Soviet Union (later Russia) and then by other states, including France, Israel, and India.[7] Remotely sensed images are generated either by the telescopic lenses of cameras or by sensors on the satellites. Older satellites captured what they sensed as analog images on physical storage surfaces, such as film, while later satellites have transmitted their data as digital information that is converted to images by ground stations. With either method, what remote-sensing satellites sense and record is reflected radiation: the ordinary visible light spectrum that allows us to see colors, and, since the 1970s, the nonvisible infrared spectrum that allows, for example, for types of vegetation to be differentiated from each other by more than color.

This is all that each remote sensing satellite has in common. What follows outlines a series of satellites used for remote sensing from 1960 until 2010. It is by no means a complete list, but can serve as an introduction to the satellites used here. The orbiting platforms range from spy satellites launched by the U.S. military and intelligence agencies (for instance, Corona), to those launched with public funds to monitor the Earth's resources (Landsat and SPOT), to privately launched satellites that today make very high-resolution imagery publicly available (for instance, Ikonos and GeoEye). This sequence tells the story of the technopolitical transformation of access to remote-sensing imagery, a progression in both access and resolution that today makes very detailed images of the Earth from outer spac;e almost commonplace. The history is one of a tension between secrets and spying, on the one hand, and access and commerce, on the other, finally enabling nonprofessionals and civilians to make use of these powerful information resources.[8]

In my work, the satellites I have made use of are mostly those launched by the United States and operated by a combination of private corporations and U.S. government agencies. This is not an accident. Aside from the French SPOT satellites, launched in 1986, the United States has always had the highest-resolution imagery available and has maintained a set of policies designed to guarantee its global dominance in the field of satellite imagery.[9] This may change in the future. As with GPS satellites, other countries have launched high-resolution Earth-imaging satellites, including India, China, Japan, and Israel, and this list will expand to include Turkey, South Africa, and the Gulf Cooperation Council in the next decade.[10]

### CORONA (UNITED STATES, 1959–1972)

Begun under the Eisenhower administration in reaction to the Soviet Union's Sputnik project, the Corona program focused primarily on photographing the Soviet Union and the People's Republic of China. The series of six classified satellites—dubbed KH-1 through KH-4B in a series of secret documents titled *Talent Keyhole*—produced high-resolution images for intelligence, reconnaissance, and mapping purposes. Today, Corona negatives and accompanying documents are available in the public sphere, prominently featuring the crossed-out words "TOP SECRET."

Over time, the ground resolution of Corona imagery improved from 40 feet to 5 feet.[11] Individual Corona images are film negatives, each recording 10 miles by 120 miles of ground space. The imagery was exposed on a newly designed physical polyester film, now known as Mylar. It was collected onboard the satellite in rolls and ejected or "de-orbited" in canisters inside a capsule with small parachutes, to be picked up in midair by aircraft at a location near Hawaii. "The capsules were designed to float, so that if the plane missed, Navy boats could retrieve them. In case the boats missed, the capsules were fitted with salt plugs that would dissolve after two days in the ocean, causing the capsule to sink beneath the waves, so the film could never fall into enemy hands."[12]

Rather than orbiting the earth for long periods of time, Corona satellites were "tasked" on missions to specific sites and territories. Corona was alternately used to spy on and to map certain locations. On its first successful one-day mission, August 18, 1960, KH-1 orbited the Earth only three times, taking pictures of 1.65 million square miles of the Soviet Union and Eastern Bloc countries on three thousand feet of film. Later missions lasted up to nineteen days, and the KH-4 satellites were equipped with two cameras—for both intelligence and mapping purposes. The last imagery was acquired by the KH-4B satellite on May 31, 1972. According to historian Keith Clarke, "The systems worked so well that in short order the CIA was using Corona to map the world, remap the U.S., and to evaluate all 1:24,000 topographic maps for revision."[13]

The archive of over eight hundred thousand Corona images—2.1 million feet



of film in thirty-nine thousand canisters[14]—was declassified on February 22, 1995 with President Clinton's Executive Order 12951. The archive became available to the public three months later.[15]

### LANDSAT (UNITED STATES, 1972– )

Appearing concurrently with the nascent environmental movement of the 1970s and dubbed the ERTS-1 (Earth Resources Technology Satellite), Landsat names a series of seven satellites launched by the National Aeronautics and Space Administration (NASA). The first was launched in July 1972. Together, they comprise the first publicly accessible remote-sensing program. Of these seven satellites, only Landsat 5 and Landsat 7 are currently functioning. A further satellite, known as the Landsat Data Continuity Mission, is scheduled for launch in 2013.[16]

Over time, ground resolution of the Landsat images has increased from 80 meters to 15 meters, which is officially described as "moderate." Each Landsat scene measures 170 by 185 kilometers (106 by 115 miles) of ground space. At its highest resolution, Landsat can picture large buildings and airstrips. According to a NASA presentation on Landsat, "this is an important spatial resolution because it is coarse enough for global coverage, yet detailed enough to characterize human-scale processes such as urban growth."[17] Landsat satellites orbit the Earth on predictable paths. The same coordinates are imaged at nearly the same time of day, every fourteen to eighteen days.

Because Landsat imagery is inexpensive and readily available, it is used frequently by researchers to investigate and highlight large-scale patterns related to climate change, natural resource management, land development, or disaster recovery. However, Landsat was not always so accessible. In the early 1980s, the program was privatized, and the National Oceanic and Atmospheric Administration (NOAA) selected the Earth Observation Satellite Company (EOSAT), later known as Space Imaging, to archive, collect, and distribute Landsat data as well as to build, launch, and operate the next two Landsat satellites (with government subsidies). As NASA tells the story today, "commercialization proved troublesome, with NOAA and EOSAT raising the cost of images by 600%, effectively "pric[ing] out many data users." Faced with competition from the newly launched French SPOT satellite and with coverage collapsing because EOSAT acquired imagery only when there were customers to buy it, Landsat images nearly disappeared by the end of the decade. "By 1989," reports the NASA Landsat history, the program was in such shambles that "NOAA directed EOSAT to turn off the satellites (no government agency was willing to commit augmentation funding for continued satellite operations, and data users were unwilling to make the hefty investments in computer processing hardware if future data collection was uncertain)."[18]

Over the course of the 1990s, control of Landsat's satellites and its imagery output was gradually returned to the U.S. government.[19] The pivotal role of Landsat imagery in the planning and implementation of the Gulf War,coupled with competition from the newer and cheaper SPOT, led to the Land Remote Sensing Policy Act, signed into law by President Clinton on October 28, 1992. It bolstered the Landsat program, stating that "continuous collection and utilization of land remote sensing data from space are of major benefit in studying and understanding human impacts on the global environment, in managing the Earth's resources, in carrying out national security functions, and in planning and conducting many other activities of scientific, economic and social importance."[20] The latest satellite, Landsat 7, was launched in 1999, and on July 1, 2001, operational control of the entire system and its archive was officially returned to the federal government, with EOSAT/Space Imaging giving up their commercial right to Landsat data. The program appears to be set to continue with the Landsat Data Continuity Program. Landsat images can be obtained from http://landsat.gsfc.nasa.gov.

### SPOT (FRANCE, 1986– )

SPOT, an acronym for Système Probatoire d'Observation de la Terre, is a series of five satellites launched between 1986 and 2002 by the French national space agency, the Centre National d'Études Spatiales (CNES), in collaboration with Swedish and Belgian scientific agencies. At the time of its initial launch, SPOT 1 posed a serious challenge to the U.S. and Soviet monopoly on satellite imagery by offering 20-meter and 10-meter spatial resolution, significantly better than Landsat. Of the five satellites, SPOT 4 and SPOT 5 are currently functioning, and Astrium GEO Information Services (the private owners of the system) planned to launch two new satellites in 2012 and 2013 (SPOT 6 and 7) with ground resolution as high as 1.5 meters, as well as a successor pair of satellites called Pléiades, offering half-meter resolution (the first was launched in September 2012).[21]

Over time, SPOT image data has improved from 20 meters to 2.5 meters ground resolution at an altitude of 832 kilometers (517 miles). This resolution is able to capture small buildings, but not their details. SPOT orbits around the polar axis, capable of returning to the same place on Earth every twenty-six days.

In June 2010, the company announced a data-purchase agreement with the U.S. government allowing access to all image data collected by SPOT 4 and SPOT 5 over the United States. As with Landsat imagery (in partnership with NASA), the U.S. Geological Survey can distribute these images for free.[22] SPOT announced that its image data will therefore be the "most widely used medium resolution commercial sources of Earth observation data in the U.S. government."[23] This purchase may be the U.S. government's response to the pending danger in the Landsat data



gap should a new Landsat satellite not be launched. Archival and recent can be purchased online through the SPOT catalogue at Astrium.[24]

### IKONOS (UNITED STATES, 1999– )

Launched by the private company Space Imaging (the transformed EOSAT, now known as GeoEye) in September 1999, Ikonos-2 was the first satellite to make high-resolution satellite imagery available to civilian users, leading the *New York Times* to describe it some weeks later as "the world's first private spy camera."[25]

John Pike, then in charge of space policy at the Federation of American Scientists, told the *Times* that high-resolution imagery "was revolutionary when it was available to the nuclear powers, and one expects it to have similar potential now that it is commercial."[26] Robert Wright, writing in the *New York Times Magazine*, called it "a geopolitical milestone. Able to discern objects only a few feet wide—to see at 'one-meter resolution'—it will give presidents, generals and assorted political actors around the globe a kind of power once confined to elite nations."[27]

Ikonos was launched with the capability of providing image data with 1-meter ground resolution in a swath 11.3 kilometers (7 miles) wide from an altitude of 681 kilometers (423 miles). It functions by combining 82-centimeter (32.28-inch) resolution black-and-white ("panchromatic") images with 4-meter (13.12-foot) resolution multispectral images to create 1-meter (3.28-foot) color imagery (pan-sharpened).[28] At 1-meter resolution, Ikonos can distinguish a tank from a truck. Every point on Earth can be revisited by Ikonos every three to five days. Although its lifespan was a proposed seven years, Ikonos is still functioning.

Ikonos does not collect a steady stream of images. Its sensors are turned on only to record image data when tasked. Once the satellite is assigned an objective and the image data is received by a purchaser, it becomes available for repurchase and can be ordered and received through a website that includes the image data's longitude, latitude, and date stamp, but not the identity of the tasking agency or individual. Between its launch in 1999 and mid-2011, Ikonos had imaged more than 280 million square kilometers (over 100 million square miles) of the Earth's surface.[29]

The simultaneous provision of high-resolution image data to civilians, the U.S. military, and other governments globally was made possible by President Clinton's March 10, 1994, Presidential Decision Directive, which "among other things, loosened restrictions on the sale of high resolution imagery to foreign entities."[30]

According to the European Space Agency, "the spacecraft operations of Ikonos-2 are unique among the current commercial imaging satellites in that they allow each international affiliate to operate its own ground station(s). These ground stations are assigned blocks of time on the satellite during which they can directly task

On the front page of the *Washington Post* on March 3, 2005, Dana Priest revealed the existence of a secret CIA prison, code-named the Salt Pit, near Kabul, Afghanistan. Eight months later, she reported that the Salt Pit had been an early part of a "hidden global internment network," a series of so-called "black sites," in which the CIA housed and interrogated terror suspects. Her first article had offered enough detail to send GlobalSecurity.org looking for earlier satellite images of the Salt Pit, and so the second article included a high-resolution Ikonos satellite image of the building.

Top: Salt Pit, as seen by Ikonos satellite, January 25, 2001. COURTESY GEOEYE

Bottom: Salt Pit, as seen by Ikonos satellite, July 17, 2003. COURTESY SPACE IMAGING MIDDLE EAST

Ikonos, and immediately receive the downlinked imagery for which they tasked."[31]

The launch of Ikonos allowed the United States to retain its position as the primary provider of highest-resolution image data globally, but in so doing, it introduced sensitive issues of "shutter control," which, in the words of former Space Imaging vice president Mark Brender, "provides a lever by which the U.S. government can interrupt service when there is a 'threat to national security or foreign policy concern.'"[32] Rather than exercising shutter control, however, the U.S. government has deployed other means of controlling imagery during sensitive times: for example, purchasing the rights to all Ikonos image data over Afghanistan and Pakistan for the two months directly following the September 11, 2001 attacks on the United States. Images from the Ikonos archive, as well as new (tasked) acquisitions, are available for purchase worldwide through GeoEye.

## QUICKBIRD-2 (UNITED STATES, 2001– )

QuickBird-2 was launched in October 2001, less than a year after the loss at launch of its predecessor, QuickBird-1. It is a high-resolution Earth-observation satellite owned by DigitalGlobe. It operates in a polar orbit, 482 kilometers (299.5 miles) above the Earth, with a swath width of 18 kilometers (11 miles). It is capable of sub-1-meter resolution, as high as 65 centimeters (25.6 inches).[33] Like Ikonos, QuickBird does not collect image data unless tasked to do so. It can revisit some sites beneath its orbit as frequently as every two and a half days, others within no more than six days. QuickBird-2 is also subject to shutter control, although the U.S. government has never implemented it.

QuickBird-2 and the other satellites in what DigitalGlobe calls its "constellation of sub-meter spacecraft" have emerged as major providers of overhead image data to the U.S. government. In a 2002 memo to the director of the National Imagery and Mapping Agency (NIMA), then–CIA Director George Tenet specified that "it is the policy of the Intelligence Community to use U.S. commercial space imagery to the greatest extent possible" and that the U.S. government should use commercial satellites unless military ones provide better resolution with classified image data.[34] DigitalGlobe has since been awarded two contracts by the U.S. government: $500 million from the NextView program in September 2004 and $3.5 billion over ten years from an EnhancedView contract in August 2010.[35]

The "sub-meter constellation" also does nongovernmental work. DigitalGlobe has agreements with humanitarian and human rights initiatives, among them the Satellite Sentinel Project at Harvard University, to provide QuickBird-2 and other images of zones of conflict in nearly real time. In March 2011, for instance, a DigitalGlobe vice president announced, on the company's blog, the release of satellite images of burned and destroyed villages in the Abyei region of Sudan. He wrote: "We've collected, processed, analyzed and delivered imagery and information in record time, given the urgency of the situation and the need to demonstrate to both sides that the world is watching." He added, for context, that this was simply part of the satellite business:

> we do keep a constant eye on the planet, to gain early insights into the business, market, environmental and political changes that impact people around the world. That's why we are keeping such a close eye on Sudan. It may be hard to watch, to look at an image and know someone's home is gone, a livelihood destroyed, that many lives have been lost. All involved are seeking the truth in pictures, and delivering valuable information and insight to both sides of the country. We certainly hope that one day, peace will come to this nation.[36]

QuickBird-2 image data can be purchased at digitalglobe.com, along with that of its fellow DigitalGlobe satellites WorldView-1 (50-centimeter/19.7-inch resolution) and WorldView-2 (46-centimeter/18.1-inch resolution).

### GEOEYE-1 (UNITED STATES, 2008– )

The revolution in the privatization of high-resolution imagery from outer space that is exemplified by the generation of satellites from Ikonos on stems both from the declassification efforts of the 1990s and a series of U.S. government decisions to "support the continued development of the commercial satellite imagery industry by sharing the costs for the engineering, construction and launch of the next generation of commercial imagery satellites."[37] One result was the September 2008 launch of GeoEye-1, a private satellite owned by GeoEye with resolution below a half meter (41 centimeters, 16.41 inches). Its swath width is just over 15 kilometers (9 miles), and from its sun-synchronous polar orbit 681 kilometers high (423 miles), it can revisit anywhere on Earth once every three days, passing overhead, like other imaging satellites, at 10:30 a.m., local time. Like Ikonos, also owned by GeoEye, and QuickBird-2, it is subject to shutter control and does not collect imagery unless tasked to do so.

According to GeoEye, "While the satellite collects imagery at 0.41-meters, GeoEye's operating license from the U.S. Government requires re-sampling the imagery to 0.5-meter for all customers not explicitly granted a waiver by the U.S. Government."[38] Nevertheless, at this reduced 50-centimeter resolution, the home plate of a baseball diamond is visible from space.

GeoEye's CEO wrote in January 2010:

> The defense and intelligence communities have developed a huge appetite for unclassified, high-resolution, map-accurate satellite imagery. One leading reason is that our government can freely share unclassified images with allies, coalition partners and disaster relief workers, thus speeding collaboration and time-critical decision-making. Another reason is that commercial imagery is highly cost-effective because we can resell excess capacity and imagery to commercial customers.
>
> As a result, the use of satellite imagery by analysts and mapmakers at military headquarters is the norm.[39]



After the U.S. government, GeoEye's second major customer is Google. Since mid-2009, a lot of GeoEye-1 imagery has been freely available to Google Earth users. Although the Google logo was prominently displayed on the launch rocket—such that *Wired* magazine could title an article "Google's Super Satellite Captures First Image"[40]—Google does not own the satellite. Instead, through its Google Earth interface, it distributes and makes accessible imagery produced and tasked by others. (There is of course a possibility that Google has commissioned GeoEye imagery collection for its own purposes, but if so, it's a closely held secret.) It is unclear whether Google displays the GeoEye imagery at its full resolution, and since one cannot download images from Google Earth in the same way as one can from GeoEye itself—where each pixel has a size of one square meter and a longitude, latitude, and spectral signature—it's rather difficult to find out. For its full resolution and data, GeoEye-1 image data can be purchased at www.GeoEye.com.

### GEOGRAPHIC INFORMATION SYSTEMS (GIS)

The Global Positioning System and remote-sensing satellites simply generate data. GIS is the generic name for software that allows users to locate data spatially. Any line on a spreadsheet, item on a list, or field in a database that records a physical address has the potential, once linked to its geographic coordinates, to become a point on a digital map. Once that point is recorded, it can be linked to or labeled with any other sort of data: the address can be connected to the name of a road, a dollar amount, a color or a shade, something a person said, a crime committed or thwarted, an encounter with an animal or a deity, or almost anything else that can be stored in a database—and that includes nonquantitative data.

Environmental Systems Research Institute (ESRI) is the Microsoft Word of GIS software and has the generic Web domain name www.GIS.com. GIS is described by ESRI as a system that "integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information."[41]

The most popular textbook on GIS, *Geographic Information Systems and Science*, describes the "field of GIS as concerned with the description, explanation, and prediction of patterns and processes at geographic scales. GIS is a science, a technology, a discipline and an applied problem solving methodology."[42] The textbook description says nothing about hardware and software, and rightly so, because it focuses on how GIS has radicalized and transformed the methodologies and processes of cartography, geography, urban planning, urban design, data management, archeology, sociology, and public health, among many other fields and practices. Although these are very different disciplines, they all have a stake in using maps as a basis for research and analysis.

Over the course of its short history, GIS has been commonly talked about as having transformed cartography into spatial data management. GIS has become a metaphor for the role that data now play in the drawing of new maps of the world, especially its cities and its resources. Often, the data is newly created for the map. What GIS does well is to layer diverse sets of information onto a single digital file or map.

Both these things—data displayed on maps and a layering of data onto maps—have long histories. Depending on where one starts the historical trajectory, one will end up with a very different interpretation of the meaning and uses of GIS. For example, some urbanists and public health researchers put the origin of GIS in John Snow's 1854 map of cholera in London. For them, the social data and statistical methods embedded in GIS are critical to the ways in which they define it.[43] These methods, which were developed later by Charles Booth in his poverty maps of London in 1898–99 and then by the Chicago School of sociological research in the first half of the twentieth century, constitute in effect the history of the modern city and define the modern history of cartography.[44]

But there are other genealogies. Some cite Ian McHarg's 1969 *Design with Nature* as the origin of GIS.[45] McHarg famously produced manually layered topographical maps with multiple sources of information in order to suggest ecologically smarter layouts for highways.[46] Slope, surface drainage, scenic value, residential values, forests, institutions, erosion, and so on were layered together into what McHarg called a "composite," an image in which one could see the effects of the layers on one another. The overlays bore titles such as "Composite: All Social Values" or "Composite: Physiographic Obstructions." McHarg's maps featured proposals such as "Recommended Minimum-Social-Cost Alignment" for a highway construction project. McHargian users of GIS have an expanded and design-oriented view of the built environment, one that incorporates ecological, landscape, and urban patterns, as well as the social forces that might affect those patterns.

The dominant history of GIS traces only the hardware and software that make up the GIS we know today on our computer desktops. The history section



of *Geographic Information Systems and Science* begins in the mid-1960s in Canada, where the first "real GIS" was a "computerized map measuring system."[47] It was produced to create the Canada Land Inventory System, a project—classically cartographic—to identify resources and their potential uses.[48] A second phase of rapid development, they write, came from the U.S. Census Bureau, which, planning for the 1970 census, created the DIME (Dual Independent Map Encoding) program, allowing the creation of digital records of every street in the United States such that the population could be referred and aggregated to specific geographies. From the perspective of emerging GIS software development, these two programs responded to the "same basic needs in many different application areas, from resource management to the census."[49]

These narratives and genealogies are important as examples (and this is not the full scope of genealogical narratives of GIS) because neither data collection nor software are neutral in the uses of GIS. Sociologists, urban planners, advocacy groups, and other users of GIS software often tend to downplay the art of mapping and can unknowingly, or knowingly, as Mark Monmonier has argued, "lie with maps."[50] GIS software, which hides from the viewer or user of the map the statistical operations that the maker of the map utilizes, can make this traditional possibility a great deal easier. A more polite term for this, which acknowledges the explicitly aesthetic operations of some GIS users and recognizes the deployment of maps for persuasive purposes, as well as for the management of people and things, would be that of Dennis Wood, "the power of maps."[51]

Obviously, the design of the data and the reasons for its collection have an effect on the biases of the map. Now that many specialists other than cartographers can make maps, it is especially important to understand the sources of data they rely on, the products of which are maps and images that are having an effect on policy, cities, landscapes, privacy, and beyond.

Remote sensing had an enormous influence on the data and imagery in GIS. Aerial exploration of the Earth's surface not only generated the image bases for all sorts of maps, but also allowed interpreters to discover new things about everything from land use to population density to changes in landscapes and landforms. The Corona program was already using satellite imagery to map large parts of the United States and elsewhere by coordinating its measurable images with mapping reference grids (longitude and latitude). And as the 1990s dawned, GPS emerged as an unprecedented and inexhaustible source of new data points.

However, no one, really, would be using GIS were it not for the emergence of desktop and then portable computers and the World Wide Web, which dramatically democratized the availability of data-processing power in the late 1980s and early 1990s and effectively put GIS–like data and software into mass circulation.

With the ubiquity of personal computers and the increased availability of GIS software and geospatial data—whether from GPS, remote-sensing satellites, or public and private libraries and archives—the ability to access, interpret, and put to use digital images of events occurring anywhere in the world, on any scale, from the local to the global, is no longer the sole property of governments, militaries, and large corporations. What the dissemination of these technologies has enabled is the democratization of what I have called "para-empirical" investigations. What follows here are nine such investigations, together with reflections on the ways in which they can help us understand better how the images generated by this hardware and software are used, how the rest of us can explore their unintended consequences and unexpected byproducts—and how sometimes we can make such images ourselves.