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I Can See It From Afar; I Can Hear It From Afar

Intelligence From Space[1]

by Robert A. McDonald, Ph.D.

The middle of the 20th century witnessed a revolution in intelligence gathering; one that gave the world a new perspective—from afar. With the successful launch of America's Grab electronic reconnaissance (ELINT) satellite in June 1960 and the successful launch of America's Corona imagery reconnaissance (IMINT) satellite two months later, the US Intelligence Community marked the beginning of what would be a growing capability to see and hear intelligence targets of interest from space, hundreds of miles above the Earth's surface. The discipline of national reconnaissance was born.

The perspective from space changed the practice of intelligence gathering. It gave intelligence officers the ability to monitor denied areas; regular access to remote targets of interest, the means for collecting large quantities of data, and the perspective of a synoptic view. It also gave those collecting intelligence the security of distance from the target. Operating from space has made observation very different.

Understanding Collection of Intelligence From Space

What defines space? In its simplest definition from a geocentric perspective, space is what is beyond the Earth's atmosphere and extends into the universe. For the purposes of collecting intelligence from satellite platforms, space can be considered to begin somewhere in the upper atmosphere at the point where a satellite is able to orbit the earth. This generally is at 100 kilometers (62.1 miles) above Earth's mean sea level, an altitude known as the Kármán line.[2]

The environment of space is hazardous and unfriendly, putting intelligence operations at risk. Space is a near vacuum with pressure nearly at zero. It is extremely cold with temperatures dropping to absolute zero. Gravity at the altitude of where satellites orbit the earth is much less than on the surface of Earth. At 200 miles (321.8 km) altitude, gravity is about 90% of what it would be at sea level; however, spacecraft in orbit constantly are falling toward the Earth in a circular motion that creates the orbit, and any objects in a spacecraft would be in a microgravity environment while in this "free fall."[3] There are also radiation belts with very high energy particles that have the potential to interfere with satellite operations. Electromagnetic energy (e.g., x-rays, ultraviolet, gamma rays, microwaves, radio waves), along with meteoroids and the charged particles of cosmic rays all are present in space. The very high energy particles can pass through the skin of a satellite, be absorbed by its electrical components and directly affect the electronics of the satellite, as well as have adverse effects on the data in any on-board memory. The harsh environment of space, with its threatening temperature, vacuum conditions, radiation belts, and solar storms, all are important operational threats that designers of reconnaissance satellites and the operators of satellite reconnaissance missions must take into consideration as they deal with the physics of space missions.[4]

The designers and operators of satellite reconnaissance missions face the practical realities of the physics of space missions — the challenges of leaving earth and circling it, i.e., launch operations and orbital motion.

Launch Operation. The first challenge is getting into space—launching a satellite so it has enough

1. Editor's Note: The author wrote this article in an unofficial capacity as an independent activity, and it represents his personal assessment and views. The content of the article does not reflect the official position of the National Reconnaissance Office or any other US Government entity. It has been approved for public release.

2. The Karman line is named for Theodore Von Kármán, who in the 1950s identified the dividing line between aeronautics and astronautics. Aeronautics depended on the atmosphere; astronautics depended on the absence of an atmosphere. Note that the USAF and NASA define space as beginning at an altitude of 80.5 km/50 mi, the altitude at which anyone who reaches it is awarded astronaut wings. Montgomery, J. and St. John, A., *Space Environment*, *Aerospace Dimensions*, Module 5. 2nd Edition, Maxwell AFB, AL: Civil Air Patrol, 2010.

3. This "free fall" would be like riding in an elevator after the cable breaks (Montgomery and St. John, *Space Environment*.

4. Damon, T., *Introduction to Space: The Science of Spaceflight*, Malabar, FL: Orbit Book Co., 1990: 45-60; and Montgomery and St. John, *Space Environment*.

Terminology for National Reconnaissance

National Reconnaissance is the term for the discipline and practice of space-based intelligence collection and associated activities. It comprises technical intelligence collection funded by the National Reconnaissance Program and conducted by the National Reconnaissance Office (NRO) under its mission to conduct research, development, acquisition, launch, and operation of satellite reconnaissance systems and other missions as directed, to include the NRO communications infrastructure. The most common terminology for national reconnaissance is "satellite reconnaissance."

Over the years, for security reasons, there have been euphemisms used in place of the term "satellite reconnaissance." During 18 years of its early history, the mere "fact of satellite reconnaissance" was classified, and the term "overhead" came into use—an ideal term because of both its ambiguity and its application to national imagery and SIGINT operations with either high-altitude aircraft (i.e., the U-2 and SR-71) or satellites (i.e., Grab, Corona, and their follow-on systems). It was only after President Carter declassified the "fact of photoreconnaissance satellites" in 1978, during his policy discussions related to SALT II, that there could be open acknowledgement of space borne intelligence.

The phrase "National Technical Means" or "NTM" also has been used for space-based reconnaissance activities. This usage was derived from language in the 1972 SALT I Interim Agreement and Protocol on Limitation of Strategic Offensive Weapons. At that time, the US and USSR agreed to use this euphemism because of the then sensitivities associated with public acknowledgment of satellite reconnaissance. The treaty avoided the term, "satellite reconnaissance" and merely stated, "… each Party shall use national technical means of verification at its disposal in a manner consistent with generally recognized principles of international law."

Because of its use in an international treaty, the terminology, "national technical means," has a narrower, specialized, diplomatic meaning linked to the language in the treaty; however, it has become convenient to use "national technical means" (and its acronym, "NTM") as shorthand for national reconnaissance. The usage of the terminology, however, has a treaty context, and therefore, actually has broader meaning than merely "national reconnaissance." National technical means would include not only collection via satellites, but also via aircraft, seismic and electronic sensors, and other technical means designed to monitor a state's activities related to treaty compliance.

The expression "national reconnaissance" is the more precise terminology for use when referring to nationally-controlled space-based intelligence collection and related activities.

power or thrust to counteract the force of gravity. The weight of the spacecraft, its payload, and its launch vehicle are major factors in determining the energy necessary to achieve orbital altitude. Weight, therefore, is a significant consideration in the design and construction of satellites. The launch initially will be vertical in order to move the spacecraft through the dense part of the atmosphere at a speed that is low enough to keep it from burning up. Once the vehicle is at the appropriate altitude, it then is put into orbit.[5]

Orbital Motion. The second challenge is getting into orbit— pitching the spacecraft over horizontally and accelerating to orbital speed. After the spacecraft is beyond the densest part of the atmosphere, it is given sufficient horizontal velocity so that its curved path does not intersect the surface of the earth. That motion parallel to the surface of the Earth will keep the spacecraft in orbit. Selecting and inserting the satellite into the right orbit is critical to the success of the reconnaissance mission. The eccentricity, altitude, inclination, period, and resultant ground trace collectively describe the nature of the satellite's orbit and its potential applicability to a particular reconnaissance mission.[6] These various orbital characteristics are fundamental to defining such mission requirements as the field of view and frequency of access that the reconnaissance satellite would have over any intelligence target on the Earth's surface. The nature of the orbit both provides opportunities and places limitations on the intelligence gathering capabilities of any particular reconnaissance satellite. For each reconnaissance mission, the planners and operators must tailor the orbit to the mission of the reconnaissance satellite.[7]

Different Earth orbits offer satellites varying perspectives, and each type of orbit is valuable for a different purpose. Some orbits appear to hover over a single spot, providing a constant view of one portion of the Earth, while other orbits may circle Earth, passing over many different locations in a day, providing frequent revisits. Some orbital maneuvering is possible to adjust the orbit, but this takes energy, and energy requires fuel. An orbit can be modified by applying

5. Damon, T., *Introduction to Space*: 27-44.

6. Eccentricity refers to the shape of the orbit, which is most often elliptical. Inclination is the angle of the orbit, e.g., 90 degrees is a polar orbit; zero is an equatorial orbit. Period is the time to complete one orbit. Ground trace is the track over the Earth's surface.

7. Damon, T., *Introduction to Space*: 27-44; and Riebeek, H., "Catalog of Earth Satellite Orbits," *Earth Observatory*, 2009. Retrieved from *http://earthobservatory.nasa.gov/Features/OrbitsCatalog/* (accessed 29 Jun 2014).

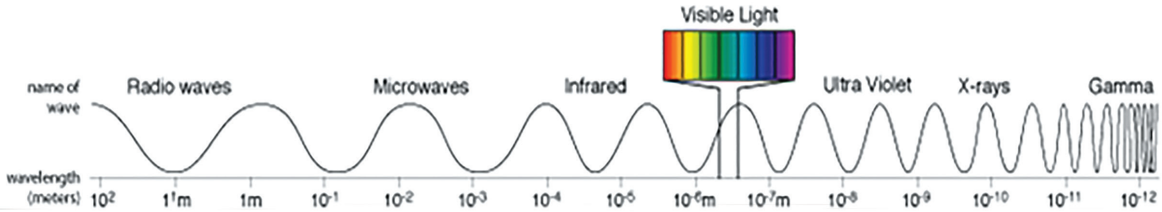

Figure 1. The Electromagnetic Spectrum (Source: NASA, 2011)

thrust at the proper time and in the proper direction. The orbit can be increased in size by applying energy opposite to the direction of motion; the orbit can be decreased in size by applying energy (or retrofiring) in the direction of motion. The eccentricity of the orbit also can be changed. An orbit can be circularized by applying a particular amount of energy at apogee.[8]

After a reconnaissance satellite is in the appropriate orbit, the focus turns to the collection of data, and these data are in the form of electromagnetic radiation. This is the essence of intelligence from space, collecting radiation along the electromagnetic spectrum.

The Electromagnetic Spectrum. All matter on Earth radiates energy either as particle energy, such as the alpha particles from uranium, or as pure energy, such as in the electromagnetic spectrum.[9] (See Figure 1.)[10] The visible part of the electromagnetic spectrum consists of the colors that are in a rainbow – from reds and oranges, through blues and violets. The waves in the electromagnetic spectrum vary in size from very long radio waves the size of buildings, to very short gamma rays smaller than the size of the nucleus of an atom (see Table 1). Objects of higher temperature radiate shorter waves; objects of lower temperature radiate longer waves.[11] All matter that has a temperature above absolute zero emits electromagnetic radiation over a continuum of wavelengths. Green vegetation reflects green light from the sun; transmitters on the Earth's surface emanate radio waves; even the human body, a living organism with a temperature of 98.6° F, emits radiation in the form of infrared. These, and all other objects on the Earth's surface, absorb and reflect other ambient radiation in the environment.[12]

Types of EM Radiation	Wavelength
Radio Waves	10^{11} micrometers
Radar	10^{5} micrometers
Infrared	10^{2} micrometers
Visible Spectrum	1 micrometer
Ultraviolet	10^{-1} micrometers
X-Rays	10^{-2} micrometers
Gamma Rays	10^{-4} micrometers

Table 1. Types of Radiation in the electromagnetic (EM) spectrum (Damon, 1990, p. 49, 75).

With all matter being either direct or indirect sources of electromagnetic radiation, any radiation that is not otherwise absorbed, but emanated or reflected, can be collected by sensors on reconnaissance satellites.[13]

Objects and scenes on the Earth's surface have properties that determine how and what kind of radiation they emanate, absorb, and reflect. These properties provide the basis for analyzing the collected electromagnetic radiation, the results of which become intelligence from space, or the intelligence products of what has become "national reconnaissance."

Sometimes national reconnaissance satellites might target electromagnetic radiation from the visible spectrum and produce literal pictures that will become imagery intelligence (IMINT); in other cases the reconnaissance satellites might target radiation such as radio waves and electronic signals that will become electronic intelligence (ELINT); and in still other cases reconnaissance satellites might target

8. Damon, T., *Introduction to Space*: 27-44; and Riebeek, H., "Catalog of Orbits."
9. Astrophysicists will tell you that all objects in the universe emit electromagnetic radiation.
10. Electromagnetic radiation can be viewed as a stream of photons, which are mass-less particles. Each photon contains a certain amount of energy and travels at the speed of light in a wave-like pattern. The type of radiation is determined by the energy in its photons. Radio waves have low-energy photons; microwave photons have a little more energy, and as you move along the spectrum, the amount of energy increases with gamma-rays having the most energy. (NASA, 2013)
11. Damon, T., *Introduction to Space:* 75. NASA, "The Electromagnetic Spectrum," 2011, *http://science.hq.nasa.gov/kids/imagers/ems/index.html*. NASA, "Electromagnetic Spectrum – Introduction," 2014, [NASA Goddard Space Flight Center]. *http://imagine.gsfc.nasa.gov/docs/science/know_l1/ emspectrum.html*.

12. Environmental Protection Agency (EPA), "Uranium," 2012. *http://www.epa.gov/radiation/radionuclides/uranium.html#properties*; NASA, "The Electromagnetic Spectrum"; Nuclear Regulatory Commission (NRC), (2013). "Radiation Basics," 2013, *http://www.nrc.gov/about-nrc/radiation/health-effects/radiation-basics.html*.
13. EPA, "Uranium"; NASA, "The Electromagnetic Spectrum"; USNRC, "Radiation Basics."

radiation that, after analysis, might become more esoteric kinds of intelligence.

Reconnaissance satellites have the potential—although not always the capability—to carry a range of sensors that potentially could detect and collect the available radiation across the entire electromagnetic spectrum. (See Figures 2, 3, and 4 for examples of historic visible, radar, and infrared collection.)

In its most basic sense, intelligence from space is nothing more than expanding the capabilities of the human senses across the electromagnetic spectrum through the use of innovative technology as sensors, and by raising into space the altitude of observation. But this is a capability that was not always available to human observers and intelligence analysts. It only became a reality with the 1960s space-age revolution in intelligence collection.

Figure 3. Example of space-based radar image showing Point Reyes, CA, 1964. The arrows point to dense rain squalls where visibility was less than ¼ mile. (Source: NRO experimental Quill program; courtesy of CSNR Reference Collection as published by CSNR in *Trailblazer 1964: The Quill Experimental Radar Imagery Satellite Compendium*, edited by J. Outzen.)

Figure 2. Example of visual spectrum image, Shea Stadium, Queens, New York City, 1980 (Source: NRO Hexagon KH-9 image prepared by CIA's NPIC; courtesy of CSNR Reference Collection)[14]

Figure 4. Example of infrared image acquired as part of an experimental mission by the Corona film-return system in 1968. (Source: An NRO image prepared by CIA's NPIC; as published in 1997 by the American Society for Photogrammetry & Remote Sensing in *Corona Between the Earth and the Sun*.)

The Growth & Origin of National Reconnaissance From Space

Space reconnaissance grew out of the airborne strategic reconnaissance missions at the end of World War II. It is a story of how humans, trying to see more and hear more than their senses could acquire and process, were able to sense the radiation of the world in ever-evolving, increasingly sophisticated, and dramatically technical ways. Over time, pioneering innovation and imagination developed sensors to detect various forms of radiation. It required four revolutions over centuries to bring about the 1960s space-based revolution and the discipline of national reconnaissance.

The first revolution (which took place between the 9th century B.C. and the 17th century) extended the sensory range through the use of lenses for vision and funnels for hearing; the second revolution (which took place in the air during the mid-19th century) looked

14. The CSNR Reference Collection is a part of the Center for the Study of National Reconnaissance (CSNR), the NRO's independent social science research body that conducts research into the discipline, practice, and history of national reconnaissance—explaining the discipline of national reconnaissance, identifying lessons from its practice, and documenting its historical experience. This, and other similarly identified photographs and images included in this guide are from that collection.

upward in altitude and used balloons for reconnaissance platforms; the third revolution (which took place during the early 20th century) used the increased altitude of aircraft and their speed as new platforms for observation.

The Fourth Revolution—Emergence of Space Intelligence. The fourth revolution, in the middle of the 20th century, raised the platform for overhead remote sensing beyond the atmosphere, providing a synoptic view of the world. In 1960, the US Intelligence Community brought the world its first capability to listen from space by acquiring—from antennas on an orbiting satellite—electromagnetic signals emanating from transmitters on the Earth's surface, and to see from space by acquiring—from film on an orbiting satellite—images of the earth's geospatial surface. The earliest national reconnaissance satellites—the first a signals intelligence, or SIGINT, satellite, and the second an imagery intelligence satellite—set the standard for all national reconnaissance programs that were to follow. Understanding their stories is fundamental to understanding the discipline of national reconnaissance.

The First SIGINT Reconnaissance Satellite—Grab. The world's first intelligence collector from space was the Galactic Radiation and Background (Grab) satellite.[15] The Naval Research Laboratory (NRL) designed Grab to be an ELINT search and technical intelligence collector against air and ballistic missile defense systems in the Soviet Union. It collected radio frequency (RF) pulses from Soviet air defense radars and transponded the data to huts at ground stations that encircled the Soviet Union. Personnel at the ground stations recorded the data from the satellite and then dispatched tapes with these data, initially to NRL, and then to the National Security Agency (NSA) and the US Air Force Strategic Air Command (SAC), when analysts exploited the data and developed technical intelligence about Soviet radar.[16]

The Grab series of ELINT satellites had five missions between June 1960 and April 1962 (see Figure 5). There were launch failures and problems attaining orbit.[17] Only two missions proved to be successful. Nevertheless, Grab 1, launched in June 1960, was operational for nearly three months. The intelligence collected fundamentally changed the US National Intelligence Estimates (NIEs) on the Soviet Union's capability to defend against a US strategic nuclear strike. While estimates suggested that the Soviets had a minimal capability to defend itself, the Grab intelligence made it clear that the Soviets could detect and defend itself against a US nuclear attack.[18]

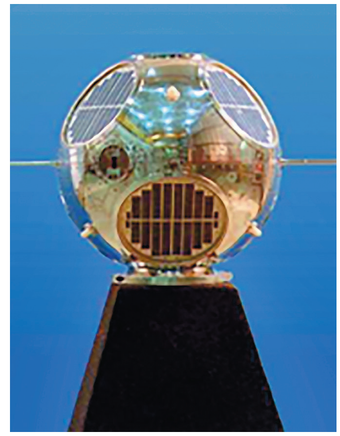

Figure 5. The Grab satellite, approximately 20 inches in diameter and weighing 40 lbs. (Source: NRL; CSNR Reference Collection

Corona—The First IMINT Reconnaissance Satellite.[19] The world's second intelligence collector from space was the Corona IMINT satellite that the CIA and Air Force made a success, even though many earlier believed it was highly improbable that a photo reconnaissance system could return film from space.[20] Corona's ini-

15. Grab was the unclassified name for project Dyno, which was the classified name for this SIGINT satellite program. As part of the Grab cover, a legitimate scientific payload, the solar radiation (SolRad) measurement mission package was launched on Grab. (National Reconnaissance Office, History of the Poppy Satellite System. Draft Program C manuscript in the Center for the Study of National Reconnaissance (CSNR) Reference Collection, prepared 1978. [Formerly a classified Top Secret/SCI document approved for release 6 June 2012.] Wilhelm, P. (2002). "Cutting Edge Work at the Naval Research Laboratory." In R. A. McDonald (Ed.), *Beyond Expectations—Building an American National Reconnaissance Capability: Recollections of the Pioneers and Founders of National Reconnaissance*, Bethesda, MD: American Society for Photogrammetry and Remote Sensing, 2002:155-161.

16. McDonald, R. A. & Moreno, S., *Raising the Periscope—Grab and Poppy—America's Early Elint Satellites*. Chantilly, VA: Center for the Study of National Reconnaissance, 2005; Potts R. L. *U.S. Navy/NRO Program C Electronic Intelligence Satellites (1958-1977)*. Draft manuscript in the Center for the Study of National Reconnaissance (CSNR) Reference Collection, prepared 3 Sep 1998. [Formerly a classified Secret/SCI document approved for release 13 June 2012.]; Wilhelm, Naval Research Laboratory.)

17. These kinds of mishaps should be expected in the development of innovative, complex, first-of-a-kind programs. The second launch, in November 1960, experienced a failure on launch. The Thor rocket burned out 12 seconds early, and range safety destroyed the vehicle. (NRO, History of Poppy.)

18. McDonald, R. A. & Moreno, S., *Raising the Periscope*; Potts, *NRO Program C*.

19. Corona was the classified name for the project. For its initial period of development and operation, the CIA and the Air Force conducted its activities under the cover of the Discoverer flight series.

20. While Corona was the first operationally successful photo-satellite reconnaissance system, there were a series of predecessor developmental satellite activities that included the Military Satellite System, known as Weapon System 117L (WS 117L). The WS 117L was a family of separate subsystems that were to carry out different missions. By 1959, WS 117L had evolved into three separate programs: Missile Defense Alarm System (MIDAS), the basis for later satellite-borne missile warning systems; the Satellite and Missile Observation System (Samos), a family of read-out and film-return photo reconnaissance satellites, later to be cancelled; and the soon-to-be-operational Discoverer Program, which was a cover for the clandestine Corona program

tial failed attempts seemed to validate this view. The Corona program experienced twelve unsuccessful attempts before having a successful mission. However, the CIA and the USAF persevered. Finally, Corona Mission 9009 (cover named Discoverer Mission XIV) returned some 3,000 feet of film providing more than 1,650,000 square miles of coverage of the Soviet Union.[21]

Corona was a film-based IMINT system that used traditional film, ejected it from orbit, and recovered the film capsule as it re-entered the atmosphere. After processing at Kodak, the film was available to photo interpreters at the CIA's National Photographic Interpretation Center (NPIC) in Washington, DC.[22,23] The first mission had limited resolution and cloud cover, but it provided enough information to locate major airfields and military installations, as well as identify the types of aircraft. It also helped interpreters develop signatures for what Soviet installations looked like, something that would guide identifications in future missions.[24]

After Corona's third mission in June 1961, the NPIC interpreters had clear imagery over the western Soviet Union and saw the first intercontinental ballistic missiles (ICBMs) and medium-range missile bases. What they saw gave them the evidence to conclude that even though the Soviets had started to build missile bases and production facilities, the Soviets had almost no operational missiles. Prior to this there had been an intelligence gap about Soviet strategic missile capability. This information gap had created the perception of this "missile gap."[25] Corona imagery provided the evidence that the Soviets did not have an operational capability for strategic missiles. Space intelligence had debunked the so-called "missile gap."

Continued Evolution of Intelligence From Space. Throughout the early development of national reconnaissance in space, the Grab and Corona programs had difficulties, but they had the support of the President. President Eisenhower personally approved the Grab and Corona programs, and it was Eisenhower who was willing to support them even when they seemed to be failing. Eisenhower's military assistant, Air Force General Andrew Goodpaster told Ed Miller, a pioneering engineer on Corona's recovery system, that Eisenhower was an "intelligence junkie" and always wanted to know what was "over the top of the next hill." In spite of repeated failures in the Corona program, Eisenhower told Goodpaster, "They'll get it right. They'll get it right." And of course they did get it right, and have gotten it right many times more.[26]

The Grab and Corona programs were only the beginning of national reconnaissance in space. The Grab program transitioned into the follow-on Poppy program and multiple other follow-on SIGINT programs. Corona operated from 1960 until 1972—well beyond its planned two years. But the NRO soon launched Corona's replacements, the first of its high-resolution Gambit imagery systems in 1963 and then, eight years later in 1971, the broad-area search Hexagon imagery system. As early as 1978, the NRO began its transition from these film-return systems to near-real-time digital imagery collection. All of these follow-on national reconnaissance systems over the years provided the nation with invaluable information from space, not only in the area of national security, but also for many civil applications.

(Perry, R L. *A History of Satellite Reconnaissance: The Robert L. Perry Histories*. CSNR Classics Series. 2012. Washington, DC: Center for the Study of National Reconnaissance (U.S. Government Printing Office). [This is the edited, published version of a series of formerly classified, draft manuscripts prepared from 1964-1974.] 592 pp. U.S. Air Force, Space and Missile Systems Center, SMC (2004). "Chapter V Satellite Systems," [Chapter in *Historical Overview of the Space and Missile Systems Center, 1954-2003*: 33-54, History Office, Space and Missile Systems Center on Los Angeles Air Force Base]. *http://www.losangeles.af.mil/shared/media/document/AFD-060912-025.pdf* (accessed 21 Sep 2014)

21. McDonald, R. A. "Introduction: Models for Success—Recollections of Accomplishments," in R. A. McDonald (Ed.), *Beyond Expectations—Building an American National Reconnaissance Capability: Recollections of the Pioneers and Founders of National Reconnaissance*, 2002: xxiii-xxxvii, Bethesda, MD: American Society for Photogrammetry and Remote Sensing.

22. McDonald, R. A. "Introduction." In R. A. McDonald (Ed.), *Intelligence Revolution 1960: Retrieving the Corona Imagery That Helped Win the Cold War*, Chantilly, VA: Center for the Study of National Reconnaissance, 2012: 1-13.

23. The NPIC subsequently was incorporated into what initially was the National Imagery and Mapping Agency (NIMA) and then became the National Geospatial-Intelligence Agency (NGA) in 2003.

24. Doyle, D. S. "Photo Interpreter Challenge" in I. Clausen, E. A. Miller, R. A. McDonald, & C. V. Hastings, *Intelligence Revolution 1960: Retrieving the Corona Imagery that Helped Win the Cold War*, Chantilly, VA: Center for the Study of National Reconnaissance (Printed by U.S. Government Printing Office), 2012: Chap. 8, 65-69.

25. The National Intelligence Estimates at the time had concluded that there was a missile gap and that the Soviets could launch ICBMs in an initial attack against many US targets. (McDonald, R.A., "Corona's Imagery: A Revolution in Intelligence and Buckets of Gold for National Security." In R. A. McDonald (Ed.) *Corona Between the Sun & the Earth: The First NRO Reconnaissance Eye in Space*, Bethesda, MD: American Society for Photogrammetry and Remote Sensing.

26. Miller, E. A. "Satellite Recovery Vehicle Challenge." In I. C. Clausen, E. A. Miller, R. A. McDonald, & C. V. Hastings, *Intelligence Revolution 1960: Retrieving the Corona Imagery that Helped win the Cold War*, Chantilly, VA: Center for the Study of National Reconnaissance (Printed by U.S. Government Printing Office), 2012; Chp 5, 41-48.

This fourth revolution has been an amazing transformation from the collection of comparatively limited, poor quality imagery and limited narrow intercepts of signals to the timely collection and processing of large volumes of data from across a growing range of the electromagnetic spectrum.

Intelligence From Space Over the Years

Since the 1960s, the NRO has perfected its space-borne collection systems and expanded their range of applications. In its collection activities, the NRO has interactively worked with all the intelligence collection disciplines—IMINT, SIGINT, HUMINT, MASINT, open source, and the like— tipping off other collection capabilities. For example, a SIGINT collector might identify a radar signal, and that would tip off an IMINT collector to look at a particular location to both confirm the "find" and collect imagery for detailed analysis.

Photoreconnaissance missions during the Cold War worked interactively, conducting search and surveillance activities against specific targets. The Hexagon KH-9 broad-area search system would search large geographic areas for new Soviet threats and identify intelligence targets of interest. In subsequent operations, the NRO would point precisely the Gambit KH-8 high-resolution imaging system at the target to collect high-quality images that would provide a higher level of detail for more in-depth analyses. Figure 6 shows a naval target acquired during a broad-area search KH-9 mission; Figure 7 shows another naval target acquired during a high-resolution KH-8 surveillance mission.

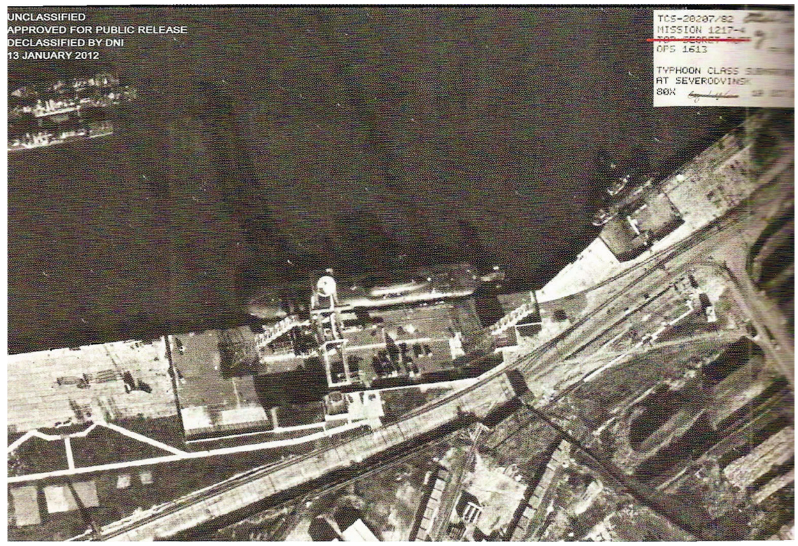

Figure 6. Broad-area search coverage of a Naval Intelligence Target of Interest, Severodvinsk, former Soviet Union, 1982 (Source: NRO KH-9 image prepared by CIA's NPIC; courtesy of CSNR Reference Collection)

Figure 7. High-resolution surveillance coverage of a Naval Intelligence Target of Interest at Mykolayiv, former Soviet Union, 1984 (Source: NRO KH-8 image prepared by CIA's NPIC; courtesy of CSNR Reference Collection)

The national security applications of space-based intelligence have been broad and many. Some of the more significant applications include monitoring and assessing strategic threats, mapping, target planning, influencing arms control policy, monitoring nuclear proliferation, contributing to scientific and technical intelligence analyses, supporting military operations, as well as civil interests.

Monitoring and Assessing Strategic Threats. One of the earliest national security applications has been monitoring and assessing strategic threats, especially the threat from the former Soviet Union. National reconnaissance answered questions such as: How many strategic bombers and ballistic missiles did the Soviet Union have, how were these systems deployed, what were their capabilities, what other weapons systems were the Soviets developing, and what were their capabilities likely to be? National reconnaissance is ideal to answer these questions because its platforms can monitor vast areas of terrain and search for changes that might be of interest. FIGURE 8 shows coverage of Yurya, some 500 miles east of Moscow, where the NRO had been collecting imagery in 1961. At that time, there were no intelligence targets of interest in the highlighted area.

However, the NRO continued to collect imagery of this and other areas. One year later, NRO assets acquired coverage in which analysts identified the first evidence of a Soviet deployment of an intercontinental ballistic missile (ICBM) launch complex. (FIGURE 9)

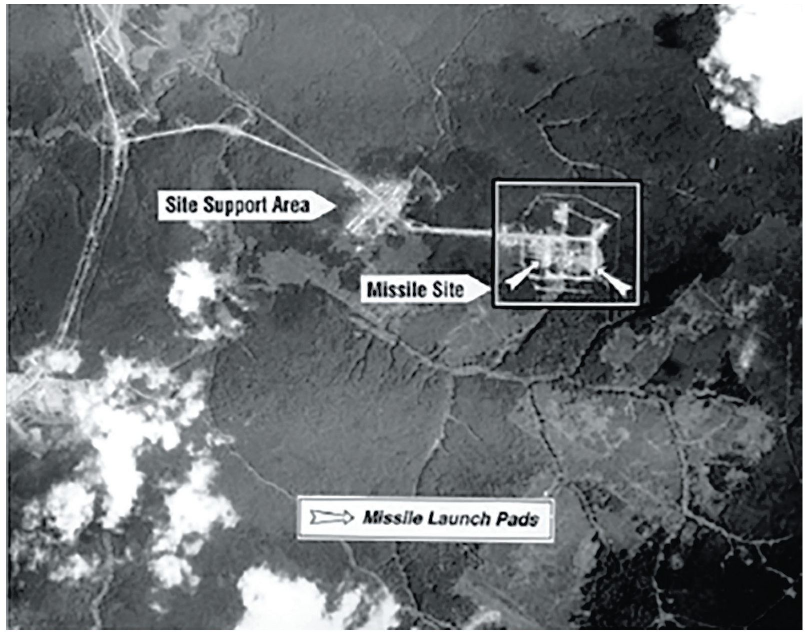

Figure 9. Yurya ICBM Complex showing construction of an SS-7 launch site, almost 1 year after the date of the reconnaissance image in Figure 8, June 1962 (Source: NRO KH-4 imager prepared by CIA's NPIC; courtesy of CSNR Reference Collection)

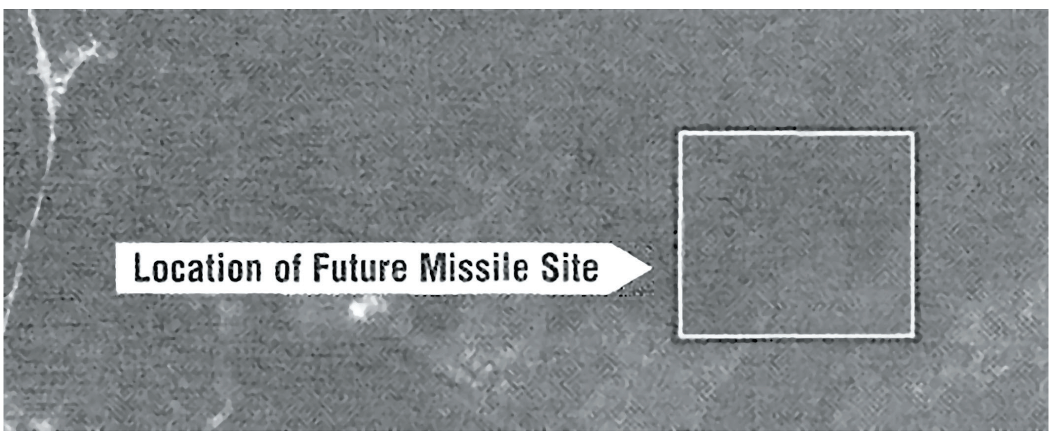

Figure 8. Cold War image of the USSR at the future site of an ICBM launch site, future site of Yurya ICBM Complex June 1961.

Prior to the advent of the digital age, the NRO relied on its film-return systems for mapping imagery. The Hexagon satellite, in particular, had a dedicated mapping camera. See FIGURE 11 for an example of this kind of mapping image.

The NRO also would monitor the Soviet Union for research and development activities such as missile testing in order to assess the USSR's progress in weapons development that might impact on the strategic threat. See FIGURE 10 for an example of a Soviet missile test facility.

Mapping. Mapping is a valuable application of national reconnaissance data where satellites can obtain significant image coverage and geodetic data in support of US military requirements. Imaging satellites provide photogrammetric control data with the required geometric accuracy to assist cartographers in constructing accurate maps.[27]

Figure 10. Tyuratam Missile Test Range, former USSR, August 1984. (Source: NRO KH-9 panoramic camera image prepared by CIA's NPIC; courtesy of CSNR Reference Collection

27. McDonald, Robert A. "Corona, Argon, and Lanyard: A Revolution for US Overhead Reconnaissance." In R. A. McDonald (Ed.), *Corona — Between the Earth and the Sun: The First NRO Reconnaissance Eye in Space*, Bethesda, MD: American Society for Photogrammetry and Remote Sensing, 1997: 61-74.

With the advent of the digital age, both the collection of imagery and the preparation of mapping products turned to the digital world. As a consequence of that transition, intelligence and mapping information have become comingled into new products called geospatial intelligence products.

Figure 11. Hexagon KH-9 mapping camera imagery of Kubinka Airfield (near Moscow), former Soviet Union, 1979, at 20X magnification. (Source: NRO image as prepared by NPIC, courtesy of CSNR Reference Collection.)

Even though the primary mission of national reconnaissance imaging systems has been for national security purposes—both mapping and intelligence, there have been extensive applications for domestic mapping. During the Cold War, even though 95% of the total coverage was directed at acquiring imagery of foreign areas, the NRO acquired at least 5% of its imagery coverage for domestic purposes, primarily mapping.

From Maps to Geospatial Intelligence [28]

The 20th century cartographic agencies—such as the Army Map Service, Air Force's Aeronautical Chart and Information Center, the oceanographic and charting services of U.S. Naval Hydrographic Office, the U.S. Geological Survey, and the Defense Mapping Agency—used satellite reconnaissance imagery to produce basic maps.

The digital age and the precise geo-location of 21st century national reconnaissance data changed that with satellite reconnaissance imagery being one component of what has come to be a more sophisticated and integrated product—a geospatial intelligence (GEOINT) product.

GEOINT is an integrating intelligence discipline that exploits and analyzes imagery, along with a range of other geospatial-related information, such as geodetic, geomagnetic, gravimetric, aeronautical, topographic, hydrographic, littoral, cultural, and toponymic data. The integration of these data results in the production of visual depictions and descriptions of physical features along with any other geospatial data—all referenced to precise locations on the Earth's surface.

The technology of the 21st century saw the transition from map products to geospatial intelligence products.

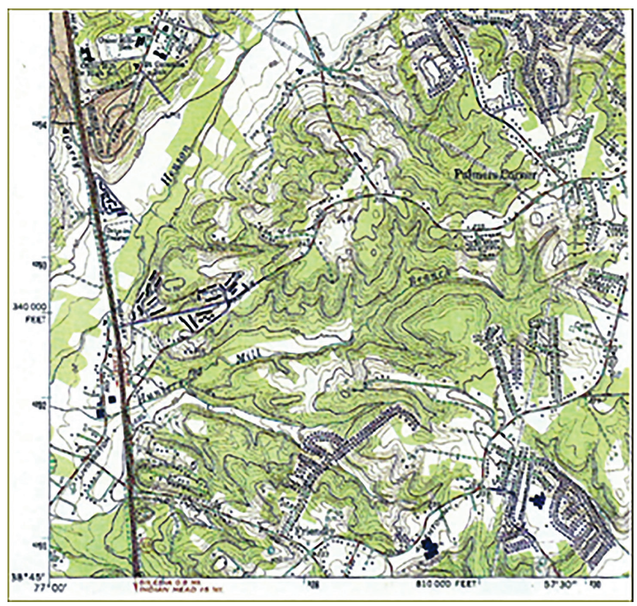

Figure 12. USGS topographic map (southwest corner of 1965 Anacostia Quadrangle), 7.5 minute series. (Source: USGS; courtesy of CSNR Reference Collection)

Even during the early days of the Cold War, when national reconnaissance imagery was highly classified, the IC had established arrangements with the U.S. Geological Survey (USGS) where the USGS would use imagery from the classified national reconnaissance systems—in special facilities—for domestic map production. See Figure 12 for a map product where the USGS had used national

28. DoD Instruction 5000.56, Programming Geospatial-Intelligence (GEOINT), Geospatial Information and Services (GI&S), and Geodesy Requirements for Developing Systems, July 9, 2010; CJCS Instruction CJCSI 3110.08D, Geospatial Information and Services Supplemental Instruction to Joint Strategic Capabilities, Plan (JSCP), 10 Dec. 2010; Joint Publication 2-03, Geospatial Intelligence in Joint Operations, 31 Oct 2012; Digital Nautical Chart, NGA Products & Services, *https://www1.nga.mil/ProductsServices/NauticalHydrographicBathymetricProduct/Pages/DigitalNauticalChart.aspx*; (accessed 11 October 2014).

reconnaissance data to update the map (indicated by the purple overprinting).

Target Planning. National reconnaissance supported military targeting from its beginning. The first Grab SIGINT satellite mission collected technical data useful for targeting. FIGURE 13 is a pictorial depiction of the raw data that the Grab sensors collected. Though initially difficult to interpret, analysts were able to extrapolate from these data the type of radar that was emitting the signal, where it was located, and what its effective range was. Among the signals that analysts identified in the Grab data were those of Soviet early warning, height-finding, and ship-borne type radar.

The volume of data from its first mission had been very large, a major surprise to analysts at the time. In reviewing the tapes, the analysts were able to determine the magnitude of the Soviet air defense system, an intelligence issue of high interest to US Cold War target planning. With the data, the National Security Agency (NSA) analysts changed their estimates and Air Force analysts determined the location and capabilities of Soviet radar sites and the associated Soviet air defense weapons. The intelligence analysts put these kinds of data together with other intelligence information to produce products similar to the one depicted in FIGURE 14.[29]

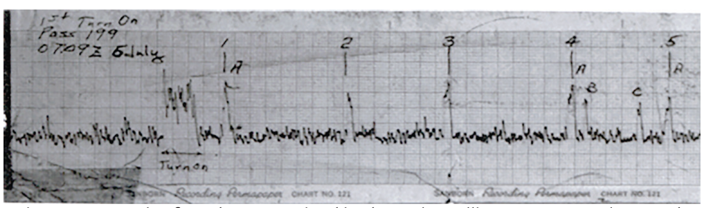

Figure 13. Example of raw data transmitted by the Grab satellite. (Source: Naval Research Laboratory, courtesy of the CSNR Reference Collection.

These intelligence products were particularly valuable to the Strategic Air Command (SAC) target planners, whose bombers would have to encounter Soviet air defense forces in any nuclear confrontation. Because of this, the follow-on SIGINT satellites, along with NRO's IMINT satellites—which also provided photographs of the actual targets—became critical intelligence sources for SAC to use in building the single integrated operations plan (SIOP), the US general nuclear war plan. National reconnaissance data has continued to play an important role in the planning of wide range of specific military operations that have included bombing missions and special operations actions.[30]

29. McDonald & Moreno, S. *Raising the Periscope*; Potts, *Program C.*
30. McDonald & Moreno, S. *Raising the Periscope*; Potts, *Program C.*

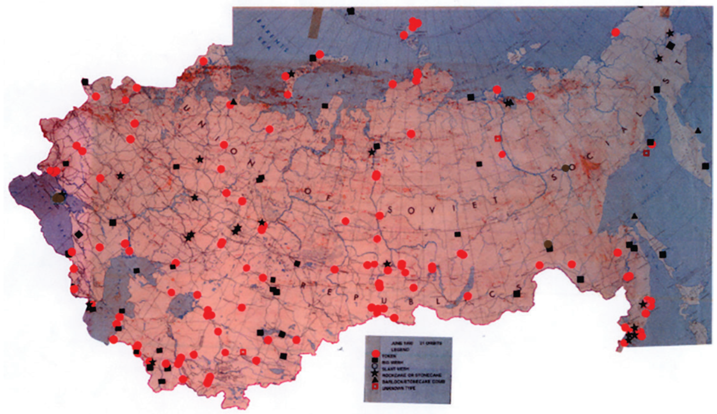

Figure 14. A "map plot" of selected signals that the Grab satellite collected over the former Soviet Union and transmitted to the ground stations (Source: NRL, courtesy of the CSNR Reference Collection.)

Monitoring Nuclear Proliferation. National Reconnaissance systems, by virtue of being "on station" at all times, are in a position to monitor activities that prepare for and test nuclear weapons. In this way these systems are ideal to support the requirement to monitor and detect the testing of nuclear weapons. FIGURE 15 is an example of a nuclear test in China during the Cold War.

Influencing Foreign Policy. National reconnaissance has played a major role over the years in supporting many foreign policy objectives. One of the most important Cold War examples is how national reconnaissance gave US policymakers both the data and the confidence to enter into arms control agreements. It was national reconnaissance systems (under the euphemism of "National Technical Means") that provided concrete data on Soviet strategic systems and became the primary means for subsequent treaty verification. For example, it was national reconnaissance imagery that made it clear that the Soviets were constructing the SS-7 ICBM at Yurya (see previous FIGURE 9). And then to comply with the subsequent 1972 SALT I Interim Agreement on Strategic Missiles, the Soviets deactivated the SS-7 ICBM system, and destroyed its launch facilities. Since then, national reconnaissance systems have had a long history in building arms control confidence and treaty verification.[31]

National reconnaissance also has influenced and been an instrument in addressing human rights violations. The State Department used reconnaissance imagery to publicly document violations such as ethnic

31. McDonald, Robert A. "Corona, Argon, and Lanyard: A Revolution for US Overhead Reconnaissance." In R. A. McDonald (Ed.), *Corona – Between the Earth and the Sun: The First NRO Reconnaissance Eye in Space*, Bethesda, MD: American Society for Photogrammetry and Remote Sensing, 1997: 61-74.

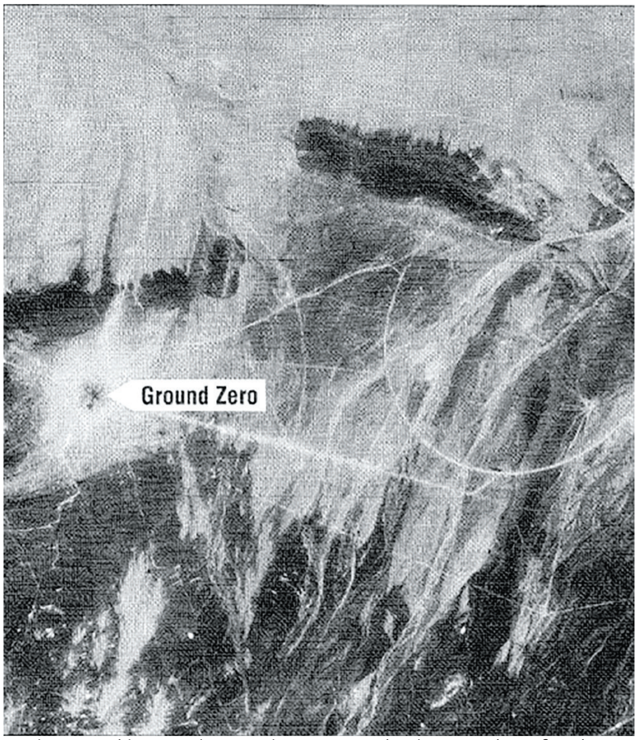

Figure 15. Chinese nuclear test site at Lop Nor showing ground zero four days after the nuclear test, 1964. (Source: NRO KH-4 image as prepared by CIA's NPIC; courtesy of CSNR Reference Collection).

Figure 16. Comparative images showing appearance mass burial Site Near Izbica, Kosovo (Source: Image released by DoD and State Department, April and May 1999; courtesy of CSNR Reference Collection).

cleansing. The two images of Izbica (former Yugoslavia) in FIGURE 16 show the appearance of mass grave sites of a Serbian massacre of the Kosovar Albanians. The State Department used the imagery to corroborate earlier reports from refugees and other evidence.[32]

Contributing to Scientific & Technical Intelligence Analyses. National reconnaissance can provide the Intelligence Community with information to do detailed scientific and technical analysis of foreign weapons systems. FIGURE 17, of a Soviet aircraft carrier, is an example of a high-resolution image that was used for that purpose.

Playing a Role in Military Operations. National reconnaissance can be a significant contributor to a wide range of military activities and operations. These have included maintaining order of battle information, monitoring the operational deployment of adversary submarines and other weapons systems, applying knowledge learned from scientific and technical assessment of space intelligence to the development of US weapons. Of particular interest is national reconnaissance's historic role in planning and evaluating military operations. FIGURE 18 is an example of one such image that DoD used in planning a 1998 attack on the Zhawar Kili Support Complex, a suspected terrorist training facility in Afghanistan. The coverage captures in one image, all of the natural, cultural, and terrorist-related activities in that scene.[33]

The digital age has introduced additional dynamic tools to use with national reconnaissance data for mission planning, especially with regard to manipulating and displaying large volumes of spatial and temporal data in geospatial products. One example is the use of displayed visualization of large volumes of multi-source data to detect changes that reflect patterns of human activity. These geospatial patterns, when temporally displayed, are not only valuable for military mission planning, but also for battlefield forensics. When the geospatial display, which can render millions of data elements, is given temporal motion (i.e., reflect the changes over time), patterns emerge that suggest specific activities, such as

32. McDonald , R. A. "NRO's Satellite Imaging Reconnaissance: Moving From the Cold War Threat to Post-Cold War." *Defense Intelligence Journal*, Vol. 8, No. 1, Summer 1999.

33. JCS Chairman, General Henry Shelton held a press conference after US missile strikes against terrorist-related targets associated with the then Al Qaeda leader, Usama Bin Ladin. He pointed out how planners had concluded this site was a terrorist training camp. McDonald, "Imaging Reconnaissance."

Figure 17. A high-resolution Cold War image of a Soviet aircraft carrier under construction, Mykolayiv, former USSR, 4 Jul 1984 (Source: An NRO Gambit KH-8 image with annotation by NPIC; courtesy of the CSNR Reference Collection.)

Figure 18. Image of Zhawar Kili Support Complex, Afghanistan. (Source: Released by DoD, 20 August 1998; courtesy of CSNR Reference Collection.)

communications patterns, that can explain battlefield activities. See FIGURE 19 with a static image annotated with points of activity.

Bomb Damage Assessment. FIGURE 20 is an example of national reconnaissance imagery from Operation Desert Fox[34] where military analysts used it to compare the pre- and post-strike status of a military target. The figure shows both the pre- and post-strike coverage of the headquarters building of Baghdad Directorate of Military Intelligence Headquarters and how it had been reduced to rubble in the post-strike coverage.[35]

Supporting Civil Requirements. Space-based intelligence can acquire information that not only is useful for national security purposes, but also useful to satisfy civilian requirements, which can include monitoring changes on the Earth's surface (e.g., surveying glaciers and bodies of water), assessing the impact on natural resources (e.g., environmental monitoring, assessing mining activities), assessing natural disasters (e.g., evaluating tornado damage), and conducting scientific research (e.g., the study of geology and archeology).[36]

The Value of Intelligence From Space

Intelligence collection from space represents the birth of the discipline of national reconnaissance—the fourth revolution in reconnaissance, which has provided a way to observe and collect a broad range of electromagnetic radiation from above the Earth's surface.[37] This revolutionary capability has a number

34. Operation Desert Fox was the 1998 military operation executed when Iraq refused to permit unrestricted United Nations inspection for weapons of mass destruction.

35. U.S. Department of Defense, Pentagon press briefing with Vice Adm. Scott A. Fry, U.S. Navy, director, J-3, Joint Staff and Rear Adm. Thomas R. Wilson, U.S. Navy, director, J-2, Joint Staff, Dec. 18, 1998, *http://www.defense.gov/photos/newsphoto.aspx?newsphotoid=1722*; McDonald, "Imaging Reconnaissance."

36. In the late 1980s and early 1990s the then Director of Central Intelligence's Committee on Imagery Requirements and Exploitation (COMIREX) had been exploring the feasibility of declassifying the Corona program and much of its film. This coincided with early 1990s interests within the scientific and environmental communities for unclassified access to early satellite reconnaissance imagery for scientific purposes. President Clinton's 1997 Executive Order to declassify Corona film made the imagery broadly available for use by the scientific community, as well as for the wide range of other civil purposes. (McDonald, "Corona, Argon, and Lanyard": 61-74)

37. Historically, the early NRO was heavily involved in airborne national reconnaissance through its Program D. The NRO mission as stated in DoD directives is to be "... responsible for research and development (R&D), acquisition, launch, deployment, and operation of overhead reconnaissance systems, and related data-processing facilities to collect intelligence and information to support national and DoD missions and other United States Government (USG) needs ... " (DoD Directive

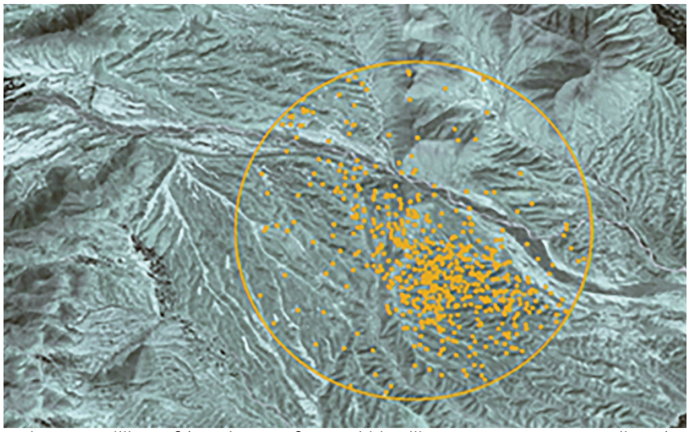

Figure 19. Millions of data elements from multi-intelligence sources as temporally and geospatially displayed on an overhead image. (Source: Unidentified overhead image; courtesy of CSNR Reference Collection.)

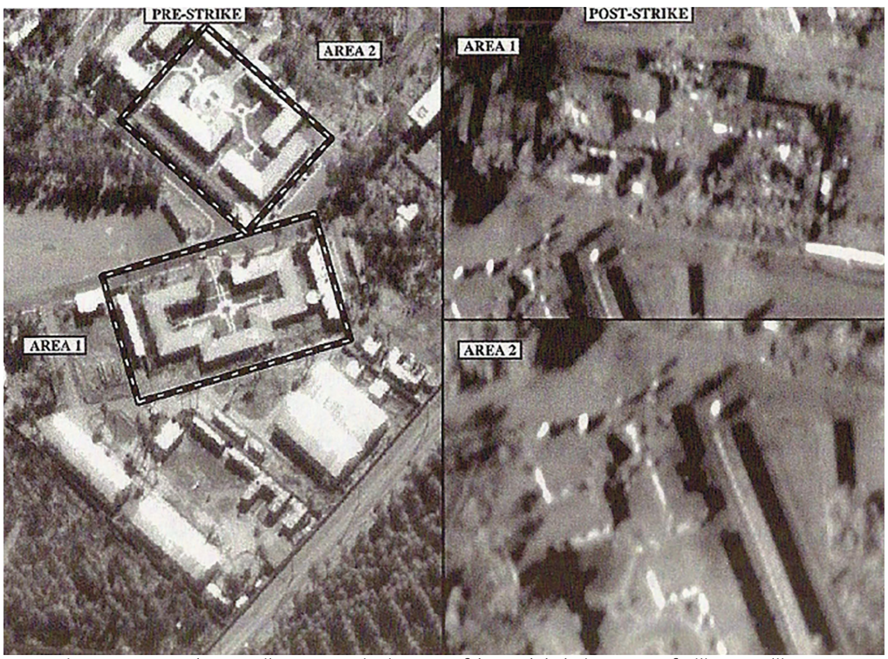

Figure 20. Pre- and post-strike comparative imagery of the Baghdad Directorate of Military Intelligence Headquarters, Iraq, 1998, (Source: Image released by DoD, 17 December 1998; courtesy of CSNR Reference Collection.)

of characteristics that make it exceptionally valuable to the Intelligence Community. First, it provides unique access to the world's surface. It can listen and look into areas of the Earth where access is denied for political reasons or military and environmental threats. Second, and perhaps equally important, is the fact that the very nature of national reconnaissance—i. e., its view from space—offers a synoptic perspective of the terrain of interest. And finally, it can provide a broad, simultaneous view of the electromagnetic radiation emanating from a large area of targets of interest, wherever the radiation may be on the electromagnetic spectrum.

An example of the capability of national reconnaissance to collect "big data" is how a single frame of a space image can offer a wide view of the landscape. FIGURE 21 shows extensive coverage of terrain in the New York City area at contact scale on a partial frame. It captures coverage that extends from Long Island to New Jersey.

The power of the information content is such that a small portion of that frame can be enlarged 30X to display specific details of the relatively small area of the U.S. Merchant Marine Academy (FIGURE 22).

The follow-on Hexagon KH-9 camera would capture an even greater swath of the Earth's surface, a footprint of 370 nautical miles wide (FIGURE 23). This simultaneous collection of electromagnetic radiation from large areas of the Earth's surface gives intelligence officers an opportunity to "see it all."[38]

The SIGINT and IMINT national reconnaissance platforms have the capability to provide persistent and predictable coverage of the Earth's terrain. The map at FIGURE 24 (next page) offers an early example of this. It portrays a typical Corona KH-4A coverage of the Eurasian land mass over a four-day period. Impressive, when compared with what a single aircraft with a camera could acquire during the same period.[39]

The comprehensive intelligence that national reconnaissance missions acquired during the 20th century played a critical role in ending the Cold War, and then went on into the 21st century to contribute to the success of almost all military and intelligence operations since then. We know from those experiences the tactical advantage—and often strategic survival—that came to the US because of the benefits from the intelligence collected by the space-based sensors.

Two US Presidents publicly have underscored its great value. In 1967, President Lyndon B. Johnson remarked:

5105.23, "National Reconnaissance Office (NRO)," June 28, 2011).

38. McDonald, "Corona, Argon, and Lanyard."

39. The map does not indicate which areas were cloud covered, but on most early missions, about 50 percent of the imagery was obscured by clouds. (McDonald, "Corona, Argon, and Lanyard.")

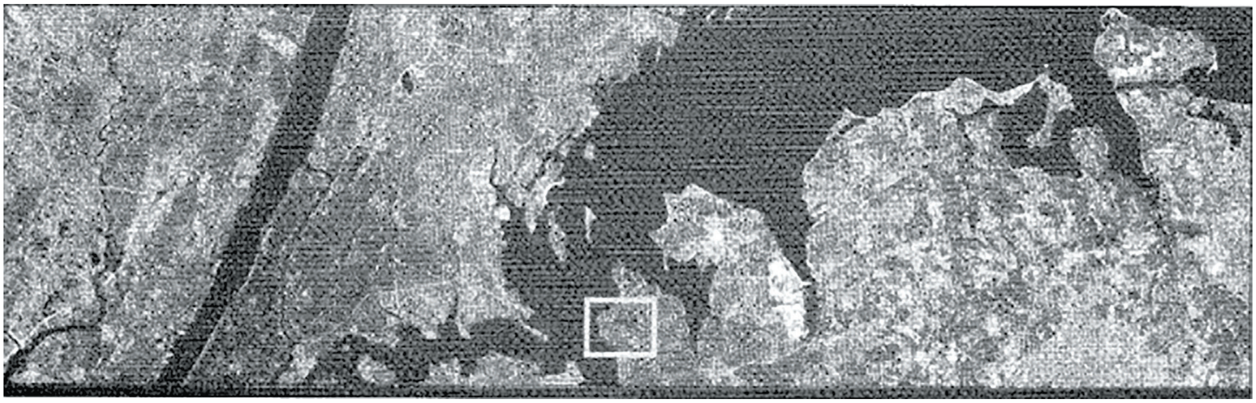

Figure 21. Portion of a KH-4B frame at contact scale with the area around the U.S. Merchant Marine Academy in Great Neck, Long Island, highlighted in a box, 1970. (Source: NRO Corona imagery as prepared by CIA's NPIC; courtesy of CSNR Reference Collection)

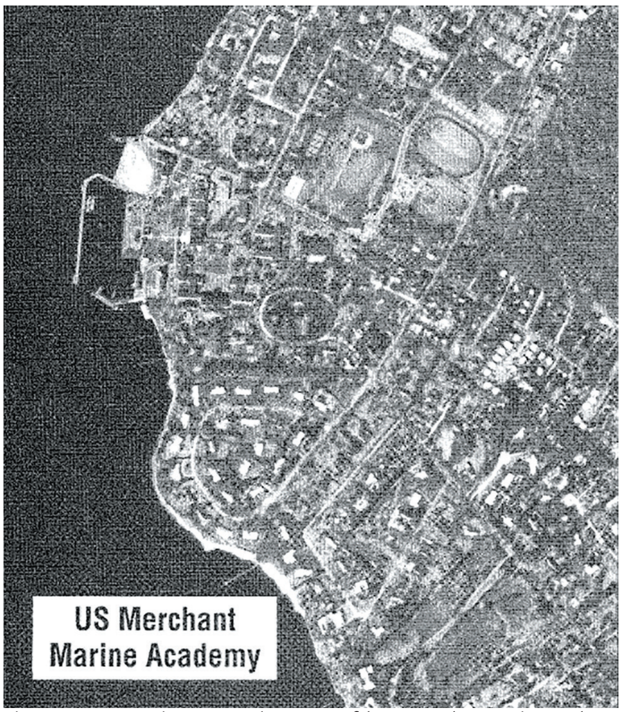

Figure 22. An approximate 30X enlargement of the US Merchant Marine Academy at Kings Point on the Great Neck Peninsula, 1970. (Source: NRO Corona image as prepared by CIA's NPIC; courtesy of CSNR Reference Collection)

"We've spent $35 or $40 billion on the space program. And if nothing else had come out of it except the knowledge that we gained from space photography, it would be worth ten times what the whole program has cost. Because tonight we know how many missiles the enemy has ... "

— President Lyndon. B. Johnson, remarks to educators in Nashville, TN, 16 March 1967.

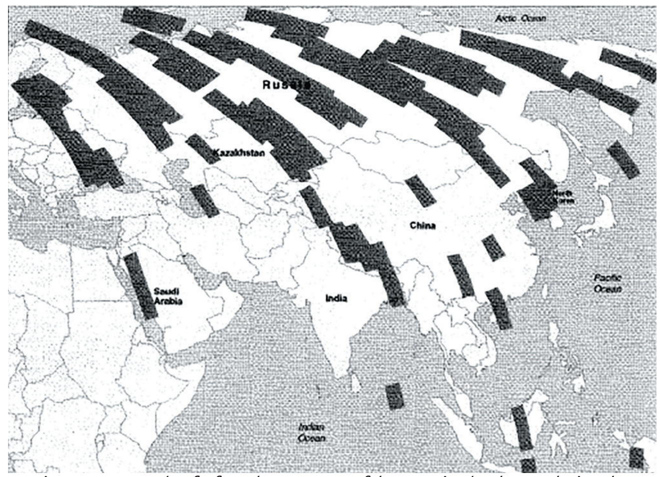

Figure 24. Example of a four-day coverage of the Eurasian land mass during the 1965 Corona Mission 1017. (Source: Map prepared by CIA's NPIC; courtesy of CSNR Reference Collection.)

In 1978, President Jimmy Carter, while building support for the SALT II treaty, also highlighted the value of space-borne imagery intelligence in maintaining peace:

"Photoreconnaissance satellites have become an important stabilizing factor in world affairs in the monitoring of arms control agreements. They make an immense contribution to the security of all nations. We will continue to develop them."

— President Jimmy Carter, temarks at the Congressional Space Medal of Honor Awards Ceremony at Kennedy Space Center, FL, on October 1, 1978.

Figure 23. Graphic depiction of the ground area in a single Hexagon KH-9 panoramic camera frame for its coverage of the 370 nautical miles between Cincinnati, OH and Washington, DC (Source: CSNR Reference Collection)

And since the late 1970s, the US has continued to develop and refine its national reconnaissance capability. The capability has become so common that, in the 21st century, many began to take space-based data collection and its associated technology for granted. Each new improvement often is seen to be routine.

The business of national reconnaissance is far from routine. The development and refinement of national reconnaissance has taken place over an extended period of time. All of its advances took imagination, pioneering innovation, and perseverance, often through many trials and errors that are inevitable in the development of untested technology. The creation of the US national reconnaissance capability also took a significant investment in time and funding. But the benefits since the latter half of the 20th century and into the 21st century unquestionably are invaluable.

The legacy of national reconnaissance has been one that has changed the way we view the world. It has created breakthroughs in the engineering and management of aerospace technology; it has revolutionized the technology and operation—not only of intelligence—but also of military and commercial activities. This revolution of national reconnaissance gave the world a new perspective on all natural and cultural features on the surface of the Earth—the ability to view and listen to events and activities on the Earth's surface from the safety and exceptional vantage point of space.

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