The Hermeneutics of Airphoto Interpretation

by

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ABSTRACT

This thesis examines the cultural and political applications of aerial photography. The thesis emphasizes the historical development of aerial photography technologies and the incorporation of these systems into national policy. The majority of the discussion details the U-2 reconnaissance program. There is an account of the evolution of the system under Eisenhower, explanation of its selection over other intelligence programs, development of photographic equipment, and the formation of a professional staff to analyze the U-2 imagery. This thesis analyses the use of U-2 imagery under Kennedy to precipitate and then monitor the resolution of the Cuban Missile Crisis.

The analysis of the technologies and historical record utilizes a methodology defined as hermeneutical. Hermeneutics is the study of communication, or the exchange of knowledge

accomplished through a text. The treatment of aerial photography as a text provides insight into the multiplicity of roles it played in national policy.

Normative logic has knowledge emanating from photography, deciphered by science and passed on to policy makers. There has been no concerted effort to integrate the politics and the science of aerial photography. This thesis challenges that discursive separation of science and politics. By examining the entire process, from flight planning to analysis to briefing of policy makers and finally to the formation of policy, a different model of information exchange emerges. The science and politics of airphoto interpretation share a co-dependency where knowledge transfer is not a one-way street, but an interactive, co-dependent exchange.

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PROLOGUE

This Thesis examines the epistemology of aerial photography. The discussion will focus on the processes through which knowledge is derived from aerial photography. The Thesis takes a holistic approach that outlines both the scientific and political aspects of generating information from aerial photography.

Typically, geographic literature on aerial photography makes a discursive separation between the scientific and the political. Geographic texts are concerned with either the politics or the science of aerial photography. The scientifically orientated works provide useful information on the technical aspects of aerial photography, but decline to discuss the political, moral and social issues involved with its use. Likewise, texts concerned with the political uses of aerial photography generally ignore the actual collection of such information.

The object of this thesis is to bridge the gap between the science and politics of aerial photography. Aerial photography will be situated as a remote sensing system that generates meaning on many levels. Given the prescribed holistic approach, the discussion will examine the system of aerial photography from the physics of light to the formulation of national policy.

CHAPTER I

AN INTRODUCTION TO THE LOGISTICS OF MILITARY PERCEPTION

Photo intelligence has come to play an important and highly accepted role in formulating national policy. Photo intelligence (PHOTOINTEL), or more specifically aerial photography and satellite imaging, has played an important part in American policy from Desert Storm to the NATO intervention in the former Yugoslavia. The wealth of information that PHOTOINTEL can convey make it a valuable source of information for formulating national policy in the late twentieth century.

The photographic message is perceived as an impartial record free from human subjectivity. The information PHOTOINTEL provides is therefor seen as being beyond criticism. A photograph is proof positive. The other sources of intelligence that policy makers rely upon, such as human agents, are unable to provide information as powerfully convincing as photography.

Photograph's are seen as being free from human subjectivity because of the ease with which we can take a photograph. A simple click of a button records everything in sight. Other representative media, such as drawing, are time consuming processes with plenty of opportunity for the introduction of subjectivity. This reputation persists despite the relative ease with which photographic images can be altered.

Perhaps the most celebrated use of PHOTOINTEL was the discovery of Soviet Missiles on the island of Cuba in 1962. Aerial photography both alerted the Kennedy administration to the presence of the missiles and formed the basis for the justification of their subsequent policy. Aerial photography was relied upon almost exclusively by President Kennedy during the crisis. He relied upon aerial photography because of its

Despite the virtues of PHOTOINTEL, the Cuban Missile Crises was a novel application of the technology. Since cameras were first brought aloft in aircraft, there was a latent resistance to the technology. Aerial photography was seen as too limited and too obscure for many applications. This resistance continued into the Eisenhower administration of the Fifties. The criticism of aerial photography as source of information is the difficulty of interpreting the images. While photographs taken on the ground are familiar and easy decipher, aerial photographs often experience extremes of scale and perspective that are difficult to overcome.

This thesis is examines the extraction of information from aerial photography. The focus is on both the technology of interpreting photography and on the institutions required to utilize that information. The primary historical example is the Cuban Missile Crisis where president Kennedy consistently selected PHOTOINTEL over other sources of intelligence. The narrative will focus on the myriad of ways in which information was extracted, disseminated and ultimately used by the Kennedy administration.

1.1 CHAPTER STRUCTURE

The structure of this thesis is roughly chronological. The remainder of this chapter introduces the historical context of aerial photography prior to the Cuban Missile Crisis. Chapter Two details Dwight Eisenhower's overhaul of the American intelligence community that made Kennedy's use of PHOTOINTEL possible. Chapter Three examines the technology involved with strategic reconnaissance in the decades after World War Two. Chapter Four is an accounting of the daunting task involved with interpreting aerial photography. Chapter Five analyses the use of PHOTOINTEL by Kennedy during the Cuban Missile Crisis. Chapter Six concludes the narrative on military vision developed in this introduction by detailing the trends in PHOTOINTEL after 1962.

1.2 MILITARY VISION

Kennedy's use of PHOTOINTEL during the Cuban Missile Crisis did not occur in an historical vacuum. The technologies available to him in 1962 were the result of a long trend in the development of aerial photography. The history of aerial photography has been not a only a history of technological advancement, bit one of social and institutional change as well. An understanding of PHOTOINTEL in 1962 is dependent upon an understanding of the social and technological trends leading up to 1962.

1.21 Intensification

Military history has been a history of intensification and acceleration. As advancement followed advancement, there was an increasing need for more powerful weapons, more soldiers, more supplies, and faster deployment. Every war in modern history was an expansion of the last in terms of scale, speed of action and number of participants involved. The following narratives illustrate the history of intensification.

First Bull Run, an early battle of the American Civil War, fought on July 21, 1861, involved 32,500 Confederates versus 35,000 Union troops. Total casualties of the battle were about 5000. The battle of Gettysburg, two years later, saw 171,000 troops fight over a period of three days. Total casualties at Gettysburg were over 53,000. The American Civil War claimed about 600,000 lives when it was over in 1865 (MacDonald, 1992).

In the first full year of World War One, 1915, the British lost 612,000 men on the western front in France. The French lost 1,292,000 men in the same year. On July first of that year, the British started a massive offensive on the German army across the Somme river. The offensive stalled, both sides entrenched and the fighting lasted four months. The British lost 420,000 and the French 195,000 during this extended battle alone. The Germans suffered 650,000 in the defense. Total losses in World War One for all participants were about 12 million (Stokesbury, 1981).

The increase in devastation started again a short 20 years later with the start of World War Two. In the West, the war resulted in the death of 6 million Germans, 3 million Poles and under 1 million American and British. In the East, 7 million Chinese and 2 million Japanese lost their lives. The Soviet Union had the dubious distinction of outdoing them all with upwards of 27 million war dead. A conservative estimate of total casualties for all combatants during the war is 60 million.

Technological advances were a large factor in the increasing destructiveness of war. Each war saw the introduction of new weapons and techniques for killing. The development of military vision was closely related to the development of armaments. With each advance in weaponry, the increased ranges removed the opportunity for direct human vision in battle and necessitated enhancements of human vision. The typical soldier was gradually distanced from his enemy, both physically and perceptually.

1.22 Developments in Military Vision

The distancing of the common soldier from his enemy started with the first organized military units. The act of subordinating oneself to a military unit removed a large amount of responsibility from the individual soldier. One of the first recorded wars was the conflict between the Lower and Upper Egyptian Kingdoms on the Nile River. These two kingdoms fought each other in 3500 B.C. when mankind was barely advanced beyond the stone age.

At the dawn of civilization, militaries already consisted of specialized troops. There were infantry, slingers, cavalry and charioteers. Individual soldiers lost a perception for the overall battle, but gained a specialized role. They were able to focus on their individual task. Long range vision, beyond their immediate surroundings, was the responsibility of superior officers who told them what to do.

At first, military commanders joined their troops in battle after planning the battle ahead of time. Alexander the Great was known for his great physical prowess in battle at the head of his army. Alexander quickly became the exception, rather than the rule. Later commanders were more successful leading from the rear of the army where they could direct the battle during the actual fighting. Julius Caesar was noted for his brilliant leadership from the rear during his Gaul Campaigns from 58 to 52 B.C.

The separation of the commander from the battlefield resulted in the need for an extension of vision. Early manifestations were the organization of mounted reconnaissance units and the practice of setting up headquarters on hills overlooking the expected battle site. This situation was generally effective for many centuries. Battles were slow and small enough that there was time to send out a reconnaissance patrol, or for the commander to view the action personally. Battles quickly became so large and complex that further enhancement of vision was needed however.

An initial mechanical development was the invention of the optical lens. The first eyeglasses appeared in Italy around 1300. In 1608, Dutch opticians mounted several lenses in a long tube to make the first telescope. Galileo used telescope technology, shortly after its invention, in his famous astronomical research. Typical Seventeenth Century telescopes had magnifications from 8 to 30 times.

Telescopes were only of limited use because they were still restricted by line of sight. It was useful for shortening distance, but did not allow the commander to 'see over the next hill.' Communications, aircraft and electronics were breakthroughs in military vision that allowed the transcendence of physical space.

Communications

Since the earliest wars, commanders relied upon specially designated reconnaissance troops to gather information on the enemy. These scouts would 'see' for their commanders by proxy. The formation of larger armies necessitated the need for more coordination between scout troops and commanders, who could be separated by many miles. Speed was the critical issue. The faster information could be relayed to those who needed it, the more useful it would be.

Communication over short distances was conducted with voice, musical instruments, smoke or flags. Communication beyond the range of vision required the use of mounted couriers or runners. For example, after the ancient battle of Marathon, between Athens and Sparta, the victorious Athenians sent a courier home. The use of couriers is slow and often difficult. The Athenian courier died as a result of his exertion. The development of electronic communication would allow armies to transcend physical space.

The telegram allowed for near instantaneous communication across thousands of miles. First invented in 1837, the telegraph revolutionized long-range communication. Previously, letters or couriers could take days, weeks or months to carry their messages. The telegraph could transmit information at the speed of light. The telegraph allowed strategic information to reach national command centers very quickly.

The British and French constructed extensive telegraph networks during the Crimean War. The telegraph allowed them to coordinate the actions of a multi-national force of British, French and Turkish armies. The coordination allowed by the telegraph included an extension of telegraph lines to Paris and London. The national leaders of the allied countries were informed of the outcome of battles shortly after their conclusion. That information would have taken days to arrive by ship or land courier (Mattelart, 1994: 8).

A further reduction of individual responsibility on the part of soldiers at the battle site came with the extension of communications. National leaders in London or Paris were able to direct the fighting during the Crimean War much more closely than they could in past wars. When local commanders where faced with an important decision, they could consult with superiors far away. The speed at which collaborative decisions could be made dramatically increased.

Aircraft

The second trend in the extension of vision was the use of aircraft to improve the perspective of the observer. Human flight was possible at the end of the Eighteenth Century when the Montgolfier brothers launched the first manned balloon in 1783. Early balloons consisted of a light cloth bubble from which a basket was suspended. Hot air, or a light gas such as hydrogen, pumped into the bubble caused a buoyant force that lifted the basket. Modern balloons have a small burner in the basket to generate heat for lift.

Balloons of the nineteenth century depended on gas pumped from the ground, or stayed aloft as long as the initial fill allowed. The most commonly used gas was hydrogen. Hydrogen is the byproduct of a reaction between iron and sulfuric acid. Contemporary ballooners would generate hydrogen by mixing the two in an air tight box with a hose leading to the balloon's envelope.

Napoleon's army experimented with balloons but did not find them useful. The bulky support equipment required for balloon operation was too difficult to transport long distances. The primary value of the balloons was the terror they caused with the English. During the Napoleonic Wars, the English were concerned that the French would launch an invasion of Gibraltar or the British Isles with balloons (Van Creveld, 1991: 184).

The American Civil War saw a more intense use of aircraft. During Union General McClellan's advance down the Virginia peninsular in 1862, Professor T.S.C. Lowe coordinated the launching of balloons for reconnaissance purposes. Prior to the war, Lowe enjoyed a successful career operating balloons for entertainment purposes. He was asked to form a balloon corps at the start of the war in 1861.

Lowes' balloon corps consisted of three balloons and portable equipment to generate hydrogen. The balloons could achieve an altitude of about 1000 feet. Balloons were safe at this altitude, because artillery of the time could not elevate their guns high enough. The launching of a balloon was a risky affair because the balloons had to reach this altitude before they were shot down.

Once safely aloft, the balloons provided effective, though limited, intelligence. Shortly after their introduction, telegraph wires were connected to the basket so the pilot could report enemy movements without landing. The primary advantage of the balloons was that they forced the Confederates to waste valuable time concealing their movements during battle. Unfortunately for T.S.C. Lowe and his balloons, the Union Army did not know this until after the war.

The difficulties associated with balloon operation compared to the benefits proved to be their demise. During the peninsular campaign of 1862, the terrain was relatively flat and clear. However, a large proportion of the Civil War was fought on hilly, forested land. The limited altitude of 1000 feet was not sufficient to significantly increase perspective. Balloons were phased out of the organization of mobile armies the following year. Future use of balloons was limited to occasional use during sieges, like the one on Richmond in 1865 (MacDonald, 1992: 38).

Small balloon corps remained in the organization of most major armies into the Twentieth Century. Their lingering presence was the result of a 'what-if' attitude. The use of balloons in warfare did not generate spectacular results, yet they were not so useless as to warrant discarding them altogether. They were successfully used for mail delivery during the German siege of Paris in 1870.

The use of lighter-than-air technology was revived by the Germans in World War One. Dirigibles, or zeppelins, were balloons with a hard shell filled with hydrogen or helium. The Germans used dirigibles extensively during the war for reconnaissance, especially at sea.

In both world wars, balloons and dirigibles were used in an anti-aircraft role. *Barrage balloons* were raised above cities and military bases to serve as obstacles for attacking aircraft. Barrage balloons were flown at altitudes of about 2500 to 3000 feet and from 6000 to 8000 feet, typical attack altitudes of aircraft. They were never manned (U.S. War Department, 1945: 357).

The development of heavier-than-air flight provided the necessary performance advances for truly effective military vision from the air. The first successful aircraft was flown by the Wright brothers in 1903 at Kitty Hawk, North Carolina. The American military lost this early lead in air power because Congress refused to fund the development of aircraft for several years. The evolution of the aircraft quickly shifted to Europe.

The first combat use of airplanes was during Italy's invasion of Libya from 1911 to 1912. A small number of aircraft where used successfully for reconnaissance and artillery spotting. Primitive attempts were made at aerial photography with less success. While individual pilots brought rifles and small bombs aloft, there was no concerted effort to use aircraft directly as a weapon (Van Creveld, 1992: 185). The impression of aircraft as reconnaissance tools would continue through the early years of World War One.

The first use of aircraft in the war mirrored the Italian campaign of 1911. Aircraft were used to spot enemy troop movements, to adjust artillery fire and take aerial photographs. As with any weapon, aircraft saw its role diversify over the course of the conflict. At the start of the war, enemy pilots were generally friendly with each other. When passing in the air, they would wave and signal. Congeniality soon ended when the war intensified. Pilots first carried pistols, then rifles and finally machine guns to shoot at each other. Aircraft began to specialize, some were fast and had long ranges for reconnaissance while others traded speed and endurance for maneuverability and weaponry.

Aerial photography as a means of intelligence proved very important to the conduct of battle. The great destructive power of World War One armies tended to obliterate terrain. Maps were made obsolete as buildings, features and vegetation simply disappeared under artillery fire. The practice of using cavalry for reconnaissance was impractical because of a dependence on maps for locating position. Maps no longer represented the terrain. As a result, units could not find their position in the wasteland.

The advantage of aircraft was that it could quickly gain an overhead perspective unavailable to those on the ground. A single aircraft could travel about 100 to 200 kilometers per hour and record the surrounding terrain with cameras. After only several hours of developing and analysis, these battlefield images essentially become maps with very current information.

At the start of World War One, the major powers had a total of 500 aircraft between them. As aircraft became more useful and specialized, the need for them grew. At the conclusion of the War, the British alone had purchased 50,000 aircraft (Van Creveld, 1992: 288).

There was continued dramatic improvements in aircraft development during World War Two. The majority of changes were extensions of ideas initially developed during World War One. In the 1940s, airplanes were used for strategic bombing, launched from ships, attacked submarines and operated at night. The Germans even pioneered the use of jet engines.

The operation of aircraft at night was the result of electronics, another major advance in military vision. Aircraft enhanced vision by improving the perspective of the viewer. Electronics improved vision by enhancing vision itself.

Electronics

The first electronic enhancement of vision was the light bulb. The light bulb was able to penetrate darkness by using electrical resistance to super-heat a filament and produce light. Searchlights, immensely powerful light bulbs, were important for air defense in both world wars. Searchlights would locate enemy aircraft and use their light to direct anti-aircraft fire.

The standard German searchlight of World War Two was the *Searchlight 37*. This searchlight had a lens diameter of 60 inches and generated 990 million candlepower with a 24 kilowatt power supply. The searchlight could illuminate an aircraft at an altitude of 16 500 feet up to five miles away. The searchlight was frequently equipped with a pair of binoculars synchronized with the light beam for purposes of locating aircraft (U.S. War Department, 1945: 356).

The first active sensors had limitations that restricted their usefulness. A searchlight had the ability to clearly illuminate a target, but also clearly illuminated its own position. The majority of World War Two searchlights were remotely operated because of the frequency with which they were attacked. The other disadvantage was that their range was limited. A searchlight could only see an aircraft when it was relatively close. Searchlights defending a city, for example, only spotted attacking aircraft when they were about to release bombs. Searchlights were soon too slow, had too limited a range and were too vulnerable for modern war.

Sensors were needed that could penetrate the darkness of night and distance. As discussed previously in Chapter Three, there are two general strategies for remote sensing, active and passive. Starting in World War Two, efforts were made to extend the range, both in terms of distance and the EM spectrum, of human vision.

The first non-visible active sensor was radar. The principle of radar is similar to the principle of searchlights. A radar sensor broadcasts a signal in the radio wave portion of the EM spectrum. The sensor sees the echo of the returning radiation much as humans see the light returning from a searchlight.

The first primitive radars were developed by the British in 1939. British plane position indicators (PPI) were used to great effect during the Battle of Britain in 1940. Early PPI sets were only able to return the direction and distance of incoming aircraft. The British were able to efficiently disperse limited numbers of fighter aircraft to intercept attacking German bombers. In the following years, radar technology was improved to the point where it could give accurate altitude and speed data. Radar was also mounted on ships and aircraft.

Sonar operates on a similar principle as radar, only sound is used instead of EM radiation. Underwater detection is the primary applications of sonar. The principle is that sound waves are detected as they bounce off an object. The 'ping' heard during underwater battles in submarine movies is the signal broadcast of an active sonar. Passive sonar was deployed when sensors were developed that were sensitive enough. Passive sonar hears sound generated by the target object. The development of this technology was delayed because of the difficulty in filtering out background noise.

A variation of passive sonar was used above ground to locate aircraft. Elaborate networks of listening devices were employed by the British and Germans during World War Two. The networks listened for the approach of aircraft. The position of the aircraft was then calculated by comparing the data from the widely dispersed listening stations. Sound waves do not travel as well in air as they do in water. Sonar use out of water is less effective because of this.

1.3 AERIAL PHOTOGRAPHY

Aerial photography was first systematically used during World War One where it did not meet with universal acceptance despite its value. While the resistance to aerial photography was partially due to limitations in the contemporary technologies, it was primarily due to cultural limitations within the military establishment. The aristocratic general staffs of the European armies perceived photography, as well as most change, as usurping their cultural influence. For example, they continued to prefer horse cavalry, with its aristocratic appeal, for reconnaissance. The lack of a trained staff to efficiently obtain, process and interpret the photography also limited its uses. It is not surprising that the American military, largely free from the aristocracy of European armies, was at the forefront of aerial photography during World War One.

World War Two saw even more extensive use of aerial photographic technologies. Despite improvements in the equipment, a latent resistance to aerial photography continued through out the war and into the 1950s. The Eisenhower administration laid out a plan to overhaul the United States intelligence services. This plan improved upon earlier developments under Truman with a strong emphasis on the development of technological intelligence programs. The Central Intelligence Agency (CIA), previously formed under Truman, acquired large funding for new technology.

This period saw a rift between two camps in the intelligence community. One side favored a reliance on traditional under-cover human agents (HUMINT) and the other on technological strategies (TECHINT) including aerial photography (PHOTOINTEL). The rift was further aggravated by class differences. Those who favored HUMINT tended to belong to highly regarded Eastern families, while those who favored TECHINT originated from Mid-Western and Western states.

Since the dawn of government, officials have hired individuals they know and trust. Allen Dulles, the CIA's founder, was no exception. The first appointments to senior level CIA posts saw a large number of Ivy League educated men. These individuals then hired the same type of people as their subordinates. The CIA of the 1950s was largely staffed by people from a narrow social caste. The pressure to increase TECHINT activities resulted in an influx of new, unfamiliar people. Although the old-guard resisted, American intelligence efforts focused on technology and moved away from a reliance on HUMINT.

The new intelligence programs, which included the U-2 program, proved to be very effective. Success was particularly evident during the Cuban Missile Crisis. This turn of events is usually attributed to an extensive program of technological development during the Eisenhower program. However, the formation of government agencies, policies and a professional interpretive staff to handle the photography collected by the new platforms were of equal importance.

CHAPTER II

AERIAL PHOTOGRAPHY IN THE FIFTIES

This chapter details President Eisenhower's overhaul of American intelligence capabilities. The most important aspect of these reforms in terms of the Cuban Missile Crisis is the shift within the American intelligence community to a reliance on technological intelligence (TECHINT) gathering methods such as PHOTOINTEL. The new TECHINT specialists were generally alienated by their more traditional colleagues. President Kennedy turned to TECHINT for information because of the impartial aura of TECHINT and the outsider status of its practitioners.

2.1 INVENTORY OF IGNORANCE

The United States found itself in a difficult position regarding intelligence on the Soviet Union with the advent of the Cold War. The intelligence that did exist was primarily dependent upon captured German reconnaissance from World War Two and a limited network of human agents that was also highly dependent upon German sources. General Reinhard Gehlen, Adolph Hitler's intelligence chief for the Eastern Front, was captured in 1945 and put to work for the American government. Using old contacts and extensive files that he had buried as a bargaining tool, Gehlen started an extensive intelligence network in Eastern Europe and Russia. The *Gehlen Org*, as his organization came to be known, supplied the American government with almost all its intelligence on the Soviet Union until 1955 (Zepezauer, 1994: 6).

Efforts to improve this situation were complicated by stiff Soviet resistance to HUMINT efforts and the movement of most industry East of the Urals during World War Two. This movement was particularly critical because Soviet industry was now located far inland in regions with sparse populations that made reaching them with aircraft and human agents difficult. The result was that the Soviet Union was a huge unknown.

The Soviet explosion of an atomic and then a hydrogen bomb came largely as a surprise to the American government. Without extensive intelligence gathering options future surprises were sure to follow. Dino Brugioni, an interpreter during the Fifties and Sixties, used a circa 1900 minerals map compiled by Herbert Hoover to pinpoint Soviet nuclear material resources after the detonations (Brugioni, 1991: 6). While this particular effort was successful, it was the exception and not the rule and American intelligence during the late Forties and Fifties was largely ineffective at obtaining important information on the Soviet Union.

Eisenhower became President in 1953 and immediately began a program to overhaul American Intelligence. He pressured the CIA into developing a comprehensive photographic intelligence program. His emphasis on aerial photography was the result of his own World War Two experience and a highly influential report of the wartime United States Strategic Bombing Survey (USSBS).

The USSBS was a comprehensive study of the effects of strategic bombing and aerial photography. The study was commissioned in 1944 by the American military and examined the photographic evidence of bombing runs in the Pacific theater. The study concluded that aerial photography provided the war effort with the single most valuable source of information. According to the study, 80 to 90 percent of wartime intelligence was derived from aerial photography (Brugioni, 1991: 7).

Aerial photography met with stiff resistance in the American intelligence community despite its success during the war. This resistance was primarily due to the backgrounds of high ranking officials in the CIA. For the most part, the CIA was run by members of respected Eastern families educated at Ivy League schools. These individuals were highly educated in the Liberal Arts and favored 'old-style' human intelligence to newer forms of technological intelligence. In a manner similar to the aristocratic World War One generals their social order was threatened by the more scientific disciplines. Their social order, commonly referred to as the 'old-boy network' proved very damaging to American security.

Aerial photography's effectiveness was often damaging to the careers of human agents with jobs to protect. Given the difficulties of HUMINT in the Soviet Union, what information agents could learn was frequently erroneous, or at best, educated guesses. Each individual agent complicated the problem by generating their own version of the situation. Aerial photography reports were not popular when they proved large numbers of individuals wrong.

Eisenhower recognized that the inventory of ignorance resulted in a nation living in fear. Any defense policy developed in such an atmosphere would result in a paranoid armed camp. The existing intelligence programs were simply playing on these fears to further self interests. For example, the U.S. Air Force had a policy of continually over estimating Soviet bomber strengths in order to secure more funds for their service. The formation of an armed camp represented more than a waste of funds: it could also result in a tragic misappropriation of funds. While the Air Force was demanding more bombers, the Soviets were secretly developing ballistic missile programs that would largely make bombers obsolete.

The political damage that could result from ignorance was just as important. Every politician who was at odds with the current administration could select some service's estimate of Soviet strength to meet his political agenda and to damage the administration. John F. Kennedy's presidential victory over

Richard Nixon is largely attributed to a campaign that emphasized the dangers of falling behind the Soviets in military strength (Reeves, 1993: 18).

Photo intelligence promised to provide Eisenhower with a source of information that could overcome ignorance and unconditionally discredit inflated claims of Soviet strength. Aerial photography served as the basis for an overhaul of American defense during the Eisenhower administration. Eisenhower's programs were highly successful in assessing the Soviet Union. He felt these technologies were important enough to national security that he did not publicly reveal them to the country during his administration. This secrecy was despite the fact that his party lost a presidential campaign to a Kennedy ticket that was based on a missile-gap.

The possibility that the Soviets had more missiles, bombers or nuclear bombs than the United States was a hot political issue during the Fifties. Kennedy played upon the fears of a missile-gap and accused the Eisenhower administration of not keeping up with the Soviets. There was a missile-gap, but it was in favor of the United States. The true situation was apparent very early in the Eisenhower administration.

Eisenhower's reforms encompassed a wide variety of programs. The most significant were the U-2 program and the *Corona* reconnaissance satellite. Both of these programs represented major advances in the intelligence field. The *Corona* program will be detailed in the conclusion and the U-2 program discussed in depth below.

2.2 THE U-2 AIRCRAFT

The initial U-2 program was sponsored by the CIA in response to an unwillingness on the Air Force's part to develop such a plane. Eventually, after its success was proven, the program was turned over to the Air Force. The CIA set out to design an aircraft that could overcome difficulties in spying on the Soviet Union. A high flying aircraft with great range that could avoid Soviet air defenses and detection was needed.

Aerial reconnaissance was previously gathered, at great risk, with conventional aircraft. A typical strategy was to fly as close as possible to the Soviet Union and take oblique shots across the horizon. These missions rewarded the risks with little useful information. Oblique photography presents difficult problems of changing scale, particularly in areas away from the aircraft. Additionally, most Soviet installations were hundreds of miles inland - well out of range of such imagery. Electronic eavesdropping (ELINT) was as important as the photography. Aircraft, equipped with special sensors, flew on the fringes of the Soviet Union. When Soviet air defenses turned on their radars, the aircraft recorded them. Radio signals were also intercepted in this manner.

In the early Fifties, the American government was so desperate for intelligence that fighter aircraft were sent along with the surveillance craft. All told, over 100 airmen were lost in reconnaissance efforts over the Soviet Union (Rich, 1994: 124). These losses were largely unpublished at the time, but it was only a matter of time before a public scandal developed. This situation generated a desire for a plane that could fly above Soviet air defense without being detected or shot down.

Perhaps the most amazing attribute of the U-2 is the simplicity and low cost of its design. Operating with Lockhead in 1954 at a top-secret facility, the Skunk-Works, the CIA designed and built 20 such planes for the sum of $22 million. In this age of billion dollar stealth bombers the development of the U-2 program was a bargain. Just as remarkable was that the first test flight was only eight months after the program was started. {Soviet style design}

The U-2 was able to fulfill its mission over the Soviet Union for 4 years. Not until Gary Powers was shot down in 1960 were Soviet missiles advanced enough to harm the U-2. Even after 1960 they proved highly effective in other parts of the world, particularly over Cuba. The U-2 continues to operate around the world in 1995 in a modified form as the TR-1.

The U-2 was a very light, glider-like design. It was not particularly fast, but was able to climb well over 70,000 feet. The actual altitude depended upon atmospheric conditions and the weight of the pilot and equipment. The highest recorded flight of a U-2 was 74,500 feet (Rich, 1994: 126). At the time this was about 25,000 feet higher than the ceilings of any existing aircraft or missile. Contrary to predictions, the plane was easily spotted by Soviet RADAR. The plane flew at only 400 knots and the Soviets were able to track the plane over its entire flight. They were unable to harm it, however. The U-2 bypassed the air defenses of the Soviet Union by simply flying over them. This strategy worked well until the Soviets developed the SA-2 anti-aircraft missile.

The SA-2 was deployed around Moscow in 1958. Throughout 1959, the deployment of the missile was expanded to Soviet industrial sites. Gary Powers was shot down by an SA-2 on May 1, 1960. This sparked an international controversy and brought an end to U-2 flights over the Soviet Union. An SA-2 was also responsible for the downing of Rudolf Anderson in a U-2 over Cuba in 1962 (Brugioni, 1991: 43).

The U-2 proved to be a particularly difficult plane to operate. The extreme altitudes at which it flew required the pilot to breath pure oxygen and wear a special flight suit. The pilot's pre-flight preparations took two hours and included a gradual introduction to breathing pure oxygen, consumption of low-bulk and high energy food to avoid the need for defecation on the long flight, a physical check-up by a doctor and extensive briefings on the flight plan and targets.

The aircraft was so delicate that great care had to be taken by the pilot and flight control. In Europe, a U-2 and pilot were lost when a Canadian jet plane saw the take-off of a U-2 and came in close to investigate the strange aircraft. The turbulence from the Canadian plane's jet-wash ripped a wing off of the U-2. After this accident, the skies were cleared while a U-2 was taking off.

2.3 TECHNOLOGICAL ADVANCEMENTS

The development of cameras that could provide useful imagery from such high altitudes was just as important as the aircraft design itself. Fortunately, a range of technological developments emerged separately that allowed such a camera to be built. According to the Technological Capabilities Program (TCP), commissioned by the CIA, there were four technological advances that contributed to the success of cameras designed for the U-2 : Thin Base Film; The Baker Lens; Computers; and Panoramic cameras (Brugioni, 1991: 14).

Thin base film (TBF) was thinner and lighter than conventional film. This allowed significant increases in film loads with no weight increase. Cameras could also be made smaller and lighter without the need to accommodate heavy film.

A Harvard physicist, James Baker, developed a lens that gave cameras a significant increase in resolution. During World War Two, a typical resolution for an aerial camera was 25 lines per millimeter. Baker's lens had resolutions from 75 to 125 lines per millimeter. This increase in resolution was necessary to maintain detail levels of photographs while flying at high altitudes.

Computers were used to design the new lenses. The design of a lens on paper could take months with no guarantee of success. Computer assisted lens design took weeks or days and allowed for trial and error.

Previously, multiple cameras were mounted in an aircraft to expand the view. This resulted in the plane being weighed down by multiple cameras. The U-2 incorporated a camera that scanned from side-to-side as the plane moved forward. This allowed one camera to do the work of three or more.

The U-2 program resulted in long, far-ranging flights over the Soviet Union that collected enormous amounts of information on Soviet defense capabilities. However, the technological difficulties of safely flying a plane over the Soviet Union were not the end of the struggle. The photography generated by a U-2 flight was dramatically different from the photography most people are accustomed to viewing. The extremes of altitude and scale produced photography that was difficult to understand.

CHAPTER III

THE PHYSICAL PROCESSES OF AERIAL PHOTOGRAPHY

This chapter examines the physics of aerial photography. The camera equipment deployed in the U-2 was based on, what was for 1962, cutting edge technology. The high resolution optics were able to significantly shorten the distance between a high flying aircraft and the ground. The analysts who interpreted U-2 imagery relied upon an understanding of these concepts when extracting information from photography.

3.1 THE PHYSICS OF PHOTOGRAPHY

Before discussing the cameras used in aerial reconnaissance, it is necessary to review the scientific principles that govern photography. A camera does not produce perfect representations of reality. Instead it approximates our visual sense through a chemical transformation. Cameras cannot be understood without a thorough knowledge of the science involved with their use.

3.11 Cameras and Film

All cameras work on the same basic principles: the controlled exposure of a piece of film to light. The reaction of the film records the light that it is exposed to. Cameras have certain common features that allow them to accomplish this task. Diagram 1 is a representation of a typical aerial camera used in aircraft.

The magazine stores a roll of film and protects it from premature exposure. A motor within the magazine advances the film after each exposure. The film itself is drawn between two reels across a flat surface, the platen. It is important that the film lay perfectly flat across the platen or the image will be distorted. Aerial reconnaissance cameras are frequently vacuum powered to remove air pockets behind the film.

The film magazine is attached to a lens cone. The lens cone contains one or more lenses that serve to focus light onto the film pulled across the platen. The lens is the most critical part of the camera. Poor quality lenses can result in distorted images. The primary purpose of the lens is to reduce a section of the earth to a size that will fit on a piece of film.

Light enters the camera and passes through several controls prior to reaching the lens. The shutter is a switch activated door that completely seals the interior of the camera. When the shutter is opened, light is able to pass through the lens and the film is exposed. Additional light control is provided by the diaphragm, an adjustable aperture that controls the intensity of light entering the camera. Through adjustment of the diaphragm and shutter speed, the amount of light that the film is exposed to can be varied according to the needs of the situation.

Diagram 2 is a cross section of a typical piece of black-and-white film. The heart of any film is the emulsion layer which contains thousands of tiny photo-sensitive cells. The emulsion is adhered to a transparent plastic base. Behind the base is an anti-glare backing that ensures no light is reflected back towards the emulsion. Films usually have a thickness between 0.05 mm to 0.11 mm. The TBF film used in the U-2 had thickness of under .05 mm.

3.12 The EM Spectrum

The image recorded by a piece of film is not a direct record of the target object but a record of electromagnetic (EM) radiation reflected off the target. The individual photo-sensitive cells within the emulsion layer react to radiation when exposed. The more EM radiation a cell is exposed to, the more it will react. The photographic image is produced by variations between thousands of these reactions.

EM radiation can best be understood as ocean waves. As energy moves through water, it disrupts the water and creates waves. Waves come in many forms, some are small and choppy while others are large and steady. The distinguishing characteristics of waves are their wavelength and amplitude. Wavelength is the distance between two successive crests in a series of waves. Amplitude is the height of a wave, or the distance between a crest and the water level when calm.

Similarly, EM radiation occurs in a variety of forms that are distinguished by their different wavelengths. The various forms of EM radiation are detailed in Diagram 3, the EM spectrum. All radiation moves at the speed of light. The wavelength determines the frequency of the radiation. Radiation to the left of the spectrum has relatively high frequencies because it has shorter wavelengths. Therefore, more waves pass in a given amount of time. Progression to the right of the chart results in a longer wavelength and correspondingly lower frequency.

Our eyes are only sensitive to the visible bands, a small portion in the center of the spectrum. Films can be designed to record those parts of the spectrum outside human vision. In aerial reconnaissance, the most common example is the use of the infra-red (IR). Infra-red is roughly divided into the near IR and the far or thermal IR. Near IR is similar to visible radiation but human eyes are not sensitive to it. Near IR is useful when working with vegetation, which reflects strongly in the near IR. We cannot see thermal IR but we can feel its effect as heat. The cameras aboard the U-2 were frequently loaded with film sensitive to the near IR.

The images recorded by film sensitive to radiation other than the visible do not look dramatically different from normal photographs. The non-visible radiation is either represented in grey-scale or assigned an arbitrary color during developing. For example, near IR is often represented as red in developed prints.

Films are further distinguished between panchromatic and composite. Panchromatic films have one emulsion layer that is sensitive to one or more sections of the EM spectrum. An example of panchromatic film is common black-and-white film which is sensitive to visible light. The film used in the U-2 was panchromatic and sensitive to near IR, green and red radiation. The developed panchromatic film was grey-scale. All the example photographs in this thesis are grey-scale. Composite films have two or more emulsion layers that are each sensitive to different portions of the EM spectrum. Common color film has three emulsions, one for red, green and blue radiation.

3.2 STRATEGIES OF REMOTE SENSING

The source of the radiation used by a camera or remote sensor varies according to the strategy of the sensor. Remote sensors can have one of three strategies according to the source of the radiation they record:

1. Passive Reflective
2. Passive Emitted
3. Active

Passive reflective sensors record EM radiation from the sun reflected off the target. This is the strategy used most often in aerial photography. The second passive sensor records radiation emitted from the target itself, usually thermal IR. Active sensors broadcast their own source of radiation and record the echo. This technology is most often seen in radar which uses microwave radiation, and sonar which uses sound.

Soviet anti-aircraft missiles, detailed in subsequent chapters, relied upon radar to spot and target enemy planes. A radar unit, or plan position indicator (PPI), works by broadcasting a strong microwave signal. Aircraft are detected when the radiation bounces off them and is returned to the sensor. The frequency range used by a radar unit is designated with one of the following letters: K; X; C; S; L; or P. The letters refer to the portion of microwave radiation that the radar broadcasts. For example, Soviet air search PPIs relied heavily on the X band which includes radiation with a wavelength between 2.4 and 3.8 centimeters.

Side-looking airborne radar (SLAR), another form of radar, was employed prior to the development of the U-2 when overflights of the Soviet Union were not possible. Aircraft equipped with SLAR sensors were able to see approximately 100 nautical miles into the Soviet Union without traveling over Soviet territory. SLAR broadcasts a microwave signal similar to PPI radar, but records the returning signal on film sensitive to microwave radiation. SLAR imagery was hampered by extreme changes in scale away from the aircraft.

3.3 U-2 CAMERA EQUIPMENT

A U-2 was typically outfitted with two cameras, a high resolution spotting camera and a low resolution scanning camera. The two cameras were mounted in the fuselage of the aircraft in *Q-Bays* that allowed for easy access to the film. An explosive charge that the pilot could trigger to destroy the equipment in case he was shot down was included in the design. The combined weight of the camera equipment was about 750 pounds. Cameras for the U-2 were designed by Dr. Slam Land, the inventor of the Polaroid camera (Rich, 1994: 126).

The scanning camera was a low resolution design that continuously exposed film to record the flight path. This film allowed analysts to better find the location of the higher resolution imagery taken by the spotting camera. Its low resolution recorded only larger features that could easily be located on maps. The scanning camera was calibrated with the spotting camera so the two could be accurately compared.

The spotting camera used the most in the U-2 was the B camera. It was the second of three high resolution spotting cameras designed specially for the U-2. The B camera was required by the U-2 because of the extreme altitudes at which it flew. Important features of the B camera were motion compensation, ability to scan across the horizon, use of stereo pairs and high resolution (Brugioni, 1991: 185).

The B camera was loaded with two sections of film, each

5000 feet long. These rolls of film were loaded parallel and exposed together, allowing for stereoscopic analysis. The two rolls of film were big enough to expose about 4000 pairs of photographs covering 3500 nautical miles of terrain.

A space saving feature of the B camera was its ability to move into seven positions. The camera could cover the ground from horizon to horizon by exposing film in each of the seven stops. Normally such coverage would require three or more, and possibly seven, cameras. The ability of the B camera to replace up to seven cameras was critical to the U-2 program which could not afford excess weight. Ben Rich, an engineer who worked on the U-2 design, estimated that each additional pound in the aircraft weight would reduce its maximum height by three feet (Rich, 1994: 128). The final photography of a full scan across the seven positions produced coverage approximately 100 nautical miles wide.

Motion compensation was also important for quality images. Even though the film was exposed in a fraction of a second, the airplane would still move forward a significant distance. Mechanisms within the camera moved the platen to compensate for this motion. The result was imagery that was much clearer than if motion compensation was not used. The motion compensation also adjusted the platen to accommodate the lag time between the seven scan images. The resulting set of seven images was perpendicular to the flight path, as opposed to being skewered in the direction of travel.

The final feature of the camera to be discussed here is stereo imaging. Humans are able to judge distance by comparing the slightly different images we receive from our two eyes. Stereo pairs operate on similar logic. Two photographs of the same area are taken from slightly different perspectives. Through the use of special equipment, the analyst is able to compare the two images and generate an estimate of depth and relative position that would not be possible with a single photograph.

On occasion, U-2 pilots supplemented the camera equipment in the Q-bay with hand held cameras. For example, U-2 pilots used 35mm cameras with special film to monitor the Soviet space program. The U-2's flight plan would be designed to coincide with the launching of a Soviet rocket. The pilot would then photograph the rocket's exhaust from his cockpit as he flew by. An analysis of this film revealed the exact nature of the fuel used in Soviet rockets (Rich, 1994: 126).

3.4 THE PHOTOGRAPHIC TRANSFORMATION

The following discussion details the nature of the photographic transformation. The principles detailed apply to both the scanning and the spotting camera of the U-2. The scanning camera, however, had a limited use and the remainder of this thesis deals primarily with the spotting camera.

Objects in photographs are represented through the transformation of individual photo-sensitive cells or grains in the emulsion layer. Each cell reacts to the EM radiation it is exposed to. The degree of the reaction is based on the intensity of the radiation. If a cell is exposed to large amounts of EM radiation, it will be brighter than a cell that receives less radiation.

The manner in which the radiation reaches the sensor is dependent upon the strategy of the remote sensing equipment (detailed above). The camera equipment carried by a U-2 recorded the sun's reflected energy. The following discussion also applies to SLAR imagery. It is important to remember in SLAR imagery the EM radiation is broadcast by the sensor and not the sun.

EM radiation from the sun either reflects or transmits when it strikes an object. Transmittance is when some, or all, of the radiation passes through the object. For example, glass transmits visible light. Reflection is when the radiation bounces off the object. An object's reflectance or transmittance is selective depending on the frequency of the radiation.

Knowledge of an object's specific spectral qualities is useful when interpreting photographic images. A person wearing green and brown camouflage in the woods may be hard to see with the naked eye because he and his background are the same color. With infra-red photography, that person would stand out because vegetation is one of the strongest reflectors of near infra-red radiation. The person would appear very dark compared to the vegetation background because people and clothing do not reflect strongly in the near IR.

The amount of reflected energy is also dependent upon the shape of the object. The sun's radiation reaches the camera by bouncing off the target object and reaching the lens. Objects generally fall into two categories of reflectors, specular and diffuse.

Specular reflectors are relatively flat and have even surfaces. They reflect the majority of radiation striking them in one direction and appear either very bright or very dark in photography. A common example of this is sunlight striking a calm body of water. From most directions the water appears dark, but when the sun strikes the water just right, it can be blinding. A perfect specular reflector is black in all directions except one. Specular reflectors in the example imagery include runways, buildings and aircraft.

Diffuse reflectors are rough and uneven surfaces. They tend to reflect radiation in all directions. A good example of a diffuse reflector is the top of tree canopies. The mix of intertwined branches and leaves of a tree's canopy reflects radiation in all directions. A perfect diffuse reflector has a uniform brightness from any angle. Examples of diffuse reflectors in the example imagery are tree tops, dirt and canvas.

3.5 ELECTROMAGNETIC DISTORTIONS

Radiation is subject to a range of distortions before it reaches the camera and becomes part of the photographic image. These distortions fall into four general categories:

1. Atmospheric
2. Dimensional
3. Spectral
4. Temporal

3.51 Atmospheric Distortion

Atmospheric distortion is caused by an interaction between EM radiation and the atmosphere. At short ranges these effects are not noticeable. At the altitude of a U-2 flight, 70,000 feet or more, atmospheric distortion becomes very important. The atmosphere affects EM radiation in one of three ways: absorption; refraction; and scattering.

Absorption is the tendency of the atmosphere to absorb certain parts of the EM spectrum. Radiation absorbed by the atmosphere is unable to reach the sensor. Common sources of absorption are carbon dioxide, which absorbs thermal IR, and water vapor which absorbs visible and near IR radiation.

Refraction occurs when the atmosphere varies in density. EM radiation is refracted or bent from a straight line path when it passes through two bodies with differing densities. A good example of refraction is found when looking into calm water. Objects under water are slightly off-set from their apparent position, which makes grabbing a fish difficult. Refraction is an important source of error in high altitude aerial photographs.

Scattering occurs when radiation is redirected by the atmosphere. The atmosphere behaves similarly to a diffuse reflector and scatters radiation in all directions. The effect of scattering is that the atmosphere becomes the color of the scattered radiation. Shorter wavelengths tend to scatter before longer wavelengths. The sky and distant objects are blue because that radiation, the shortest visible, is scattered the most.

The design of cameras and remote sensors must take the distortion qualities of atmosphere into account. The cameras on board the U-2 used a 'yellow filter' that excluded blue radiation because of its tendencies to scatter. When interpreting aerial photography the analysts must take into account that the camera did not record entirely untouched radiation. For example, a bright blue object would actually appear very dark.

3.52 Dimensional Distortion

Dimensional distortion is the difficulties of transferring a curved and three dimensional world to a flat piece of film. In photography, this is evident by the difficulty of determining relative distance. In aerial photography, changes in dimension make photogrammetry, or the accurate measurement of photographs, very difficult.

At the high altitudes of the U-2, most objects were small enough that a loss of the third dimension was not critical to understanding them individually. However, the curvature of the earth was important. An aerial photograph taken at 70,000 feet begins to display scale problems similar to maps. The photograph is perpendicular to the ground in the middle, or principal point, of the photograph. The distance between the camera and the ground increases towards the edge, distorting scale.

3.53 Spectral Distortion

Spectral distortion is the distortion of the EM spectrum that occurs when film is developed. Panchromatic film transforms the EM spectrum into a gray-scale image. In a black-and-white photograph, a bright red object would appear the same as a bright green object. Composite films that are sensitive to non-visible radiation transform multiple emulsions into one of the three visible colors. The photo analyst has to remember that the colors in these forms of photography do not approximate normal vision.

3.54 Temporal Distortion

Temporal distortion is the often disturbing way in which photography implodes our sense of time. We experience our lives as a continuum, where each event is interconnected to the next in a fixed progression. The photograph disrupts this notion of linear time. Photography records and isolates an instant of time. We have become very good at scripting preceding and subsequent events into the moment of a photograph. For example in a picture of someone conducting a physical activity, such as running, we are able to imagine the moments right before and right after the film was exposed. We can envision the subject of the photograph running, even though they are not actually moving.

Three forms of time converge in a photograph: the past; present; and future. The photograph is a record of a past event but, as you look at the picture, the subject is not currently in motion. Through the grammar of photography, which treats photography as the here-and-now, the subject is in motion. The future of the photograph is that we can project the continuation of the event.

The implosion of time within photography can be very discomforting. Photographs of dead people, especially those taken moments before their death, are disturbing. These emotions are particularly acute when viewing photographs of dead loved-ones. We feel the joy of seeing and remembering them alive, but are faced with the terror of their eventual death.

3.6 THE POLTAVA

The transformational qualities of photographs make their analysis potentially difficult. To overcome these limitations, specialized sciences have developed. Before discussing them in chapter four, an example is presented to emphasize the need for such disciplined sciences.

Soviet missiles were discovered in Cuba in October 1962. Several months before, the United States had pictures that might have alerted the government to the missiles earlier. It was common practice for the United States Navy to photograph all Soviet ships on the high seas. Particular vigilance was paid to ships heading for Cuba. Through the use of both carrier based and land based aircraft, extensive libraries of all ships heading to Cuba where obtained. Image 1, of a Soviet ship en route to Cuba, is typical of these series of photographs.

One of the ships photographed was the Soviet ship *Poltava*. The *Poltava* was designed to carry large sections of uncut lumber. For this purpose, she had large cargo hatches that could accommodate very long logs. A photograph of the *Poltava* taken by the Navy in Caribbean waters during the summer of 1962 shows that she is high in the water, indicating either no cargo or a relatively light one.

The *Poltava* was dismissed as empty and not important. No one asked why a ship would travel thousands of miles from the lumber-rich Soviet Union to pick up lumber in Cuba. Soviet missiles were substantially lighter than a log because they were shipped with empty fuel tanks. They were essentially large pipes and a ship carrying them would ride high in the water. The cargo hatches and loading equipment on board the *Poltava* were perfect for transporting missiles.

The examination of photography as an indexical sign provided useful insight into its representational properties. The focus of the chapter was on how physical objects are represented on a piece of film. Chapter four examines how information is extracted from a photographic image. If the representation is detailed, people can easily 'read' the photograph. When the photograph is less representative, the reading process is more difficult.

CHAPTER IV

INTERPRETING AERIAL PHOTOGRAPHY

This chapter examines the logical processes with which information is derived from photography. U-2 imagery was examined by a multi-disciplinary staff at the National Photographic Interpretation Center (NPIC). The NPIC personnel conducted there analysis according to a rigorous set of interpretive rules known as Airphoto Interpretation.

4.1 TRANSPOSITION

A useful analogy for transposition is the willing suspension of disbelief required to enjoy science fiction. When we watch a science fiction movie or read a science fiction book, we are presented with a world that is clearly outside our normal experience. Yet we are able to identify science fiction as fiction. By 'turning-off' our sense of normality we enter the world of science fiction and can still enjoy the show even though it makes no sense. Photography requires a similar perspective to overcome its limitations.

Airphoto interpretation is the science that evolved to overcome the limitations inherent in aerial photography. Airphoto interpretation is not a uniform discipline. A diverse range of related sciences have evolved to overcome the limitations of photography and extract information. Examples include broad disciplines such as photogrammetry or more specialized sciences such as crateology or tentology. Airphoto interpretation is used here as a unifying term for this diverse range of subjects. The analysis of U-2 photography was a team effort that brought together a wide range of disciplines.

Before examining the science of air photo interpretation, an example will be given to develop the necessary mental framework of a photo analyst.

Examine Image 2. What is this person doing? Most readers will recognize that he is throwing a javelin, or more correctly, he was throwing at the time the photograph was taken. The image itself is not throwing a javelin, it is static both temporally and spatially. The viewer automatically scripts these attributes into their perception of the photograph. Our everyday experience easily recognizes the man's posturing as that of someone throwing a javelin.

Could the man be striking the javelin into the ground? Which way is he throwing it? Does he intend to hit someone with his throw? The reader can answer these questions because of a familiarity with the sport of track and field.

The process of identifying this photograph is relatively easy and automatic. We seldom consciously think about the logic of identification on a daily basis. In effect, we have a willing suspension of disbelief. Suspension of disbelief is important because it allows us to overcome photography's limitations. When we look at the picture of the javelin thrower, we know the image is not actually a man and that the image is not moving. The photograph's reproductive qualities are ignored and the message is transposed into our minds as though we were seeing the photograph's subject directly.

Another example will bring us closer to the task of an air photo interpreter. Look at Image 1, a picture of a Soviet ship. Is the ship moving? If it is moving, which way is it moving? How did you arrive at your answers? Most likely by examining the surf at the bow of the ship or perhaps by its shape. A reader unfamiliar with ships may not have been able to make these connections between the surf and movement. Yet CIA analysts who examined the imagery taken over Cuba had to answer more complex questions than the simple exercise above, not the least significant of which was the contents of the ship. Was the ship carrying food, medicine or nuclear missiles?

The process with which analysts classified U-2 photography was not dramatically different from the way in which you identified the runner or determined which way the ship was moving. However, it was a process neither as quick nor as simple, as exemplified by the case of the *Poltava* in Chapter III.

4.2 AIRPHOTO INTERPRETATION

> Photo interpretation is defined as the process of identifying objects or conditions in aerial photographs and determining their meaning and significance (Avery & Berlin, 1992: 51).

The task of the photo analyst is to identify the subject of an aerial photograph. As detailed above, this task can be difficult given the transformational qualities of photography. Identification involves a wide-ranging knowledge of the photograph's subject, the camera system and regional geography.

4.21 Interpretive Tasks

Photo-analysts conduct their analysis using a variety of methodologies or tasks. These methodologies allow the analyst to identify features and objects in the photograph and to postulate collateral information that may not be present in the image itself. The common interpretive tasks are:

1. Classification
2. Enumeration
3. Mensuration
4. Delineation

Classification is the procedure of assigning objects to a particular class or group. For example, objects are labeled as missiles, support equipment or buildings. Classification is accomplished by comparing an object's features to known groups and assigning them to one of those groups.

Classification is the primary concern of the military analyst. Generally analysts are presented with photography that contains unknown subject material and they must determine what is present in the image. The other interpretive tasks are utilized primarily in a supporting role, though frequently they are ends in themselves. Once an object has been identified, employment of the other tasks can reveal supplementary knowledge, like a weapon's performance characteristics.

Enumeration is the process of counting discrete objects. It is not necessary to positively identify objects before enumeration. Soviet military equipment was often identified, not by the way it looked in the photograph, but by the number present in the area. According to the rigid doctrine of the Soviets, military units were deployed in a consistent manner. Enumeration of equipment present in a photograph could reveal the exact nature of the unit deployed and other equipment not present in the image.

Mensuration is the determination of real world size by conducting scale measurements on the photograph. With a thorough understanding of the geometry of the camera, very accurate measurements can be made. The exact series of Soviet ballistic missile deployed in Cuba, the SS-4, was determined by its length of seventy four feet. Photogrammetrists are analysts who specialize in making these measurements.

Delineation is the process of separating the photograph into discrete units. Like enumeration, this does not necessarily require an understanding of what is being mapped. The photo analyst groups similar features together and examines their relationships. Delineation is particularly useful for separating human activity from natural phenomenon. Generally, man made features are linear and have a structured pattern as opposed to natural features which are typically more chaotic.

4.22 Recognition Elements

The photo analyst is able to conduct the basic tasks of airphoto interpretation through an understanding of the eight basic recognition elements found in photography:

1. Association
2. Location
3. Pattern
4. Shadow
5. Shape
6. Size
7. Texture
8. Tone

An understanding of the recognition elements is critical to an understanding of the photo analyst's job. Any object found in a photograph can be described according to one or more of these attributes.

Association is the common appearance of two features or objects in tandem. This is a particularly important concept in the identification of military equipment. If a certain piece of equipment is always found with another, its presence may help in the identification of its companion.

Location of an object in the photograph can be very important. Military equipment is often deployed in predictable locations. For example, missiles located with a clear view of the sea might be anti-ship missiles.

Pattern is differentiated from location by an emphasis on interrelations between objects and not on topographic position. Soviet antiaircraft missiles were easily identified by their regular, Star-of-David pattern.

Shadow is useful for revealing features that are not apparent in an overhead view. A tall tower would appear as a one dimensional circle if viewed directly overhead. Its height would be readily apparent if the sun cast a shadow of its shape across the image.

Shape is a very strong clue to an objects identity. Military equipment usually looks distinctive. Identification can be very easy if the photograph contains a clear representation of the subject's shape. Unfortunately, at the scale of most U-2 photography, an object's shape was not always apparent.

Size is important both in absolute and relative terms. If photogrammetric measurements are made the object's real world dimensions can be determined and compared to collateral data. Relative size is also important if exact dimensions are not practical. Is the object smaller or larger than a house? How does it compare in size to a truck?

Texture is the regularity of the reflected radiation over the surface of the feature. Smooth features reflect a uniform pattern, while rough features reflect an irregular pattern. Texture is a function of both the surface itself and the angle at which the sun strikes the object. On aerial photography, trees have rough textures and runways have smooth textures.

Tone is the brightness of the reflected radiation from an object. Bright tones indicate a strong reflectance and dark tones indicate a weak signal. Tone is represented in gray scale on panchromatic imagery. On color photography, tone can indicate strong reflectance in one of the three spectral classes. For example, in a color infra-red photograph a bright red object indicates a strong reflectance in the near infra-red band (bright tone) and a weak reflectance in the two visible bands (dark tone).

4.23 Photo Keys

Photo keys are an important aid to photo analysts. Keys are books that synthesize a variety of useful information on a subject. Typically keys have photographic examples under varying conditions and scales. Verbal descriptions and technical specifications generally supplement the photographic material. The aim is to familiarize analysts with the spectral response, i.e. the eight attributes, of their subject.

The photo analysts working for the Central Intelligence Agency (CIA) had 'black-books' on missile technology available. The black-books were compiled by CIA missile specialist Jay Quantrill. Quantrill organized all the information he could find on missiles, Soviet and otherwise, into a series of three-ring binders. The black-books were extremely important in the classification of Soviet missile equipment in Cuba (Brugioni, 1991: 199).

4.3 THE NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER

A single U-2 mission exposed about 10,000 feet of film on a single mission. The proper analysis of this photography required the involvement of large numbers of specialized individuals. To coordinate these efforts, the National Photographic Interpretation Center (NPIC) was formed in 1955. The founding director, Aurthur C. Lundhal, made every effort to bring the entire interpretive staff under one roof.

The NPIC at the time of the Cuban Missile Crisis was located in the Steuart Building in Washington D.C. The building was chosen because it was in a crime-ridden area of Washington away from the government sections of the city. The bottom three floors of the seven story building were occupied by a finance company. The NPIC staff occupied the top four floors. Every effort was made to make the operation as inconspicuous as possible. This effort was rewarded by a perfect security record during the life of the U-2 program.

All the necessary facilities were housed in the Steuart building except for the developing equipment. After a mission, the film was taken to the Naval Photographic Intelligence Center, also abbreviated NPIC (its abbreviation will not be used in this thesis). From the Navy's lab, the film was taken directly to the Steuart building (Brugioni, 1991: 190).

Once the film arrived at the NPIC, it was divided among six photo-analysis teams. The teams were a multi-disciplinary group of experts. Although the NPIC was a CIA organization, there were representatives from the Army, Navy and Air Force as well. Each team member was selected for specific knowledge, the majority of whom received their interpretive training during World War Two.

The photo analysts employed equipment specially designed for them. This equipment included hand held magnifiers of seven to thirteen times magnification commonly called loupes, and stereo plotters of up to 60 times magnification (Brugioni, 1991: 195). The stereo plotters aided the analyst in simultaneously viewing stereo pairs to simulate three dimensions. The equipment was designed to work with special light sources that used medical x-ray technology.

The film itself was analyzed directly from the negatives (Brugioni, 1991: 23). Transferring the image to print paper proved impractical. The shear quantity of film exposed made conventional developing too time consuming and too costly. Print paper also had significantly less resolution than the straight negatives. The analysis of the negatives was both cheaper and more effective.

4.4 THE ANALYSIS OF U-2 PHOTOGRAPHY

Airphotos are traditionally analyzed with one of five interpretive strategies. The goal of each strategy is to relate real world conditions to a photographic image. The strategies are an application of the interpretive tasks with a knowledge of the eight photographic attributes. Each strategy will be illustrated with an example of its use during the crisis.

The five interpretive strategies employed in the analysis of aerial photography are:

1. Field Observation
2. Direct Recognition
3. Inference
4. Probabilistic Interpretation
5. Deterministic Interpretation

4.41 Field Observation

Field Observation is the technique of visiting part of the physical site of the photograph. This strategy is most useful when there is a reoccurring feature on the photograph that cannot be identified. Visiting all unidentified features defeats the purpose of aerial photography, but a visit to select sites will give the analyst greater insight into the spectral responses of the photograph's features.

The analysts working for the NPIC did not have the luxury of visiting Cuba to check their work. However, the staff was able to imitate field observation through other means. The essence of field observation is the comparison of real world features to their photographic representations. Classification is much easier when the analysts have a firm understanding of the spectral responses of their subject.

The NPIC staff was encouraged to examine aerial photography of American military equipment and then to visit the site on the ground. All military equipment share common features and by understanding the spectral response of American equipment, analysts were better able to identify Soviet equipment.

The selection of the interpretive staff also approximated field observation. The staff employed by the NPIC had extensive experience with military equipment outside of airphoto interpretation . Significantly, many NPIC analysts had worked on the identification of German rocket technology in World War Two. This experience was invaluable in the analysis of the Soviet military presence in Cuba.

4.42 Direct Recognition

Direct Recognition is the way photography is generally read in everyday life. Analysts employ direct recognition whenever they, through experience, are able to identify an object directly without more involved analysis.

Direct recognition as a technique saw extensive use as a filtering device. Each roll of developed film from a U-2 mission represented hundreds of miles of terrain, most of which was irrelevant to the interests of the NPIC. The analysis teams would mount the film roll on the light table and quickly scan the imagery looking for possible military sites.

While all film would later be studied in detail, this screening process allowed the staff to focus on the most important information first. The imagery was also divided according to individual specialties. Possible missile sightings would go to the missile specialists and naval installations would go to the navy specialists for analysis. At this point, the teams would settle down to conduct more exhaustive interpretive strategies.

Given the experience of the NPIC's staff, direct recognition played an important role throughout the interpretive process. The staff had examined so much photography that they would frequently instinctively recognize features that would be indistinguishable to the untrained eye. In addition to the preliminary scan, direct recognition was important in the identification of aircraft.

Aircraft have unique configurations that serve to distinguish them from other aircraft. After dealing with Soviet aircraft for some time, identification was easy for the analysts if they were working with quality photography. Unfortunately, the U-2 photography was small scale, frequently blurred and the aircraft could be partially concealed. To aid the analyst, the NPIC maintained recognition manuals similar to the missile black-books. The recognition manuals included sample photography, technical drawings and specifications, details on known variants and verbal descriptions.

The task of the interpreter did not stop with simple identification. An examination of supporting equipment, buildings and runways allowed experienced analysts to discern many additional facts about the aircraft. They were able to determine the aircraft's specific series or version, weapons it carried and whether it was operational or not. Even flaws in its design could be detected.

4.43 Inference

Inference is the extraction of knowledge based on known relationships: 'where there's smoke there's fire.' Through inference, certain objects or conditions are assumed based on the presence of appropriate associated factors.

Inference is very important in the photo analysis of military equipment which is usually deployed under rigid organizational constraints. Modern militaries are very complex and rely on an extensive array of supporting hardware. Much of this equipment is designed for very specialized roles. The initial presence of Soviet long-range fighters and bombers was discovered not by direct photography, but by noticing that the Cubans increased the lengths of major runways to those found in Soviet bomber bases elsewhere (Brugioni: 1991, 740). It was no surprise to the NPIC staff when long-range bombers were photographed there later. See Image 10 of a Soviet bomber base. This image was taken on an August 29, 1962 mission that covered the entire island of Cuba. Soviet IL-28 bombers are visible parked next to a long runway.

The most overt use of inference was the deployment of Soviet anti-aircraft, or surface to air missiles (SAMs). Examine image 11 of a SAM site. The most striking feature of this photograph is the Star-of-David pattern. This pattern was the usual deployment scheme for the Soviet SA-2 anti-aircraft missile. The NPIC had similar scenes from Eastern Europe, the Soviet Union, China or wherever the missile was deployed.

The Star-of-David pattern was used to facilitate targeting and reloading. A command center and targeting radar is in the center of the deployment. The targeting radar tracks potential targets and relays the firing data to the surrounding missile launchers. This setup allows one radar set to service six launchers. The pattern also facilitated reloading. The roads were designed so missile trucks could drive up to the launcher to reload. After loading, the truck could drive through to quickly access the other launchers without backing up. The entire battery of launchers could be serviced quickly with only one truck.

The analysts at the NPIC were able to identify Soviet SAM sites in Cuba by this pattern. The following excerpt concerns film taken on August 29, 1962:

> Within minutes after the film was placed on a light table, a Center photo interpreter assigned to the mission scan team shouted, "I've got a SAM site." Excitement spread, and other photo interpreters gathered around him to look at his find. There were subsequent shouts, and before the day was over, eight SAM sites in various stages of construction were found in western Cuba (Brugioni, 1991: 104).

4.44 Probabilistic Interpretation

Probabilistic interpretation is the use of extensive information not found in the photograph itself. The external situation of a photograph is often very revealing. The example commonly given in airphoto interpretation texts is that of crop analysis. Crops can only grow in certain regions and at certain times. Aerial photography of Alaska in December will not have coffee plants.

The NPIC staff had a wide variety of information on Cuba available to them. They were acutely aware that it was a Soviet military buildup and knowledge of the political situation helped structure the analysis. When they examined imagery from Cuba, they were searching for Soviet military equipment. When confronted with the task of identification, non-Soviet equipment could be immediately eliminated. It was highly unlikely that the NPIC staff would find a sudden influx of British or American equipment.

The availability of HUMINT reports on the island was another valuable source of information. Refugees and agents provided important supplementary data about ground conditions and possible missile sightings. A report of missile sightings from recent Cuban refugees might prompt the NPIC to re-examine old imagery.

A highly involved form of probabilistic interpretation is known as crateology. Crateology involves determining a crate's probable contents through exact measurements and specialized knowledge of the dynamics involved with shipping military equipment. This analysis would be conducted on photography similar to Image 1, a photograph of a Soviet ship en route to Cuba. The analysts at the NPIC were faced with the difficult task of identifying the contents of this, and similar, ships.

The first step was a detailed mensuration of the crate. Care was needed to make the measurements as accurate as possible. The measurements depended upon a thorough understanding of the geometry of the camera. The dimensions would then be listed within a certain confidence level. For U-2 imagery, a 70 foot object, the length of an SS-4 missile, was expected to vary by about 2 or 3 feet between photographs.

An example of measurement is the determination of scale at the photograph's center or principal point. The scale can be determined as a representative fraction (RF) between the aircraft's altitude in feet and the camera's focal length in feet.

$$RF = \frac{\text{Focal Length}}{\text{Altitude}}$$

The RF scale is a relationship between the photograph and the real world. The RF is the number of units represented on the ground by one such unit on the photograph. The RF scale for a typical U-2 image is; 3 feet (focal length of B camera) divided by 70,000 feet (common flight altitude), which is 1:42,857. Therefore, one inch on an 18" x 18" print represents 42,857 inches, about eight miles, on the ground. The RF as computed is valid only at the photograph's principal point. The determination of scale elsewhere in the image is substantially more involved.

Image 1 was not taken by a U-2. It was photographed by an RF-101 reconnaissance jet at a low altitude. The RF-101 was a modified fighter aircraft. Cameras where mounted that could take photographs from the sides and bottom. While this aircraft was much faster than a U-2, it had neither the range nor the ceiling of the U-2. The use of the aircraft was therefore limited to situations with little anti-aircraft defense. The RF-101 was used to photograph ships on the high seas and occasionally made daring runs to photograph installations near the shore.

Image 1 differs from U-2 photography because of the angle at which the ship was photographed. This type of image is known as an *oblique* photograph. In oblique photographs, the platen is not parallel to the ground. Oblique images are further distinguished between high and low angles. The horizon is visible in high oblique photography and not visible in low oblique photography. Image 1 is therefore a low oblique photograph. U-2 photographs are vertical images because the angle of the platen is parallel to the ground. An example of a vertical photograph is Image 3.

Because the aircraft was within several hundred feet of the target, mensuration could be conducted with high precision. The measurements made by an analyst on this photograph would be expected to vary by no more than one inch. The oblique angle also offered the opportunity to measure multiple sides and construct a three dimensional model of the crate.

Weight estimations were also made but with substantially less accuracy. Weight estimates were done by examining the crate's construction, tie-downs and loading on the ship. If a crate was constructed of light materials and had few tie downs, the analyst would surmise that it was not heavy in relation to its size. Likewise, if a crate was solidly constructed with extensive tie-downs, it would be classified as heavy. The crate's positioning on a ship was also important. A single crate, carefully placed in the center of a ship was probably heavier than crates loaded on the sides of a ship or in an unbalanced arrangement.

After mensuration, the analyst was faced with the task of 'fitting' a cargo into the crate. Two facts aided the interpreter in this task: 1. Most Soviet cargo ships were old US Liberty ships from World War Two and blueprints were on file; and 2. Military shipping containers were relatively standardized and black-books on known Soviet shipping crates and their contents were available.

The analysts conducting crateology were intimately familiar with the techniques of shipping military equipment. Even when a crate had not been previously identified, analysts enjoyed great success in identifying its contents. Military equipment can be packaged and shipped in limited ways.

The crates on board the ship in Image 1 contain IL-28 bombers. The bombers are returning to the Soviet Union after the resolution of the Cuban Missile Crisis.

4.45 Deterministic Interpretation

Deterministic Interpretation is a rigorous methodology of quantitatively analyzing the information contained in a photograph. A common example of this is the production of topographic maps from 'stereo-pairs.' Stereo-pairs are two images of the same area taken from slightly different angles. The B camera in the U-2, with its two rolls of film, was designed to automatically expose a stereo pair with one shutter action.

We are able to see three dimensions because we have two eyes that have slightly different views. By focusing on an object, we have learned to judge distance by the way our eyes focus. Stereo-pairs utilize a similar principle. A stereoscope allows the analyst to judge the relative elevation of features photographed in a stereo-pair. Stereo-pairs are how the United States Geologic Service produced the majority of its topographic maps. The following discussion details the analysis of a possible missile site photographed near Banes, Cuba on the August 29 mission (see Diagram 4).

Initially, the Banes site was thought to be another set of SA-2 missiles because the launchers were not big enough for larger missiles. However, there were a number of inconsistencies in the photographs that disturbed the analysts (Brugioni, 1991: 120). The most obvious is that there was no Star-of-David pattern. As the terrain was rough, the analysts felt that such a deployment may have been impossible. Further considerations were that only two missiles launchers were deployed here and they were not constructed to allow for drive-threw loading. The missile trucks had to back-in to load the launchers, a timely process.

Actual missiles were not photographed at this time. This complicated the analysis. The missiles would be photographed in subsequent missions, but initially the NPIC staff were limited to what they had. By carefully analyzing that information, they were able to formulate a remarkably accurate estimate of what the unidentified missiles were.

Using the stereo scope, the missiles were found to be situated on ground between 250 and 300 feet above sea level, pointed out to sea (Brugioni, 1991: 128). This deployment was peculiar because higher terrain was located nearby which would block the missile from firing at aircraft in certain directions. If the missiles were anti-aircraft, it would have made more sense to locate them on the higher ground.

The missiles were therefore determined to be anti-ship missiles. The potential range of these missiles was also revealed by the terrain. Blocking the missiles' line of sight was a large island. A range of at least 20 nautical miles would be required to shoot over the island. The analysts felt that the elevation was significant because higher ground was passed up. The line of sight to the horizon was about 30 nautical miles from the current position. Locating the missiles on nearby higher terrain would have increased the range to the horizon. The missile range was determined to be between the figures of 20 and 30 nautical miles. Otherwise, the missiles would have been located elsewhere. In their current location, the missile launchers were protected from air attack by the higher ground and from ship attack, beyond their range, by the horizon.

4.46 Composite analysis

Composite analysis is not an interpretive strategy in the style of the previous examples but is closest to the manner in which airphoto interpreters actually worked. The photo analysts at the NPIC would utilize all the of the above strategies simultaneously.

When the anti-ship missile installations at Banes were reported to President Kennedy on September 7, 1962 he was not happy with the lack of information. Because the actual missiles were not photographed, information on them was only speculation. Dino Brugioni, an NPIC interpreter, felt that the lack of information on Banes came as a surprise to Kennedy. Prior to this report, the NPIC had provided huge volumes of detailed data on the Soviet buildup. Kennedy may have felt the NPIC was deliberately withholding information (his distrust of the CIA is discussed in Chapter Four) (Brugioni, 1991: 124).

The staff responded to the criticism by redoubling its efforts. An initial break came when similar sites were found in photography taken over China. The Chinese missiles were all deployed facing out to sea. However, there was still no positive identification. The final break came when two German scientists, captured by the Soviets during World War Two, returned home from the Soviet Union. In their debriefing, they reported working on a cruise missile that was launched from two rails mounted on a bomber.

The launchers at the Banes and China sites were comparable to the German scientist's descriptions, only land mounted. Further conversations with the German scientists revealed that the missile was ideally suited to an anti-ship role and had a range of no more than 30 nautical miles (Brugioni, 1991: 128). At this point, the launchers were positively identified as Soviet Kennel cruise missiles, deployed as an anti-ship missiles.

When informed, President Kennedy was relieved they were not long-range nuclear missiles. However, his anxiety over the possible introduction of nuclear missiles in Cuba continued. To alleviate his concern, he ordered another U-2 mission to fly on October 14. The mission was delayed until October 16 because of poor weather. The results of the flight justified Kennedy's fear of Soviet missiles in Cuba.

4.5 MISSION 3101

On October 16, 1962 after an exhaustive pre-flight procedure, Air Force Major Richard Heyser piloted his U-2 into Cuban air space at an altitude of 72,500 feet. This mission was historic in more ways than one. It was the first flight of an Air Force U-2. The program had been handed over previously to the Air Force because the U-2 proved too expensive for the CIA to operate. The Air Force was easily able to integrate the U-2 into its existing programs. Its success long since proven, it was a task the Air Force readily accepted. Infinitely more significant, this was the mission that first photographed nuclear missiles in Cuba.

Upon arrival at the NPIC, the film was divided among the interpretive teams for the preliminary scan. Gene Lydon, of the CIA, and Jim Holmes, an Air Force interpreter, were assigned a section of film covering the area around San Cristobal, Cuba (Brugioni, 1991: 170).

Because of the earlier discovery at the Banes site, much emphasis was placed on finding additional cruise missiles. While none where found, the Lydon/Holmes team found six oblong objects covered by canvas. A comparison with the scanning camera image put the location near San Cristobal, Cuba (see Diagram 4). The photograph was labeled as 'possible missile-associated installation' and the preliminary scan was continued. The San Cristobal photography then circulated between various missile specialists. Image 5 is an enlargement of that historic photograph.

The analysis of the potential missiles included mensuration, cataloguing of support equipment, topographic calculations and heavy use of the black-books. The NPIC staff finally classified the missiles as Soviet SS-4 ballistic missiles. The SS-4 had a moderate range for a ballistic missile of 1100 nautical miles and was capable of reaching the United States (see Diagram 5).

The Soviets had two other operational ballistic missiles, the SS-3 and the SS-5. The SS-3 was ruled out because it was about 20 feet shorter than the missile in the photograph, as well as out of date. The SS-5 had similar dimensions, but was the Soviets newest missile. Although it had twice the range, the analysts felt deploying such a missile would generate more problems for the Soviets than it was worth. The SS-5 used substantially different technology from the SS-4 and had not yet been deployed in the field. The Soviets did start construction of SS-5 sites but never completed them. The SS-4 classification was confirmed by subsequent reconnaissance flights.

The President was informed of the Soviet deployment after an exhaustive process of confirmation. The job of NPIC interpreters was to examine and synthesize photographic intelligence for national leaders. The people whom they reported to did not want the burden of reading the photographs themselves. The NPIC was charged with making the linguistic leap from a photographic representation to a photographic fact. The work of the NPIC was accepted and applied by national leaders, the subject of the next chapter.

CHAPTER V

AERIAL PHOTOGRAPHY IN THE CUBAN MISSILE CRISIS

The previous discussion has focused on aerial photography as an intelligence gathering system. There was no concerted focus on how the information gained through aerial photography was utilized in national policy. The preceding symbolic economies largely ignore national politics. The photo analysts at the NPIC would treat photography of Cuba the same as they would photography of the Soviet Union or China.

The NPIC was not free from political influence. The photography they were charged with analyzing was dictated by politics. Policy makers identified intelligence needs and ordered reconnaissance runs. The center received the resulting photography. The analysts' assessments were then returned to the policy makers who implemented the information into national policy.

This chapter is an examination of how the photographic message passed through the institutions of the American Government during the Cuban Missile Crisis. The central question is how the information generated by the NPIC was relied upon to formulate national policy by the Kennedy administration.

5.1 ORIGINS OF A CRISIS

It is necessary to understand the historical situation of Cuban-American relations before photography's role in the missile crisis can be understood.

The origins of the Cuban Missile Crisis lay in a chain reaction of moves, counter-moves and misunderstandings between the United States and Cuba. The two sides each thought they had legitimate security fears from the other side, fears that were constantly reinforced by the other's reciprocal defensive measures.

The historical record on the crisis contains convincing evidence that the fears of either side, particularly the United States, may have been unwarranted and exaggerated (Mathers, 1961). What is important is that these fears were very real to the participating policy makers and they conducted their agendas accordingly. To the United States government, the Cuban Revolutionary movement was a subversive threat to the peace and prosperity of the Western Hemisphere. Likewise, the Cuban Government had every reason to fear the enormous American efforts to destroy what the Cubans felt was a justifiable revolutionary movement.

As the first country in the Western Hemisphere to overthrow European colonial control and the leading hemispheric power, the United States developed a policy whereby it situated itself as the protector and moral guardian for the region's peoples. This long-running policy, called the Monroe Doctrine, after the early American President James Monroe, was based on keeping European powers out of the Americas. With the advent of the Cold War, American vigilance shifted from European imperialism to Soviet Communism.

The near paranoia of American foreign policy put it at odds with numerous left-wing, independent minded or nationalist regimes around the world. American foreign policy makers perceived a Soviet threat in every corner of the globe: from Italy to Indonesia. It is not surprising that the Cuban Revolutionary movement would soon collide with American anti-Communism.

Given the excesses of the Batista regime, the long standing dictatorship that ruled Cuba, the Cuban revolution was generally applauded as a welcome change. Fidel Castro, one of the movement's leaders, even enjoyed a cult following in the New York Times during, and for a short time after, the revolution (Mathers, 1961). John F. Kennedy, a Senator at the time, even applauded the fall of the Batista regime on the Senate floor.

The basis for much of the hardship of the Cuban people under Batista was the dominance of foreign owned companies. American companies utilized Cuba for its natural resources, primarily sugar, than exported the profits. The fledgling Cuban government attempted to keep the profits in Cuba.

Initially, efforts were made to regulate and nationalize some foreign interests. Although plans were made for compensation, these moves angered the foreign business community in Cuba who put pressure on the American government.

The first such move was an agrarian reform law of May 17, 1959 that appropriated some American owned land. This law was followed by strong anti-communist rhetoric and plans for compensation. American landowners complained to the Eisenhower administration. Eisenhower was not impressed by the Cuban rhetoric and continued to fear the possibility of Communist influence in Cuba. These fears were reinforced by a series of events within the Cuban government. On July 13, 1959, Manuel Urrutia, the president of Cuba, denounced Communism as not being responsive to the needs of common people. Four days later, the extremely popular Castro resigned as Prime Minister to put public pressure on Urrutia. Forced to choose between Castro and Urrutia, the Cuban people demanded the resignation of Urrutia, who conceded to popular demand. With his rival out of the way, Castro resumed his duties as Prime Minister.

Urrutia's ouster was not the only case of suppressed anti-communist sentiments in Cuba during 1959. In October, Major Huber Matos, a regional military commander, resigned because he felt the Communists were infiltrating the Cuban government. For his public attack on the Communists, Major Huber was sentenced to prison for treason.

Throughout 1959, the Eisenhower administration threatened Cuba by imposing economic sanctions. These threats were the result of a perceived Communist threat. However, they only served to fuel pro-communist sentiment in Cuba and force the Cubans into the Soviet camp.

Cuba's economy was based on the export of sugar and closing the market for its export would be disastrous. A large percentage of Cuba's sugar was sold to the United States under an arranged quota system. An elimination of the sugar quota could easily cripple the Cuban economy. Through the Organization of American States (OAS) the United States was able to pressure virtually the entire hemisphere into following their Cuba policy. To avoid total isolation, the Cuban government was forced to look beyond the hemisphere for trading partners. The natural choice for a new market was the Soviet Union. A trade summit in February of 1960 resulted in a trade agreement between Cuba and the Soviet Union.

The activities of the American government to subvert the Cuban government increased as evidence of Communist influence in Cuba increased. The Cuban government was plagued by sabotage in its early years. The American government looked the other way when Batista loyalists conducted operations to sabotage Cuban military, industrial and agricultural facilities. The most striking case was the explosion of the Belgian ship, *La Coubre*, while unloading arms in Havana harbor.

Any pretensions of peace between Cuba and the United States ended with the arrival of Soviet crude oil in Cuba. The Soviet oil was part of the aforementioned trade agreement. Cuba's oil refining equipment was owned by two American corporations, Texaco and Esso, who recognized the threat that the Soviet presence posed to them. The two companies refused to refine any oil originating in the Soviet Union. The Cubans responded with a comprehensive nationalization law in July 1960 that promised to confiscate nearly all foreign owned property.

Eisenhower's response was to eliminate ninety five percent of Cuba's sugar quota. Cuba averted economic disaster by selling sugar to the Soviets, who were eager to gain the Cubans' trust. Cuba followed through with its nationalization plans and took control of nearly one billion dollars in American owned assets. The only property not affected was the American Naval base at Guantanomo. Diplomatic ties were severed by the outgoing President Eisenhower on January 3, 1961. The new President, John F Kennedy, eliminated the last of the sugar quota that April.

A constraint on the Kennedy administration was the extremely narrow margin by which Kennedy was elected. John F Kennedy received only 118,518 more popular votes than Nixon. Popular wisdom predicted Nixon as the 1960 presidential winner. The election did not leave Kennedy with a clear popular mandate and forced him to tread cautiously at the beginning of his tenure. Popular opinion was Kennedy's primary concern when formulating his Cuba policy.

Richard Nixon was not the only one expecting a Republican victory in the election. The CIA also anticipated a Nixon victory and had developed a relationship with Richard Nixon while he was still Vice President. During this time, it planned an attack at the Bay of Pigs in Cuba, by a force of Cuban exiles. The plan called for additional covert sabotage, an assassination of Castro and American air strikes prompted by a phony Cuban attack on the Guantanomo Naval base.

The unexpected election results did not cancel the attack plans, but it did confuse them. When Kennedy was informed of the Bay of Pigs operation, the new president found himself in a difficult position. His election campaign was predicated on strong anti-communist rhetoric and criticism of the Eisenhower administration's perceived inaction. Canceling the plans would open him to the same criticism he directed at Eisenhower. Seeing little alternative, Kennedy authorized the invasion.

John Kennedy and his cabinet, particularly the Attorney General Robert Kennedy, had grave concerns about the soundness of the plan (Reeves, 1993: 71). Wishing to limit American involvement in the overthrow of a foreign government, Kennedy did not authorize the use of American military forces. While many blame the ultimate failure of the operation on Kennedy's actions, poor planning and the unexpected change in power doomed the operation from the start.

The inadequately trained mercenaries, who numbered only 1500, had no chance of conquering Cuba. They landed in a marsh that hindered their mobility and then seriously compounded this error by overestimating the popular support they would receive. When their invasion was not met by a peasant uprising, the Cuban military easily wiped out the tiny force.

The most ironic mishap concerned the plan to assassinate Castro. Kennedy selected eight men to form a provisional government after the invasion. The CIA had no interest in having Kennedy people head the Cuban government and detained them in the United States before they could join the invasion force. A third faction had selected one of the detainees to be part of the plot to kill Castro (Zepezauer, 1994: 20).

The Bay of Pigs disaster revealed to Kennedy a seamy underside of the American government. Kennedy blamed the failure on the CIA and military intelligence who made promises it could not keep and who could not control its own personnel. In many ways, the president felt betrayed by what had happened. These feelings of betrayal would have important implications for the U-2 program and aerial photography in general. In the coming months, Kennedy would rely heavily on the intelligence of the U-2 program.

The already poor relations between Cuba and the United States deteriorated further after the failed invasion. The trade agreement the Cubans had with the Soviet Union was quickly expanded to include military support. The two countries would soon start a defensive arrangement that would lead to increasing Soviet commitment. The Soviets deployed advisors, combat troops, naval vessels, anti-aircraft missiles and ultimately nuclear missiles capable of reaching far into the United States.

By supporting Cuba, the Soviet Union was responding to a number of historical facts in Cuban-American relations. Typical Soviet rationale for its aid to Cuba included:

1. American deployment of Jupiter missiles in Italy and Turkey, which borders the Soviet Union, as part of a NATO nonproliferation agreement. These missiles became operational in April 1962, the same month Kruschev approved the plan to put Soviet missiles in Cuba (Chang, 1992: xvii).

2. Soviet convictions that the scourge of sabotage in Cuba was at least partially American sponsored, which was true. Covert action was formally mandated as OPERATION MONGOOSE under Kennedy. The stated goal of OPERATION MONGOOSE was:

> ..the United States will help the people of Cuba overthrow the Communist regime from within Cuba and institute a new government with which the United States can live in peace (Chang, 1992: 23).

3. The nuclear missile gap which, contrary to popular belief in the United States at the time, overwhelmingly favored the United States. Extensive U-2 reconnaissance of the Soviet Union showed at most 40 Soviet Intercontinental Ballistic Missiles (ICBM) versus an American total of 170. Overall, the Soviets had about 250 combat ready nuclear warheads, while the United States maintained over 3000 (Chang, 1992: 2).

4. A proven record of American armed intervention in Cuba. American troops were sent to Cuba in 1898, 1906, 1912 and 1917. The Cubans and Soviets had no reason to suspect that 1962 would not be added to the list if they did not provide adequate defense of Cuba.

5.2 THE MISSILES REVEALED

After the collapse of Cuban-American relations the political climate was ripe with rumors and speculation over potential Soviet activity in Cuba. The possibility of the placement of offensive weapons in Cuba was used as a political weapon against Kennedy. The American public started to feel that Kennedy was not handling Cuba sternly enough. The speculation was fueled by a series of events within the Cuban and American governments.

On October 8, 1962 President Dorticos of Cuba delivered a speech to the United Nations General Assembly where he alluded to Cuban possession of:

> ...sufficient means with which to defend ourselves. I repeat we have sufficient means with which to defend ourselves: we have indeed our inevitable weapons, the weapons which we would have preferred not to acquire and which we do not wish to employ (Mathers, 1961).

The confused nature of American intelligence services made Dorticos's threats credible. For the most part, there was little cooperation between organizations. The CIA, the State Department, the Department of Defense and the service branches all conducted separate but equally inaccurate assessments of the Soviet presence in Cuba. Very few of these estimates were formulated with hard, scientific evidence. Reports were made based on the testimony of questionable sources in Cuba and the debriefing of Cuban refugees in the United States. When these reports were leaked, they became potent political weapons which the Republican opposition used to attack Kennedy.

President Kennedy was faced with the task of formulating policy with the diverse, and often contradicting, intelligence reports that reached him. The general ineffectiveness of human intelligence along with the recent wounds of the Bay of Pigs led the president to bypass large sections of the intelligence community and rely upon aerial photography.

Aerial photography had dispelled the myth of a missile-gap and provided accurate assessments of Soviet strength. It is no accident then that Kennedy turned to the U-2 to penetrate the haze that was surrounding Cuba. Photographic evidence was information Kennedy could use unconditionally: it appeared to be THE truth. Robert Kennedy believed with out aerial photography there would not have been a crisis. In his memoirs, he credits the discovery of the missiles to the U-2 program and boldly states that without the U-2 program the deployment of missiles would have gone unnoticed (Kennedy, 1967).

An interesting aspect of John Kennedy's reliance on aerial photography is that neither he nor most of his advisors fully understood it. Robert Kennedy remarked after a briefing by the CIA on the San Cristobal SS-4 site:

> I for one had to take their word for it. I examined the pictures carefully, and what I saw appeared to be no more than the clearing of a field for a farm or the basement of a house (referring to the SS-4 positions). I was relieved to hear later that this was the same reaction of virtually everyone at the meeting, including the president (Kennedy, 1967: 24).

The missiles that Robert Kennedy referred to were discovered on Mission 3101, which flew over Cuba on October 14, 1962. John Kennedy ordered this flight in response to his current political situation. The Republican opposition was conducting the same kinds of attacks that Kennedy had launched on the Eisenhower administration in the Fifties. The speculation about the Soviet presence in Cuba made Kennedy appear weak to the public. After analyzing the photography from this flight, the NPIC determined that the Soviets had deployed missiles in Cuba.

Intelligence agencies presented information to their superiors through the use of briefing boards. The NPIC designed the boards to concisely convey what information had been obtained on a given mission. Briefing boards included sample imagery, close-ups of important sites and details on the subjects found in the photography. The presentation of the boards was usually conducted by an experienced photo analyst who could explain the photography and what information it contained.

The presentation of Mission 3101 was made by McGeorge Bundy, the National Security Advisor, to the President on the morning of October 16, 1962. Bundy had been briefed earlier by NPIC staff. Bundy showed Kennedy reprints of the U-2 photography and carefully explained the photography to the President. Although President Kennedy did not fully understand what he was being showed, he eagerly took Bundy's word for what he was seeing. Kennedy held on to the briefing boards and showed them to any one in his staff who would listen (Reeves, 1993: 370).

Kennedy's initial fear concerning the missiles was that he would have to order them bombed, possibly triggering a greater conflict. To help him formulate a policy, a secret group of advisors known as the Executive Committee (EXCOM) was assembled. The group was referred to as 'the war council' by its participants (Kennedy 1967, 53). The group included ranking military officials, cabinet members and the attorney general. The EXCOM would serve as a discussion group to help Kennedy respond to the Soviet threat.

5.3 FORMULATING A POLICY

The EXCOM had two tasks facing it on its first meeting on October 16, 1962. The first was to determine the threat facing them and the second was to formulate a systematic response to deal with that threat.

Given the photographic evidence, no one on the EXCOM doubted the Soviet presence in Cuba. The only question was whether the missiles were operational or not. The photography did not reveal any evidence that they were capable of firing, nor did it say otherwise. The EXCOM decided to assume that they were operational, or could be very quickly, even though the general consensus in the group was that the missiles were not (Chang, 1992: 88). The missiles were assumed to be operational because of the possibly grave consequences of treating a fully operational nuclear missile as though it could not fire.

After assessing the threat, the EXCOM needed to devise appropriate responses to the Soviet moves. The EXCOM members had knowledge of the missiles as early as the night of October

15, although no action was taken until nearly a week later. The Kennedy administration struggled to continue business as usual while trying to formulate a policy to deal with the missile problem.

5.31 Possible Responses

Theodore Sorensen, Special Counsel to the President, condensed the discussions from numerous EXCOM meetings into four possible courses of actions, or tracks. Sorensen's summary was used to make the final decision (Chang, 1992: 114). The four tracks under consideration were:

A. Diplomatic action.
B. Unilateral air strike.
C. Naval blockade.
D. Invasion of Cuba.

Track A consisted of diplomatic action. The United States would publicly reveal the presence of the missiles and hope international pressure, through the United Nations or the Organization of American States, would pressure Cuba and the Soviet Union to remove the missiles. There would be an explicit threat of military action in the future if the diplomatic efforts failed.

The advantage of track A was that it did not force the Soviets into a military counter-measure. The EXCOM feared that the Soviets might respond to American action in Cuba by attacking Berlin or another location where the United States was vulnerable. The disadvantage was that diplomatic pressure was not always successful. While the United States wasted time diplomatically, the Soviets could be heavily reinforcing the island making future military action more difficult. There was also concern that not responding militarily would be seen as a sign of weakness in the Kennedy administration by the Soviets.

Track B involved a military air strike, without warning, on the SS-4 missile sites with simultaneous assurances that the strikes were limited to the missiles only. Track B promised to eliminate most of the missiles and send the Soviets a message of strength. Unfortunately, an air strike would probably result in reciprocal actions by the Soviets. Such action could involve air strikes on Berlin, Guantanamo naval base or even the continental United States. The United States also risked international condemnation for a unilateral attack.

Track C was a total naval blockade of Cuba under the auspices of the Rio Pact. The Rio Pact excluded European military forces in the Americas. The blockade would then be followed by a diplomatic action similar to Track A. This plan would be a measured response allowing the Soviets to withdraw peacefully without feeling the need for reciprocal actions. The blockade would also prevent further reinforcement of the island. If military action where required in the future, the defenders would not be any stronger. The blockade had additional benefits in that it would garner more international support than a military attack.

Track D involved an all-out invasion of the island to, in Sorensen's words, 'take Cuba away from Castro.' The advantages of the plan were that it ended the Castro problem forever, guaranteed removal of the missiles and would never be interpreted as a sign of weakness. The invasion would not be easy however. An invasion of the island would almost certainly prompt world-wide Soviet reaction, possibly even nuclear attack, as well as foster international condemnation. The thousands of casualties that would be incurred during the fighting also needed to be considered.

After the Bay of Pigs failure, Kennedy developed an intense mistrust of the military, and especially the CIA, to deliver what they promised. Kennedy instinctively questioned what his military and CIA advisors told him during EXCOM meetings. He did not immediately order military action out of a desire to avoid another situation like the Bay of Pigs.

President Kennedy received troubling answers during his EXCOM meetings that reinforced his apprehensions with the military. General Walter Sweeney, Commander in Chief of the Tactical Air Command, pressed for an extensive bombing of Cuba, although he admitted that no air strike could guarantee that all nuclear missiles would be destroyed before they had a chance to fire on the United States (Kennedy, 1967: 48).

With aid of his brother Robert, President Kennedy formulated a policy that would follow Track C. Despite protests from many EXCOM members, a naval blockade of Cuba was ordered. In his memoirs, Robert Kennedy detailed that there were two advantages to this plan (Kennedy, 1967: 52).

The first advantage was that a blockade was a measured response that allowed the Soviets the opportunity to enter negotiations for their removal without a loss of face. Had the United States conducted some sort of military strike, such as a bombardment of the missile sites, the Soviet Union would be forced to respond in kind. This Soviet action would in turn require an American counter-reprisal. It is all too easy to see these exchanges ending in an all out nuclear war.

The second advantage, which pleased the hawks in the EXCOM, was that while it allowed for negotiation, it also prevented further Soviet reinforcement of the island. If the negotiations failed and a military response did become necessary, the United States would not have lost any strategic advantage.

5.32 A Peaceful Solution

A comprehensive CIA report on Cuba, entitled *Major Consequences of Certain U.S. Courses of Action on Cuba*, was presented to Kennedy on October 20, 1962 (Chang, 1992: 134-143). This report synthesized all the PHOTOINTEL collected on the Soviet buildup. President Kennedy reaffirmed his desire for a peaceful solution to the crisis after reading this report. The report concluded that the SS-4 sites "could be fired in eight hours or less after a decision to launch." The final assessment of the Soviet buildup was as follows:

1. 16 SS-4 Launchers
2. 8 SS-5 Launchers (under construction)
3. 22 IL-28 Bombers
4. 39 MIG-21 Fighters
5. 24 SA-2 SAM Launchers (16 Operational)
6. 3 Cruise Missile Sites (anti-ship)
7. 12 KOMAR missile boats

At 7:00 pm on October 22, 1962 President Kennedy delivered a speech announcing the presence of Soviet missiles in Cuba. During the speech Kennedy outlined the plans for a naval blockade of Cuba and diplomatic pressure to force the withdrawal of the missiles. The blockade was officially termed a *quarantine*, as though the Soviet presence was some kind of virus. Prior to this, copies were delivered to Soviet officials who had spent the previous week giving what pathetic assurances that those missiles did not exist.

5.4 RESOLUTION OF A CRISIS

An international crisis developed after Kennedy publicly announced the presence of Soviet missiles in Cuba. The Soviets initially responded with public outrage. Soviet actions included putting its military on alert world-wide and sending sharp diplomatic protests to the United Nations. Kennedy received a letter from Kruschev that denounced the American actions as acts of war and declared the Soviet presence in Cuba defensive.

President Kennedy formally initiated the blockade on October 23, 1962. The United States Navy immediately began to enforce the blockade. The Soviets had nineteen ships on route to Cuba, so the Kennedy administration anxiously waited to see if the Soviets would challenge the blockade. Of great concern was the convergence of Soviet submarines in the Caribbean. The Soviets did nothing to allay the fears of a confrontation at sea.

The next day, sixteen of the nineteen ships turned around. Most of the returning ships were large-hatched and designed for military use. The remaining three ships continued on course with Soviet submarine escorts. The morning of October 24 was filled with tension as Kennedy waited to see what the Soviets would do. The Navy was under orders to fire on Soviet ships if they tried to break the blockade. The remaining ships altered course only miles away from the American navy. The Soviets had blinked.

The next week saw a wide range of diplomatic maneuvering, most of which was only rhetoric. The Soviets consistently denied the presence of their missiles on the island. Although Kennedy had presented photographic evidence to the American public, many in the world community had doubts. In response, Adlai Stevenson, the American ambassador to the United

Nations, arranged for an NPIC briefing to the United Nations General Assembly.

The presentation ended Soviet denials. The Soviets were then willing to negotiate an end to the crisis. The solution originated in two letters that Kruschev sent to Kennedy. The desire for peace on both sides was so strong that even a potentially tragic episode did not discourage them. On October 27, Major Rudolph Anderson was shot down by a Soviet SA-2 in his U-2. This incidence caused much international concern about an expansion of hostilities, but did not disrupt the peace process.

The first letter, dated October 26, revealed that Castro was greatly concerned about the possibility of war. In the letter he stated that the Soviet Union was only working in the interest of Cuba's safety. The nuclear missiles were deployed for this reason and not to alter the strategic balance. He implied that if Kennedy pledged not to invade Cuba there would be no need for these missiles and they would be removed (Chang, 1992: 185).

The next day Kruschev sent another letter that was far more threatening. The October 28 letter demanded that the United States remove its missiles from Turkey and in return the Soviet Union would remove the Cuban missiles. A solution could only be reached in this way if the United Nations employed inspectors to guarantee compliance (Chang, 1992:

197). The tone of this letter was angry and provocative.

After many sleepless nights, Kennedy was ready for a settlement. The terms of the first letter were acceptable, but the second was not. He did not want to appear to be trading Turkey's missiles for Cuba's missiles. Robert Kennedy found the solution to this dilemma. He advised President Kennedy to ignore the second letter. President Kennedy wrote to Kruschev that he would pledge not to invade Cuba if the missiles were removed. The brilliance of the plan was that it allowed both sides to save face. The incidence was scripted as a misunderstanding between the two super powers.

The only remaining problem was verification of the Soviet withdrawal. The Soviets were not receptive to a United Nations inspection because it would imply defeat. The answer proved to be once again aerial photography. U-2 flights were continued to monitor the withdrawal. Particular attention was placed on Cuban ports. Ships were photographed loading equipment and en route back to the Soviet Union. Crateology proved to be particularly useful for determining what equipment was returned. The previous effectiveness of the NPIC at assessing Soviet strength relaxed Kennedy's fear of a possible Soviet ruse.

5.5 INSTITUTIONS OF MIS-UNDERSTANDING

The extensive role that aerial photography played during the crisis was possible because of the development of government institutions to accommodate aerial photography. The National Photographic Interpretation Center was the most important of these institutions as it allowed the photography to be quickly and accurately analyzed and presented to policy makers. Because of its effectiveness, the process for distributing the NPIC's intelligence was streamlined. The NPIC analysts only reported to one or two superiors before gaining access to the President. In a world of unknowns, the arrival of photo intelligence was a welcome sight to policy makers. This was particularly true for President Kennedy who did not fully trust many other sources of intelligence.

The nature of photo intelligence fit the personality of President Kennedy. The President had little patience for long-winded discussion. When dealing with subordinates, he liked quick answers that got to the point (Reeves, 1993). Aerial photography presented all the President had to know in only a few pictures that did not take long to comprehend. Also, photography had an aura of truth about it that alleviated Kennedy's concern for the honesty of other intelligence branches.

This arrangement may seem commonsensical, but such a free flow of photointel is the exception rather than the rule. The institutional framework of the American government allowed the information to avoid bureaucracy and inter-service rivalries. When there is no efficient protocol for distributing information, photointel can be critically delayed from reaching those who need it. This is exemplified by the following two examples.

5.51 The British World War Two

Early in World War Two, the British formulated a plan to strike the Italian fleet while anchoring in its home base in Taranto, southern Italy. The attack was to be executed with carrier based planes from the *HMS Illustrious*. Several days before the attack, a British officer tried to obtain the latest Royal Air Force (RAF) aerial reconnaissance of the Taranto naval base. After much argument, he was denied the photographs. His primary concern was for the success of the mission, so he stole the photography and brought it back to his fleet.

The photography revealed that the Italians had recently raised barrage balloons that would obstruct the British planes along their planned attack route. Last minute changes were made to accommodate the zeppelins and British planes caused crippling damage to the Italian fleet on November 11, 1940. The ultimate success of the mission was attributed to the late-hour PHOTOINTEL. However, the photography was obtained despite the RAF, who resented the naval air corps. The same officer who stole the photographs avoided an inter-service incident by secretly returning them later without their absence being noticed (Stephen, 1991: 36).

This child-like behavior was reinforced by a basic ignorance of the benefits of PHOTOINTEL. Those not familiar with its capabilities tended not to place a high value on its use. The RAF officers who denied the photography to the navy, did not think their actions would significantly alter the course of the battle. They were just trying to make a point with the naval air corps, which was infringing on their jurisdiction with their own aircraft. The RAF officer did not consciously try to make the attack fail.

5.52 The Soviets in 1962

A misunderstanding of photointel was just as prominent in the Soviet Union in the 1960s. The deployment of Soviet missiles was conducted with the utmost secrecy until the missiles reached Cuba. Once on the island, the Soviets made no effort to conceal their presence.

Soviet SAM sites were deployed in the usual Star-of-David pattern. As was shown previously, this pattern made the identification of SAM sites easy. Those responsible for the SAMs made no effort to conceal them. Even slight modifications in the deployment pattern would have caused great difficulties for the photo analysts (Brugioni, 1991: 104).

A counter argument to this is that the Soviets wanted the missiles clearly visible to discourage over-flights. In the Soviet Union, when SA-2 protection was extended to an area, U-2 flights virtually stopped. This process was also noticed in Eastern Europe. The placement of the missiles did not concur with this argument. The missiles were widely dispersed across Cuba near the coast. The deployment appeared to be one designed to protect the entire island as much as possible. This dispersal proved relatively ineffective at denying Cuban airspace to the U-2 until very late in the crisis. The missiles were too close to the coast. A fast moving plane coming over the ocean frequently over flew the launchers before they could react. Once past the coast, the interior was relatively unprotected. The SA-2 was never systematically deployed to prevent reconnaissance of specific areas, like the SS-4 launch sites.

The SS-4 launchers were never concealed either. The Soviets would boldly clear vegetation and construct large concrete launch pads that were quickly discovered on photography. The missiles would frequently be stored in clear view at the launch sites before the launching sites were ready.

The Soviets had plenty of options available to them with regards to concealment. Beyond simply conducting their work indoors or at night, the Soviets could have used the principles of airphoto interpretation to their advantage.

Objects that are not visibly present in a photograph are often identified through a knowledge of known relationships. Missiles required specialized support equipment that was different from other military equipment. For example, the missile fuel trucks were shaped differently from regular diesel trucks and trucks that carried the warheads had a distinct square cargo bed. Many of these differences were accidents of design that had no real justifications. Modifying the support equipment to look more like regular military issue would have been relatively easy.

The Soviets made no attempts to inflate their apparent numbers. They constructed no decoy missile sites to confuse the American intelligence. Constructing roads in the Star-of-David pattern at random spots in the country side would not have fooled the NPIC analysts forever, but would at least focus their attention on insignificant terrain.

The crisis was well under way before the Soviets began to try to conceal their forces. For the most part this included working at night and the largely ineffective use of camouflage netting. Even then these actions were not part of any official Soviet policy, but initiative on the part of local commanders. It is significant that these efforts were not made until low-level flights were made by F-101 reconnaissance jets. These would have been the first American surveillance efforts visible by the local commanders.

One might argue the Soviets did not try to conceal their missiles because they were unfamiliar with American technology. After Gary Powers was shot down over the Soviet Union in 1960, the Soviets captured the U-2 camera and film intact. They even developed the film and publicly displayed the photographs. The Soviets had a thorough knowledge of the U-2's capabilities.

The only explanation for their inaction is that they made no connection between aerial photography and international policy. In the past, the Soviets were able to deny any action they took without serious implications. The world community was polarized between the two super powers and people believed what they wanted regardless of the facts. It is surmised that Kruschev felt that even if the missiles were photographed, he would be able to deny their presence in his usual manner.

Kennedy used this oversight to great advantage. His public presentation of photographic evidence of Soviet activities brought him a large proportion of world support. Kennedy's use of the photography as a propaganda weapon surprised Kruschev.

CHAPTER VI

AERIAL PHOTOGRAPHY AS MILITARY VISION

The period following World War Two saw a rapid expansion in the capabilities of military vision. The U-2 program was part of an acceleration of vision during the Cold War. The ceiling of the U-2 was soon insufficient to avoid Soviet defenses. The U-2's successor, the SR-71, was able to reach altitudes of 85,000 feet and fly three times the speed of sound. Even the incredible performance of the SR-71 was soon insufficient for contemporary needs. Cameras and sensors were mounted in satellites that could view the earth from orbits hundreds of miles above the ground.

The need for improved sensors came with these dramatic improvements in aeronautics. Optics were developed with resolutions several times finer than the lenses on the B camera. The optical capabilities of the latest spy satellites are still classified. An examination of the small number of imagery that is available to the public reveals that these new lenses can produce imagery with detail at least comparable to U-2. See Image 7 of a Soviet airfield taken by a Corona satellite in 1966. The camera that took this photograph was at an altitude many miles above that of the U-2.

6.1 DE-HUMANIZING VISION

The mechanical and electronic enhancement of military vision has affected more than the destructive potential of armies. The enhancement of vision and weaponry has served to distance the soldier from his enemy. With distance, there is a lessening of moral responsibility. It is easier to kill someone when you can't see them, or when they are represented electronically by a sensor or a computer.

The effect of distance on morality manifests itself in everyday life. If you were walking down the street and someone was struck by a car nearby, you would probably feel a responsibility to help them in some manner. If that person were struck by a car several hundred feet away, it would be easier to ignore the situation. This would especially be true if other individuals were closer to the victim than you. Distance removes a measure of the responsibility we feel for each other.

Blindness is even better than distance for removing responsibility. The majority of people would rather not see homeless people on the streets. Their presence instills feelings of guilt and a responsibility to help. If the homeless are not in plain view, it is much easier to ignore their plight.

It is rare for the soldier to directly see his enemy in modern war. The soldier directs his fire at positions over the horizon, coordinates on a map, terrain features or at anonymous buildings thousands of feet below. The ranges and scales at which war now occurs increasingly de-humanizes the enemy through distance.

Armies now award medals for hand-to-hand combat. Fighting with the knife or bayonet is considered so terrifying and rare that it deserves special commendation. Yet, hand-to-hand fighting was the primary method of killing in war until the mid-Eighteenth Century. Afterwards, hand-to-hand fighting was still common through the American Civil War, especially with cavalry. Now, it is a relic of the past.

De-humanization was evident during the EXCOM meetings of the Cuban Missile Crisis. The members of the EXCOM convened to formulate a strategy that would involve military units across the globe and decide the fate of billions. The large part of the decision making process was conducted with little outside contact. The course of EXCOM discussions frequently became morbid and detached. For example, General Maxwell Taylor, the Joint Chief of Staffs, strongly urged an air strike to destroy the Soviet missiles. He persisted in his desire for an air strike even after his subordinates informed him that no air attack would be guaranteed to destroy all the missiles. The possibility that one or two missiles might survive an attack and have a chance to fire was dismissed by Taylor as relatively insignificant (Chang, 1992: 103). The 'insignificance' of surviving missiles is dispelled by a look at Diagram 5, a map showing the range of the SS-4 and SS-5 missiles with their potential targets. Where is your home town?

The further development of technology promises to further separate combatants from their actions. The last pages of this chapter are a rundown of innovations since 1962 that distance the soldier from reality.

6.2 REMOTE SENSING AFTER 1962

The same presidential orders that resulted in the U-2 program also initiated work on reconnaissance satellites. The first satellite system was the *Corona*. The *Corona* was tested on February 28, 1959. Its first successful mission, after 13 research runs, was in August of 1960. The operation of the *Corona*, although a space vehicle, was not dramatically different from that of the U-2.

Unlike satellites today, the Corona still used photographic film. The satellite was launched into an orbit that would take it over the Soviet Union. Generally, *Corona* satellites where only able to orbit for 5 or 6 days before falling to earth. The film would be retrieved in mid-air by specially equipped aircraft or in the water by ships. The development and analysis of *Corona* photography was identical to the analysis of U-2 imagery.

The quality of *Corona* photography was at first limited. Examine Image 7 of a picture of a Soviet airfield taken on the first *Corona* mission. The resolution of this image is about 8 meters. On subsequent *Corona* missions improved optics dramatically increased resolutions to the level of conventional U-2 photography. Image 6 is a picture of a Soviet airfield taken from a later mission (EROS, 1995: 1).

The *Corona* was quickly superseded by other satellites, although it was used until 1972. The ever increasing need for speed necessitated the development of more efficient reconnaissance. There was a lag of about one week from the launch of a *Corona* until the imagery was available. Once the launch was scheduled, there was little ability to change the flight path. There was no guarantee that a particular site would not be obscured by poor weather. The ultimate success of a mission could not be determined until a week later when the satellite returned and the film was analyzed.

The current 'official' generation of American reconnaissance satellites are the Kh-11 and Kh-12 series. These satellites are designed to continuously orbit the earth for several years and film is no longer used. Recorded images are sent by radio signal to computers that instantaneously convert the electronic signals into conventional pictures. The military has three or four such satellites in continuous orbit to maintain an instantaneous field of view (IFOV) all over the world.

Sensors employing IFOVs are in wide spread use. Modern tanks have thermal sensors that generate an image of the target, complete with firing data, on a TV screen inside the tank. The American FOG-M missile is equipped with a TV guidance system that allows the gunner to pilot the missile from behind cover.

IFOV sensors are now coupled with identification friend or foe (IFF) systems. IFF systems are electronic boxes that emit a pre-arranged signal, i.e. radio waves. Friendly sensors are able to receive the signal and the friendly target is automatically classified as friendly for the sensor user. This technology is in wide spread use on aircraft.

The level of technology is such that in a war, few soldiers will ever see anything but electronic representations of their enemy. During the Gulf War, CNN and the evening news were full of examples of how the latest technologies improved our capabilities to wage war. The current generation of weapons and sensors promised to remove unnecessary death from war. Their true destructiveness was not known until well after the war.

6.3 AERIAL PHOTOGRAPHY TODAY

The role of aerial photography during the Cuban Missile Crisis was part of an overall trend in vision, surveillance and violence that continues to this day. The account of aerial photography during the Crisis is still applicable after 33 years. The only difference between 1962 and 1995 is one of intensity. In 1962, aircraft photographed national adversaries from 70,000 feet after carefully planned missions that took days to execute. The 1990s is an era where a myriad of satellites continuously orbit and monitor the earth from outside the bounds of the atmosphere.

Aerial photography, in one form or another, is in constant use. Local and national governments, private industry, scientists and individuals all use aerial or satellite photography to overcome the same obstacles that confronted the Eisenhower and Kennedy administrations. Each application of remote sensing technology touches upon the issues detailed in this thesis.

Environmental organizations use aerial photography to bypass laws protecting private property. Local government groups interested in wetlands protection routinely photograph private property to monitor their condition. With IR photography scientists are able determine water depth, varieties of vegetation present and even the possible presence of pollutants. A series of photographs showing a steady decline in the condition of a protected wetland can be used to get a legal warrant for ground inspection and photographs can be presented as evidence in the court room.

A variety of commercial satellite programs are available to the public. The two most common are the American LANDSAT and French SPOT programs. The SPOT satellite is capable of producing imagery with a resolution down to 10 meters. The sensors on board the satellite have a panchromatic and a multispectral mode. The panchromatic mode is sensitive to green and red visible light as well as a tiny portion of the near IR. The multispectral mode is sensitive to three separate bands, similar to color film: green visible; red visible; and a large portion of the near IR. The multispectral resolution is 20 meters. The American LANDSAT has a larger resolution of 30 meters. Other commercial satellite programs include the Russian KFA-1000 and the Japanese Earth Resource Satellite (JERS).

Commercial satellite data is used for a wide variety of purposes. The primary value of commercial satellites is their ability to synthesize information on large areas. They are not capable of detailed analysis of local features due to their low resolutions. Commercial satellites corporations have the technological capability to significantly increase the resolution of their imagery. Commercial satellite programs choose not to use higher resolutions because of legal questions and the limited usefulness of high resolution data. Satellites are used for research where general data on large areas is needed. Examples include Rain Forest degradation, ocean pollution and forest inventory.

6.4 DECLASSIFYING THE COLD WAR

The *Corona* images featured in this thesis were declassified on February 24, 1995 as a result of Executive Order Number 12951 (EROS, 1995: 1). The order requires that the CIA review and make available for release all obsolete satellite data by the year 2000. The order was a result of a general relaxing of Cold War restrictions on satellite data.

General Norman Schwarzkopf praised the value of satellite data for military purposes during the Gulf War, but voiced concerns about its availability to those who needed it. The Central Imagery Office (CIO) was formed in 1992 partly in response to Schwarzkopf's criticism (MacDonald, 1995: 387). The CIO collected all American satellite data under one roof. The goal was to streamline the distribution of imagery and avoid situations like that of Taranto in 1942. Security controls were removed or relaxed and extensive indexes were made.

The CIO also began the task of reviewing the possibility of the public release of data. The CIO study concluded that the earliest satellite programs represented obsolete technology. The release of their imagery would not compromise national security and would provide valuable data to the scientific community. CIO recommendations prompted President Clinton's order to declassify the *Corona* and several other early satellite programs. Executive order 12951 promised the future release of other programs once they have been assessed by the CIO.

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Image 1
F-101 Photo of a Soviet Ship, Caribbean 1962

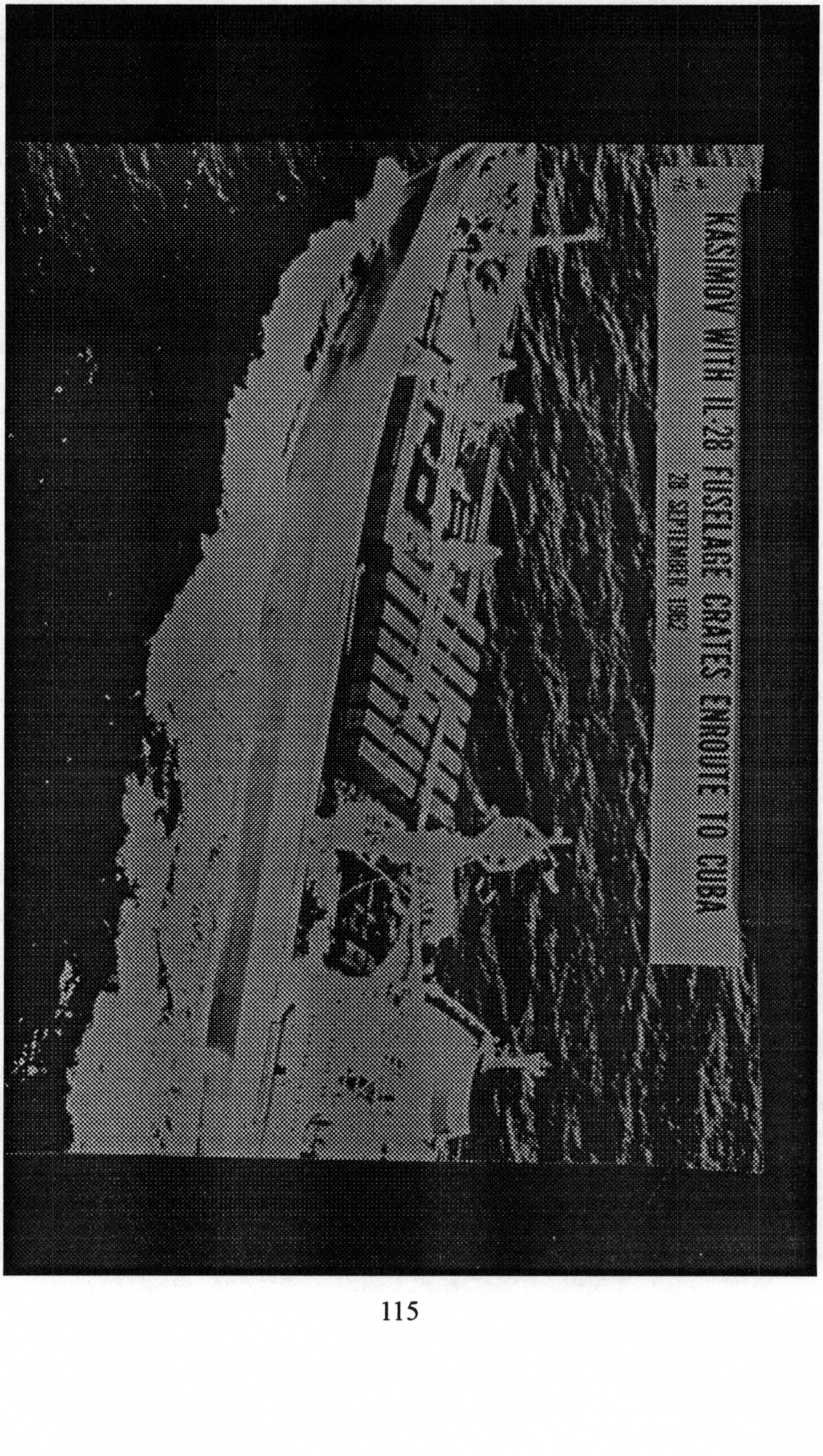

Image 2
Javelin Thrower

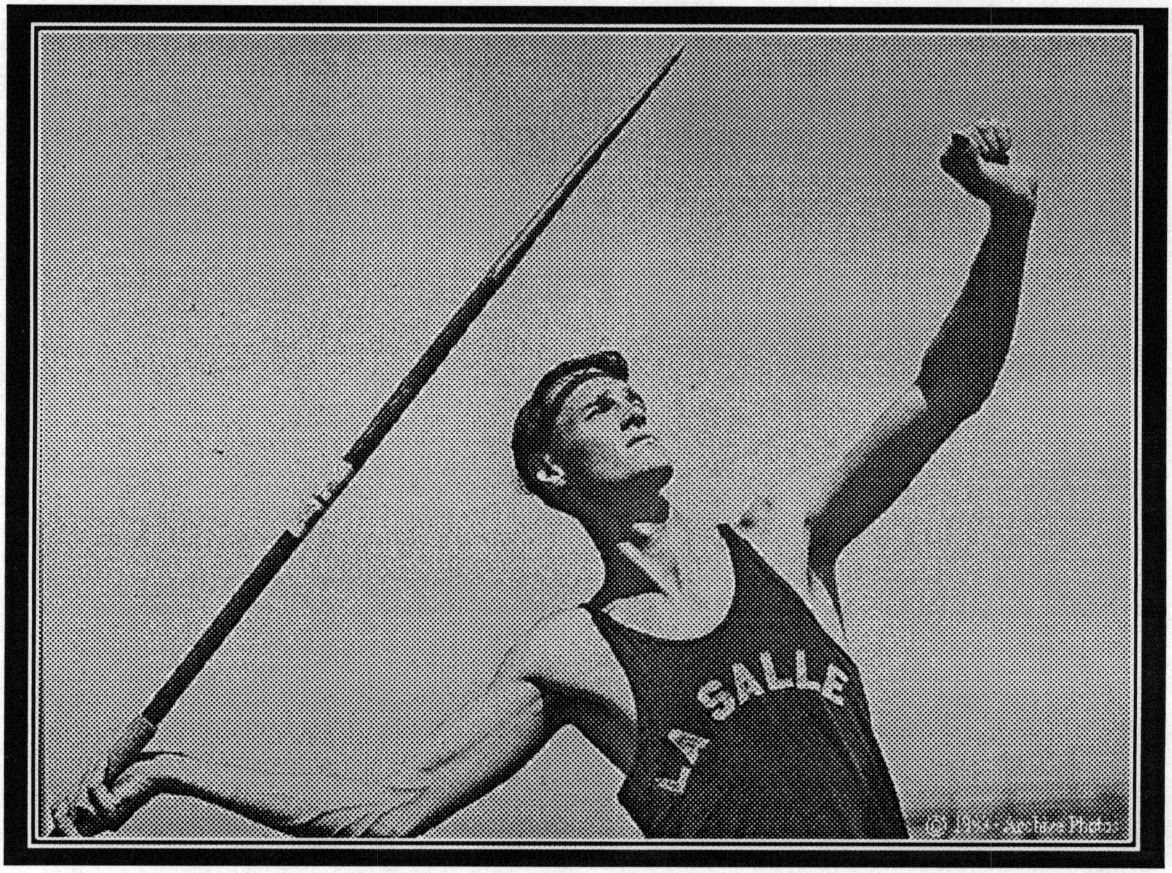

Image 3
U-2 Photo of Soviet Bomber Base, Cuba 1962

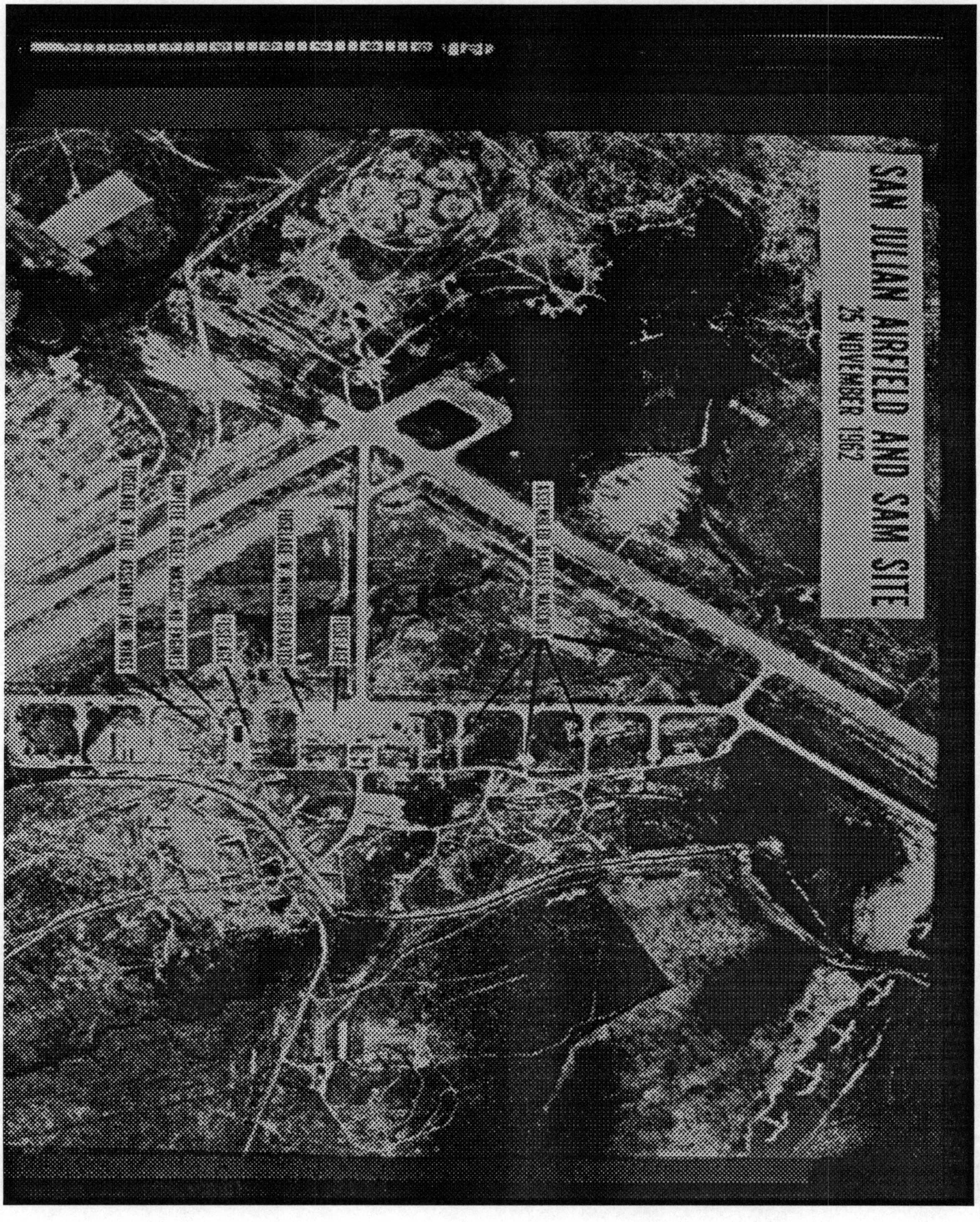

Image 4
U-2 Photo of Soviet SAM Site, Cuba 1962

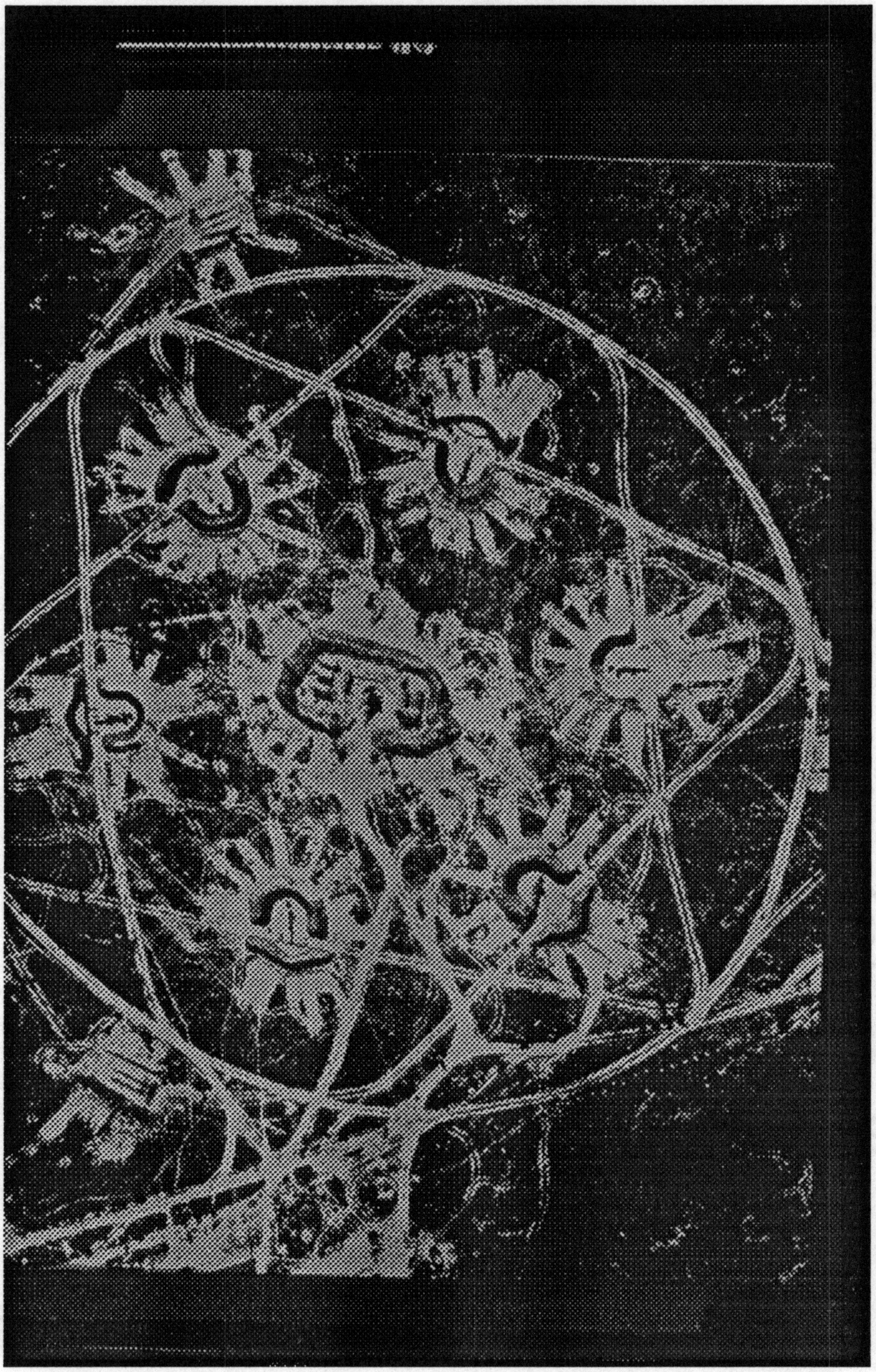

Image 5
U-2 Photograph of SS-4 Launch Site, Cuba 1962

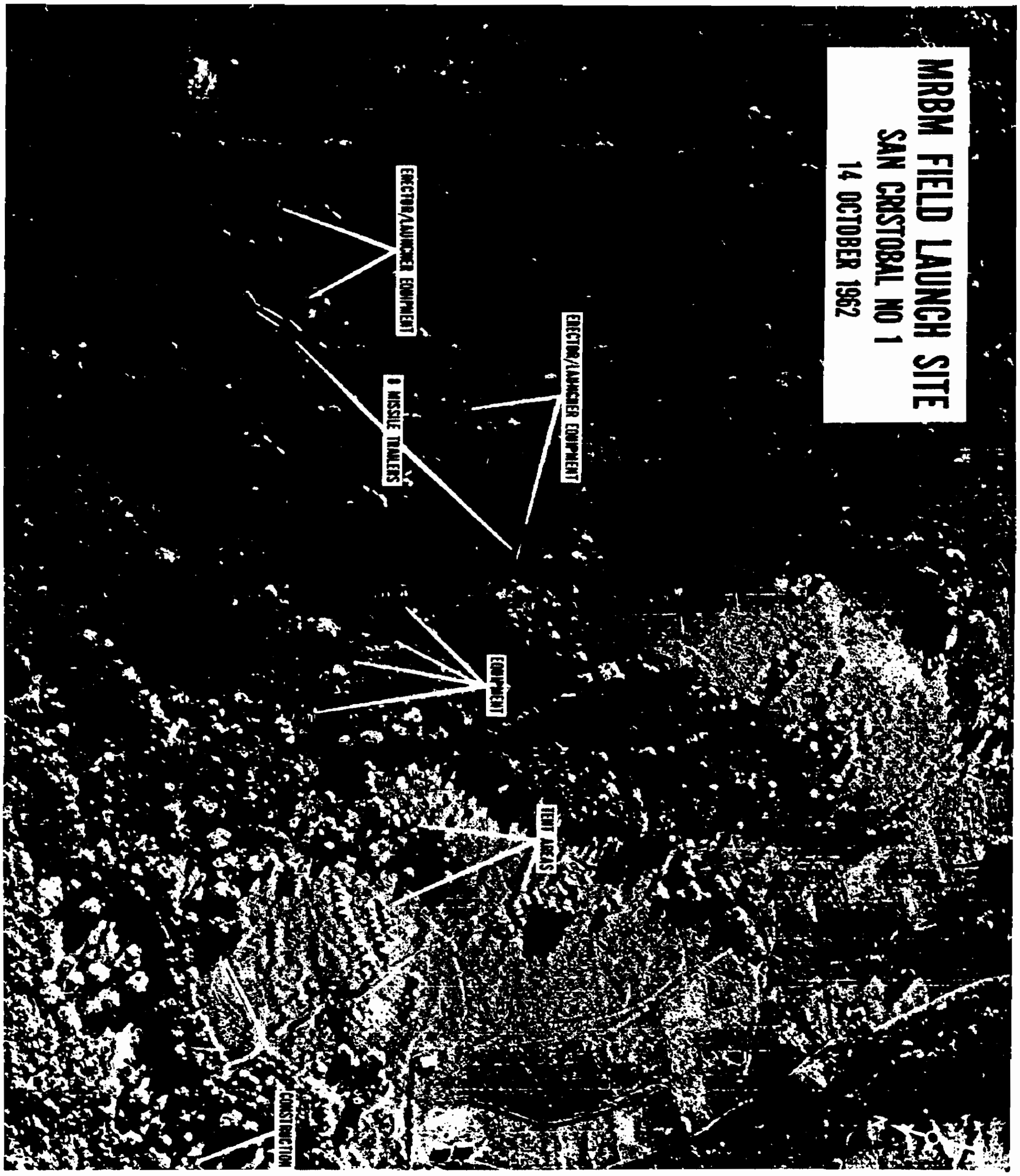

Image 6
Corona Photo of Soviet Airfield, USSR 1966

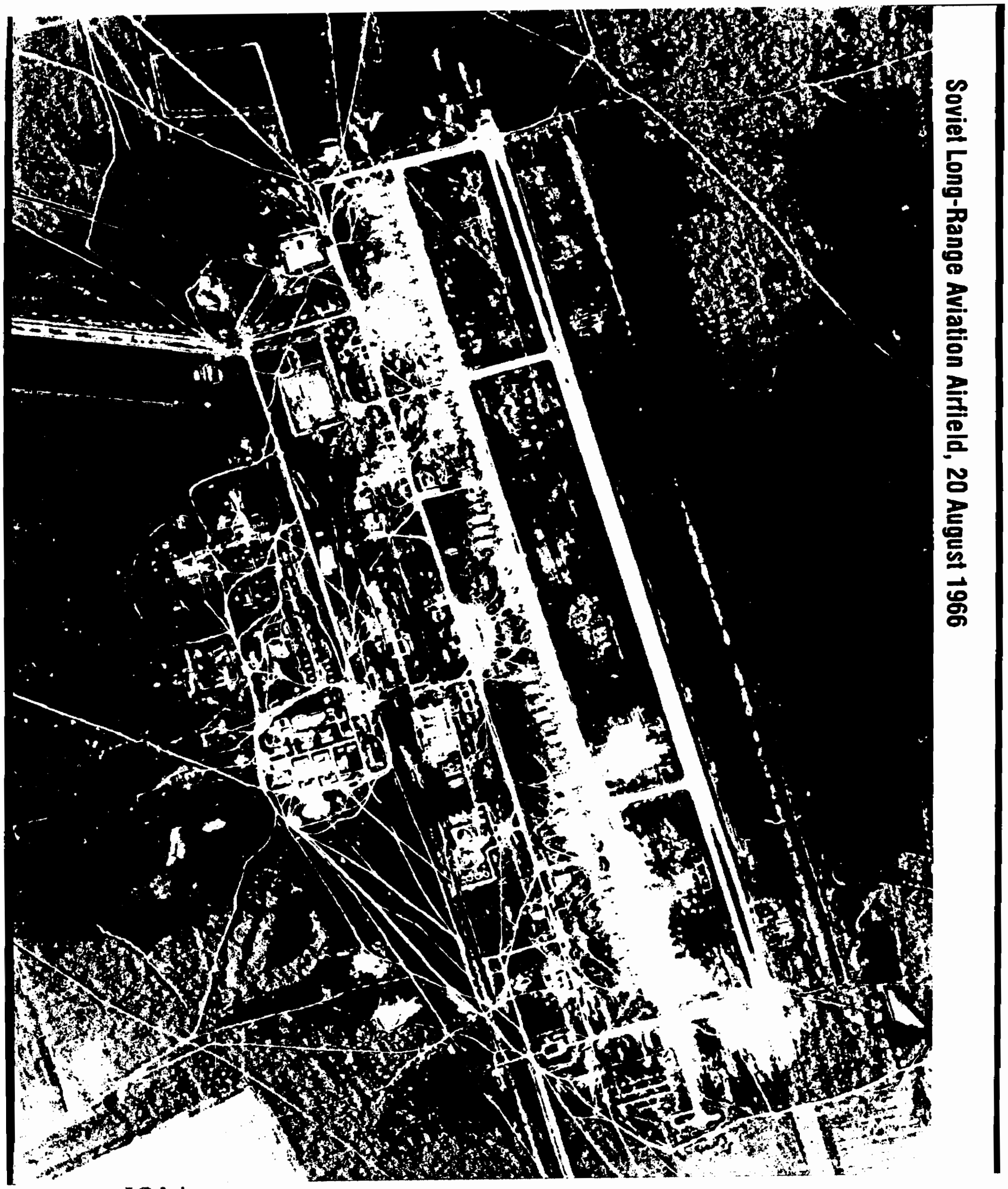

Image 7
Corona photo of airfield, USSR 1960

Soviet Airfield (first image), 18 August 1960

Diagram 1

Simple Aerial Camera

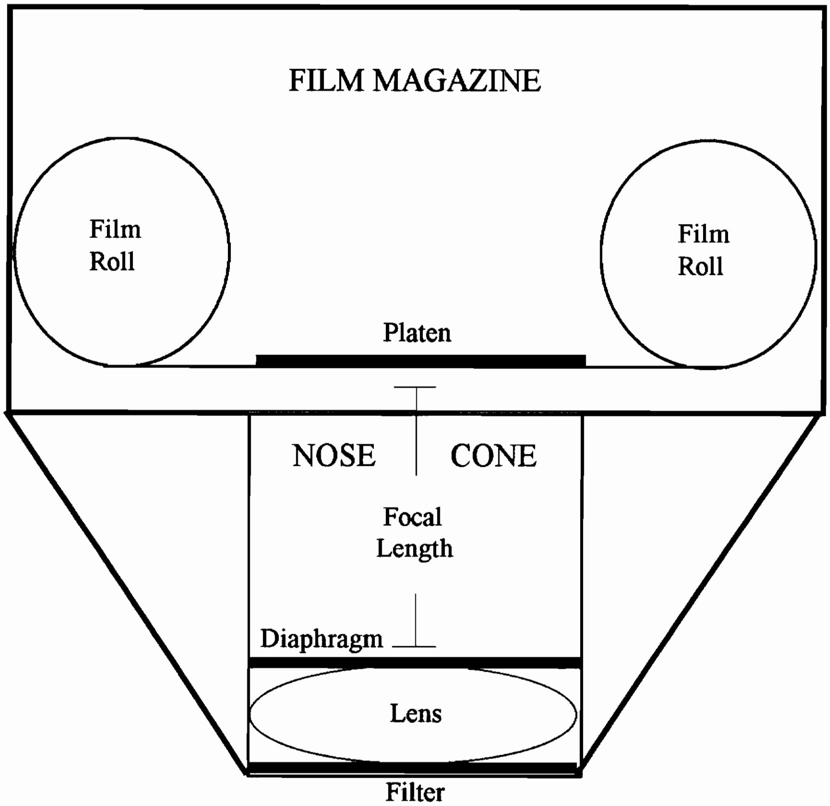

Diagram 2

Film Cross-section

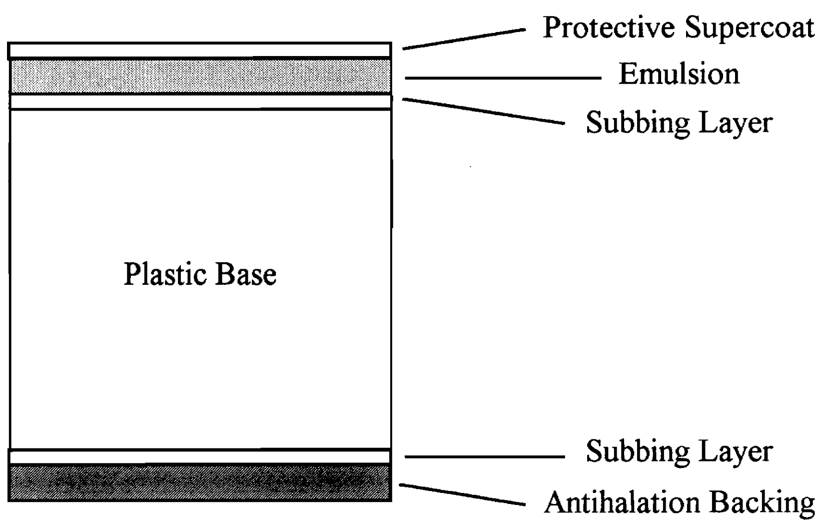

Diagram 3

EM Spectrum

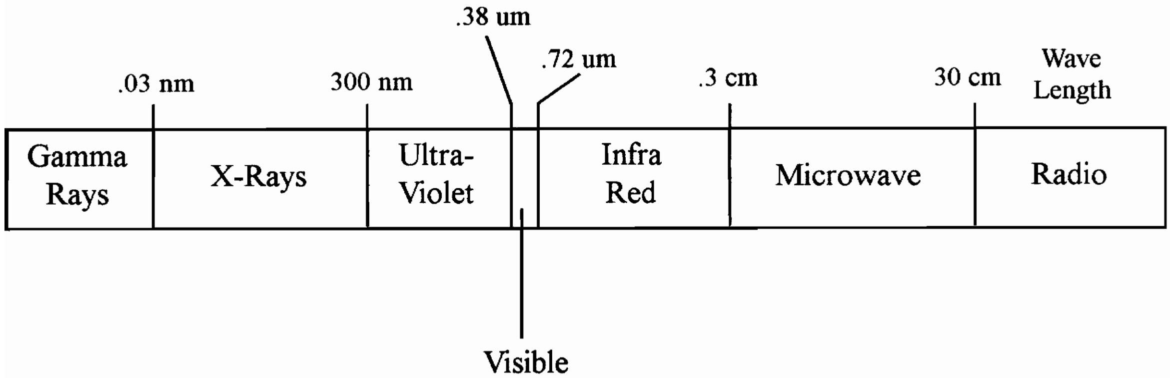

Diagram 4

The Soviet Military Buildup
Cuba 1962

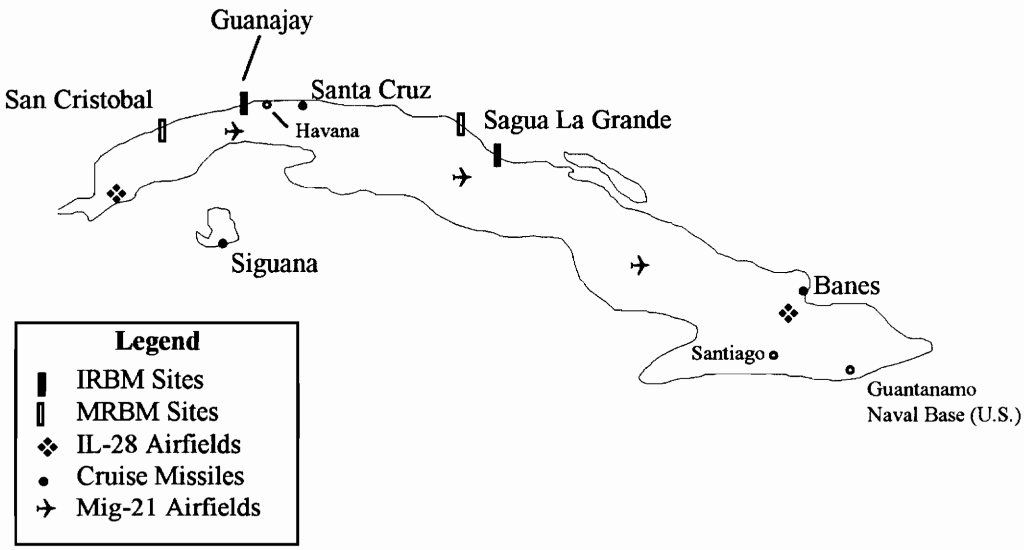

Diagram 5

Ranges of Soviet Missiles