Engineering in the CIA:

ELINT, Stealth, and Beginnings of Information Warfare

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THE LATE 1950S WERE THE HEYDAYS OF THE U-2 reconnaissance aircraft as it flew with impunity over the Soviet Union, bringing back the most-sought-after intelligence at the time: confirmation that there was no real bomber or ballistic missile gap with the Soviet Union. But the U-2 also brought back something else: a foreshadowing of its own impending demise. The U-2 camera, along with its rudimentary electronics intelligence (ELINT) receivers, had begun to pick up indications of a Soviet antiaircraft defense buildup with new and better surface-to-air (SAM) missiles and radar. The Soviet kept trying to shoot down the U-2 with interceptor fighters and SAMs; they did not succeed until May 1, 1960.

An Esoteric Subject

At the time of the U-2 shootdown, the CIA already was well along in developing the U-2's replacement, the Oxcart reconnaissance aircraft, at Lockheed's Skunk Works in Burbank, CA. The Oxcart would fly at approximately 90,000 feet at Mach 3.3. It would also become the predecessor to the Air Force's better-known SR-71 Blackbird. The CIA and the Air Force jointly also had their ultimate reconnaissance system, the Corona satellite, well under way in a parallel development — the first in a long series of reconnaissance satellites that would eventually replace all aircraft overflights, including the Oxcart.

Concerns about the vulnerability of the yet-to-fly Oxcart to a greatly improved Soviet air defense radar network were also the basis for the most secret and sensitive aspect of the project. The Oxcart was to be invisible to the Soviet radars — the first-ever stealth aircraft. The engineering approach to stealth was to create an airplane that would result in a deceptively small blip on enemy radar screens by shaping the airplane with razor-sharp edges, or chines, by tilting the rudders inboard to reduce radar reflections, and by using as much composite radar-absorbing material as possible. But how small a radar target was small enough? That depended on how good the Soviet radar was. But there were more questions about Soviet radar than there were answers.

The intelligence community had no hard information about the transmitter power of Soviet radar, its receiver sensitivity, spatial coverage of its beams, or even how widespread it was deployed, much less anything about its counter-stealth capabilities. ELINT could not provide answers to such hard questions. Further, few in the ELINT community knew anything about the Oxcart program, and fewer still knew anything about the stealth aspects of the program. It seemed to come down to making the best possible intelligence estimate with regard to the Soviet's radar capability for dealing with a high and fast airplane with a very small radar cross section. In the words of other intelligence veterans, "Estimating is what you do when you don't know and cannot find out."

Low Regard for ELINT

Many intelligence analysts considered ELINT next to useless. One prominent CIA operations officer said that his clandestine service considered ELINT the only five-letter cuss word, that he viewed ELINT as worthless, and that only agents could be relied on for worthwhile information.

ELINT was a passive, rudimentary means of intelligence collection. It involved getting a radio receiver and recorder within line of sight of Soviet radar or other

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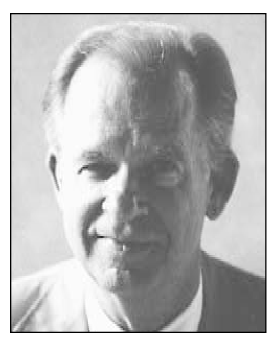

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sources of important noncommunications signals. From radio direction finding and the recordings, one could determine the radar's general location and the signal's radio frequency, pulse rate, and pulse width. From these signal parameters, an analyst could then estimate the radar's performance, but not with great accuracy or certainty. Most Soviet radar, however, was well beyond the reach of ELINT.

This was the scene at the end of 1959, when I was a new engineer assigned to the CIA's Office of Scientific Intelligence (OSI). I was soon cleared into the Oxcart project and also into the stealth aspect.

Difficult Questions

The Oxcart mission planners were especially concerned about just how widespread the Soviet's early-warning radar was and where itwas located. It seemed impossible, however, to determine the number, exact location, or any other technical information on those installations. I recalled a story from my Cape Canaveral days in the early 1950s, when the signal from a ground-based radar located nearly a thousand miles beyond our horizon was picked up at the Cape — the signal was reflected off a Thor missile during a test flight. The suggestion was then made that this same phenomenon (later called bi-static intercept) could be used to intercept Soviet high-powered radar located well over the horizon by pointing the ELINT antennas at the Soviet ballistic missiles during their flight testing, by using the missile's radio beacon for pointing, or simply programming the ELINT antennas to follow the missile's predicted trajectory.

The idea to gain greater knowledge of Soviet air defense capabilities through bi-static interception was approved by CIA management, and project Melody was born. There were no computers in those days, so our feasibility studies and engineering calculations involved solving spherical trigonometry equations using slide rules, tables of logarithms, and hand-cranked calculators. Melody was installed at a CIA monitoring site on the shores of the Caspian Sea in northern Iran. Over the ensuing years, Melody produced bi-static intercepts of virtually all the ground-based Soviet missile tracking radar, including all their anti-ballistic missile tracking sites located at a test range nearly a thousand miles away. The fixed location of Melody and limited trajectories of the Soviet missiles being tracked, however, still did not provide the locations of all the air defense radar installations throughout the Soviet Union that were needed by the Oxcart mission planners.

A New Challenge

A new Soviet early-warning radar, called the Tall King, began to appear about this time, which if deployed widely, appeared to improve significantly the Soviets' air defenses. The new, very large, and obviously powerful Tall King radar quickly became the Oxcart's nemesis. Melody's success with the high-powered, missile-related radar led to the idea of using the moon as a distant bi-static reflector to intercept and locate the Tall King radar systems deployed in the Soviet Union.

At the same time, the Lincoln Laboratory, America's premier radar-development house, had been engaged in a "radar astronomy race" with its Soviet counterpart to see which side would be first to detect and characterize the moon's surface using radar. Lincoln won handily. I visited Dr. John Evans at the labs and discussed the moon radar results and the bi-static moon idea. Drawing on the labs' understanding of the moon as a reflector of radar signals, sensitive ELINT receivers, tuned to the Tall King frequency, were attached to the giant 60-foot RCA radar antenna just off the New Jersey Turnpike near Moorestown and pointed at the moon. (The labs' giant radar antenna was preoccupied with further radar astronomy experiments.) The ELINT receivers were also optimized for the effects of the moon as a reflector, that is, using the lab's "matched filter" techniques. Over time, as the Earth and moon revolved and rotated, all the Soviet radar sites came into view one at a time, and their precise geographic locations were plotted. The extremely large number of installations that were found, and the rather complete coverage of the Soviet Union, were not good news for the Oxcart program office — or for the U.S. Air Force Strategic Air Command, which had to plot wartime bomber penetration routes.

A Talented Engineering Team

Now assigned to the Oxcart program office, I asked for, and was granted, the job of trying to get the hard technical data we needed on the Soviet radar sites to put the stealth vulnerability issue to rest. I assembled a group of engineers and scientists, many Tau Bates, who were known for their innovation and had a nose for running field operations anywhere in the world. We outfitted a C-97 cargo aircraft that had concealed antennas and operated in the Berlin air corridors, which had line-of-sight access to East German-based Soviet radars, with laboratory precision measuring instruments. There was a similarly equipped RB-47 reconnaissance aircraft that operated around the periphery of the Soviet Union.

These projects lead to a series of airborne radar power and pattern measurement systems that could measure a radar's spatial coverage and radiated power with extreme precision. During one of the flights into Berlin, the C-97 intercepted the SA-2's scanning radar, and by comparing the direct signal path with the signal reflected from the ground, we calculated the width of the radar's scanned sector — needed by the electronic countermeasures designers. The system could also measure other important radar signal parameters, including radio frequency coherence, polarization, and internal and external signal structure — details which provided even further insight into a radar's performance and would be vital to the designers and builders of electronic jammers.

The precise dimensions of the Tall King's antenna were also needed for our calculations. One military attaché got close-in ground photographs of radar sites in East Germany. The antenna was mounted on a small brick base, and we asked for the dimensions of one of the bricks. It turned out the bricks were from the nearby Pritzwalk Brick Factory. When we asked our clandestine service to filch a Pritzwalk brick, we dared not admit it was for an ELINT project. We were happy with their impression that it was to be hollowed out and used for a dead-letter drop.

Our special systems were installed in a series of Air Force planes, starting with the C-97 and RB-47, then C-130s, and finally ever more modern aircraft. Missions were flown around the world along the periphery of all Communist countries and in the Berlin air corridors. Technical reports on the mission results were published by the CIA and distributed throughout defense and intelligence communities, as well as to the industry's electronic countermeasures designers.

One of the earliest benefits of this accurately measured air defense coverage was the revelation that the Soviet's low-altitude radar coverage was far better than our analysts' earlier estimates, and the Strategic Air Command quickly changed its plans for wartime penetration to a much lower and survivable altitude.

Project Palladium

We now knew the Soviet air defense radar power and spatial coverage, but that was only half the answer to the Oxcart's stealth — and health. We also needed to know the sensitivity of Soviet radar receivers and the proficiency of its operators. We came up with an electronic scheme to generate and inject carefully calibrated false targets into the radar units, deceiving them into seeing and tracking a ghost aircraft.

Basically, we received the radar signal and fed it into a variable-delay line before transmitting the signal back to the radar. By smoothly varying the length of the delay line, we could simulate the false target's range and speed. Knowing the radar's power and spatial coverage from the aircraft precision measurements, we could now simulate an aircraft of any radar cross section, from an invisible stealth airplane to one that made a large blip on Soviet radar screens — and anything in between, at any speed and altitude — and fly it along any prescribed path. Our project was dubbed Palladium. Now the real trick was to find some way of discovering which of our blips the Soviets could see on their radar screens — the smallest size blip being a measure of the sensitivity of the Soviet radar and the skill of its operators. We began looking at a number of possible Soviet reactions that might give us clues as to whether our ghost aircraft was seen. We finally found that certain Soviet communication links could be monitored to reveal Soviet detection and tracking of the ghost — and in real time.

Every Palladium operation consisted of a CIA team with its ghost aircraft system, an NSA team to monitor the communication links, and a military operations support team. Covert Palladium operations were carried out against a variety of Soviet radar sites around the world, from ground bases, naval ships, and submarines — submarine antenna installations being the trickiest.

Fooling the Adversaries

When the Soviets moved into Cuba with their missiles and associated radar, we were presented a golden opportunity to measure the system sensitivity of the SA-2 anti-aircraft missile radar. One particular memorable operation conducted during the Cuban missile crisis had the Palladium system mounted on a destroyer out of Key West. The destroyer lay well off the Cuban coast just out of sight of Soviet radar, near Havana, but with our Palladium antenna just breaking the horizon. The false aircraft was made to appear to be a US fighter plane out of Key West about to overfly Cuba. A Navy submarine slipped into Havana Bay and was to surface just long enough to release a timed series of metallic balloon-borne spheres of different sizes. The idea was for the early-warning radar to track our electronic aircraft and then for the submarine to surface and release the calibrated spheres to rise into the path of the oncoming false aircraft. It took a bit of coordinating and timing to keep the destroyer, submarine, and false aircraft all in line between the Havana radar and Key West.

We expected the Soviets would track and report the intruding aircraft and then switch on their SA-2 radar in preparation for firing their missiles — and would also report seeing the other strange targets, our spheres, as well. The NSA team would provide the necessary feedback, with its skilled team of Russian and Spanish linguists operators, and their monitoring systems on board the destroyer. The smallest spheres reported seen by the SA-2 radar operators would correspond to the size, or smallest radar cross-section aircraft, that could be detected and tracked.

While we got the answers we went after, it was not without some excitement — and entertainment. In the middle of the operation Cuban fighter planes were dispatched to intercept the intruder. We had no trouble in manipulating the Palladium system controls to keep our ghost aircraft just ahead of the pursuing Cuban fighters. When the NSA team heard the Cuban pilot radio his controllers that he had the intruding aircraft in sight and was about to make a firing pass to shoot it down, we all had the same idea at the same instant. The engineer moved his finger to the switch, I nodded yes, and he switched off the Palladium system.

Important achievements

We had finished our special mission, concluding that the Oxcart would indeed be detected and tracked by the Soviets, which by then was no surprise to any of us. We felt that we had only proved that the Earth was round, and that as soon as the Oxcart came over the horizon, the Soviet's air defense radar would immediately see and track it. At the same time, however, we had also established realistic stealth radar cross-section goals that, if met by the next generation of stealth aircraft, would allow the aircraft to fly with impunity right through the Soviet radar beams. The F-117 stealth fighter and B-2 stealth bomber would eventually meet these goals. Another CIA engineer, with knowledge of Russian math models for calculating a complex structure's radar cross section, would pass the formula on to the Lockheed Skunk Works, which would use them in their stealth designs.

Seeking Countermeasures

Even before we had finished our projects, it had become obvious that if the Oxcart could not fly stealthily, it could in the meantime fly safely, relying on its superior performance to outfly the anti-aircraft missiles. But we would need a stable of effective electronic countermeasures in the future. Our group had already spun off two other groups: one to take on the job of developing electronic jammers and warning receivers for the Oxcart, SR-71, and the U-2s that were still flying — albeit over China rather than the Soviet Union; and a second group to continue investigating revolutionary techniques to further reduce the Oxcart's radar cross-section to an acceptable level.

The second group came up with some novel schemes, such as mounting special electron guns on the Oxcart to generate a radar-absorbing electron cloud in front of the aircraft. One of the U-2 missile warning receivers we developed was modified and installed in an Air Force fighter plane and became the basis of a later system called Wild Weasel, used to locate and destroy SA-2 missile sites in North Vietnam. Wild Weasel became the stuff of great stories and legends about the daring-do of the pilots who hunted down the SA-2 sites, launched their radar-killing missiles in close, and dodged the missiles fired at them during these encounters.

Word quickly spread about our group's newfound knowledge of Soviet and Chinese radar, and calls came in from around the world seeking more information about the capabilities of specific radar systems. Requests even came in from submarine skippers wanting to know how Chinese surface search radar could detect targets as small as their periscopes, which compromised their positions to enemy patrol boats. We assured them that the radar could not possibly see their small periscope, but that they were likely seeing the submarine's ECM (SIGINT) mast. The mast was also raised above and behind the periscope; it was about the size of a totem pole and made an ideal target as the motion of the waves varied the mast's length, effectively optimizing it for detection by the radar. After lowering these masts, the submarines were no longer detected.

Gulf of Tonkin Incident

In early August 1964 our group received an extraordinary, and prophetic, query. My boss handed me a copy of a message containing fragments from the radar operator's log from the US destroyer *Maddox*, which was operating in the Gulf of Tonkin off the coast of North Vietnam. The operator's log noted how the *Maddox* and another destroyer, *Turner Joy*, had been attacked for the second time by North Vietnamese torpedo boats — and that the attacking boats were seen only on the ships' radar and heard by the ships' sonar operators. That morning my boss said, "The people upstairs want to know if those torpedo boats were real, or could the *Maddox's* radar have been spoofed electronically, the way you spoofed their radar?" A fast read of the *Maddox* log gave few clues, and I asked if there was any more information available or expected. I came up with a list of things I needed to know before giving a confident answer, such as: visibility in the Gulf at the time, weather and surface conditions, any reports of lightning or thunderstorms in the area, the speed of the torpedo boats if moving radially toward the *Maddox*, and the presence of other ships and aircraft in the area. My boss went away with these questions, but he returned shortly to say that nothing else would be forthcoming and that I was to do the best I could with the information I had — and soon.

After a fretful hour, I concluded I would have to take the radar operator's word that he saw boats, but added that with the answers to my questions, a positive answer would be quick and easy. *The Washington Post* headlines the next morning carried President Johnson's authorization to start bombing North Vietnam in retaliation for the attacks. I learned later that the original query had come from the White House and that Secretary of Defense McNamara and others were there, along with Director of Central Intelligence John A. McCone *[CA A '22]*. I surmised that McCone was the likely source of the request because he knew about our Palladium project. I was now curious as to why the White House seemed not to want to hear what his intelligence experts had to say, so I tried for a period of time to obtain answers to my original question and to learn more about the situation in the Gulf of Tonkin that night. I did eventually learn that there indeed had been severe thunderstorms, rough seas, and most important, lightning. Ships' surface-search radar is notoriously unreliable in rough and stormy seas, and sonar even more so. Furthermore, the blips on the ship's radar screen, that the operators thought were torpedo boats, never reflected solid tracks or tracks moving steadily or radially toward the destroyers, as would happen in an attack. I finally had my answer; there never were torpedo boats involved in an attack that night.

Hen House

Our focus soon shifted to a broader range of other so-called intractable technical problems. Satellite photography had discovered a huge new radar deep in the Soviet hinterland, the Hen House. It appeared to be a phased-array radar, possibly space surveillance. By now, early ELINT satellites were in orbit, and the radar's frequency was known to be in the VHF band. A second Hen House was also under construction in the northeastern Soviet Union, a few hundred miles inland from Riga.

Judging from the size of the radar and its probable high power, I felt we should be able to pick up its signal well over the horizon via a phenomenon known as tropospheric-scatter. Studying a map, I found an island in the Baltic Sea that looked to be at about the right distance to install a tropospheric-scatter receiver system. After extensive negotiations for access to the island, dual antennas were installed (about 50 wavelengths apart to reduce the expected atmospheric fading), and the receiver was set up for unattended operation. Our Briar Patch system finally picked up the very first Hen House transmission and every subsequent transmission.

We learned that the radar tracked US reconnaissance satellites from the first orbit, and that the Soviets had an incredibly effective espionage network in place to tip off the Hen House when a US intelligence satellite was about to be launched. When there was a lengthy hold of an impending launch from Vandenberg Air Force Base in California, the Hen House would switch off and come back on the instant the satellite lifted off. We also learned that the Hen House tracked aircraft just as well and as often as satellites. The radar's precise frequency indicated its pointing angle, which was then correlated with the most likely targets being tracked.

Caught Cheating

One of Melody's more significant successes would occur during negotiations with the Soviets on the 1972 Anti-ballistic Missile (ABM) treaty — which included an obligation not to give non-ABM systems, such as the new Soviet SA-5 antiaircraft missile, capabilities to counter strategic ballistic missiles — and not to test them in an ABM mode. Intelligence analysts were debating whether the SA-5 antiaircraft missile could be upgraded to become an ABM and whether the Soviets might try to test it covertly in an ABM mode.

After nearly a year of trying to come up with an agreed-on estimate of SA-5 capabilities and Soviet intentions, many analysts believed that the Soviets would never dare cheat on such an important treaty. I suggested that we assume that the Soviets, based on their history, should be expected to cheat on the treaty by testing their SA-5 against one of their own ballistic missiles and that we need only find a way to catch them at it. Much to the chagrin of the analysts, Melody answered the question within a few weeks. Melody had been quickly modified by adding a special ELINT receiver, tuned to the SA-5's ground-based target-tracking radar frequency — which was known by then. Melody, pointing its antenna at the Soviet missiles in flight, readily intercepted the SA-5 target tracking radar signals, bi-statically, from the Soviet's Sary Shagan missile test range nearly 1,000 miles away, as the Soviets repeatedly tested the SA-5 in the forbidden ABM role.

During one of the ensuing Geneva negotiating sessions, Dr. Henry Kissinger, using intelligence derived from the Melody intercepts, looked his Soviet counterpart in the eye and read him the dates and times they had cheated on the treaty. The cheating immediately ceased, and the Soviets began a mole-hunt for the spy in their midst, who most surely had tipped us off.

Counting Troops

During the Vietnam War, the CIA was engaged in a heated debate with the Army and Secretary of Defense McNamara's office over the infiltration rate of North Vietnamese soldiers into South Vietnam. The CIA estimates were much larger than those of the Department of Defense, and if they could be validated, did not bode well for the outcome of the war. The Air Force had airdropped acoustic sensors along the Ho Chi Minh Trail (Project Igloo White) in an attempt to detect and count infiltrators. Both the Air Force and Navy also had SIGINT aircraft orbiting off the Vietnamese coast to intercept and count the number of small radios carried by the infiltrating groups, which always traveled in fixed numbers on the trail, on their trek south. A good estimate was obtained by multiplying the number of radios by the number of men per group. The problem was that the orbiting SIGINT airplanes could not fly high enough to intercept all the radios on the very long trail.

Our solution for an accurate count was simply to get an airplane, in this case the U-2, that could fly high enough to intercept all the radios simultaneously. A special radio receiver was quickly found and installed. Each U-2 could stay aloft 12 hours, and two could provide 24-hour coverage. The infiltration rate turned out to be more like a flood. McNamara's people, with their computerized estimates, would finally accede to the higher CIA numbers.

During the years that our engineering group was in existence, we would occasionally discuss just how far we could go in terms of probing, spoofing, and injecting false signals and information into an adversary's communications networks to learn covertly more about his hidden capabilities and intentions. We also brainstormed about what responses and second-order observables we might look for when radiation security, encryption, and deception were used. The process had no name at that time, but, in retrospect, we were unwitting participants in the beginnings of what is now known as the information warfare.

The CIA gave its engineers and scientists an unusual amount of freedom to find solutions to the vast and seemingly intractable problems they faced — placing a premium on academic standing, innovation, and self-reliance. Looking at today's technologies, and the intelligence challenges, I know the new generation of Tau Beta Pi engineers are more than up to the job.

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[1] **This article is based on an article by S.E. Poteat, 'Stealth, ELINT, 1960-75: Some Beginnings of Information Warfare,** *Studies in Intelligence,* **Vol. 42, No.1, 1998. The volume is SECRET. Ref. article has, however, been recently declassified.**