
4. Computers and Espionage

...and the world's first spy satellite...

It was 1959 and the Cold War was escalating steadily, moving from a state of palpable sustained tension toward the overt threat to global peace to be posed by the 1962 Cuban Missile Crisis – the closest the world has ever come to nuclear war. Quite by chance, I found myself thrust into this vortex, involved in top-level espionage work. I would soon write the software for the world's first spy satellite.

It was a summer romance, in fact, that that led me unwittingly to this particular role in history. In 1958 I had fallen for a stunning young woman from the Washington, D.C., area, who had come out to Boulder for summer school. So while the world was consumed by the escalating political and ideological tensions, nuclear arms competition, and Space Race, I was increasingly consumed by thoughts of Phyllis. We were still infatuated with each other by 1959.

So in late spring of 1959 I decided to look for a summer job in Washington. From a list of government agencies offering scientific summer internships, I selected one at random and made my first telephone call, to a place called The Naval Research Laboratory (NRL). A rather bureaucratic-sounding voice answered. He identified himself as Bruce Wald. "Do you know any computing?" "Yes," I answered. I had taken one course out of a book and had never touched a computer. Be assured, there were very few computers around in 1959. "What were your college majors?" "Engineering, physics, and mathematics," I replied. Pause, "ahem," another pause, a throat clearing, then, "Okay, well...we would love to have you come to work with us here. You have the job. Get here as fast as you can."

The day after teaching ended I drove straight through to New York City. I had bought a better (used) car, a Chevy convertible, and a girl from the Chi Omega Sorority going home to Scarsdale, New York, paid for the gas. After a quick night's sleep on a sofa at her parent's house, I drove down to Washington. My girlfriend Phyllis lived in Chevy Chase at the north end of the District of Columbia diamond, NRL being at the extreme southern tip of the D.C. diamond. Probably I stopped to see Phyllis but I am sure I also went promptly down to NRL that first day in Washington. I do know that Bruce and I went to work on his LGP-30 computer the very first day I was there. Immediately the papers for a Top Secret clearance were initiated for me. Things were moving fast. I was introduced to key personnel under

whose supervision I would be working. Two of them were Bob Misner, who seemed to have endless larger than refrigerator-sized magnetic tape recorders standing in rows throughout the building. Another was Mack Sheets, who seemed to be an expert on something called the Wullenweber, some kind of German device for determining the angular bearing of an incoming electronic signal. I was in the Intercept and Data Handling section of the Countermeasures Branch of the Radio Division at NRL. The branch head was Howard Lorenzen, one of the world's experts and a veteran in the game of electronic warfare. Lorenzen had contacts in and was an integral member of the highest Intelligence circles within the United States government.

Although it would take 18 months for my security clearance (above Top Secret) to be completed formally, no one wasted any time bringing me up to speed on the primary task: locating Russian submarines from their electronic transmissions. The method is called direction finding. From listening stations arrayed around an ocean, you triangulate the submarine's position. Even a one second coded burst to Moscow can reveal a submarine's position. Bruce's task, and now mine, was to get rid of all those full-wall ocean maps with British girls standing on ladders drawing bearing lines across them (that you see in the old World War II movies), and put the whole calculation into our little LPG-30 computer. If we could succeed, it was clear that the Navy would give us an essentially unlimited budget to issue contracts to industry to develop larger scale systems for general ocean surveillance in both the Atlantic and Pacific. During the summer, I soon surmised from the locations of some listening stations surrounding the Soviet Union that our computerized system would also be used for surveillance over land areas as well. Not only the Soviet Union but also Communist China would be under surveillance. I learned later that these high frequency direction finding (HFDF is the acronym) systems had been used in 1957 to track the Soviet Sputnik from its 20 MHz signal and thereby determine its orbit.

Direction finding is a really fascinating weapon within the panoply of electronic warfare. Unlike radar, you send out nothing. You just listen. No one but you needs to know your location. In that era and even today it is not widely known to the public, and its specifics are closely guarded secrets. I had by romantic accident been brought into some of the world's most secretive intelligence projects.

NRL had rented an apartment for me close to the laboratory. Bruce and I were given unlimited overtime and often worked late into the evenings on our little computer. Other evenings I would commute up Rock Creek Parkway to see Phyllis, who lived near Chevy Chase Circle. Sometimes the maid at her parents' house would make me breakfast and criticize me for not having an apartment nearby. Sometimes Phyllis came down to my apartment in Anacostia, but not often. Increasingly, I found myself unable to fit into the wealthy Catholic culture of her family. On the other hand, I could not wait to get back to work on the fascinating tasks the Naval Intelligence community had laid in my lap. Moreover I knew by then that NSA was the real client for much of the information in Bob Misner's large banks of magnetic recorders which were being fed daily from intercept networks.

The lay public may not fully appreciate the value of knowing the total electronic signature of your adversary's military installations and devices. We humans think of espionage information as what we can see with our eyes or hear in our ears. But the electronic spectrum is actually more valuable if you wish to know your adversary's capabilities and how to knock them out. Compare it to boxing in a ring. It is necessary to see and even hear your adversary. But it is of higher value to determine his strengths and weaknesses, where and when to be able to strike, or counterpunch.

Essentially, nobody knew computing in 1959. Of course there was Los Alamos, and a few academic centers that were forming computer staff. There were no Departments of Computer Science at universities. Certainly none of the 50 or so radar engineers in the Countermeasures Branch knew any computing at all. Mature electrical engineers like Bob Misner and Mack Sheets who were the immediate superiors to Bruce and me really had no choice but to always try to meet our demands. We would take two hour pizza lunches but then work almost all night. I was pretty harmless as a young protégé but Bruce enjoyed pushing the limits and taunting his superiors with our work-time wishes.

Of course I had no idea to whom I was talking when Bruce Wald hired me sight unseen. When I arrived in Washington, D.C., for the first time at NRL's heavy-security front gate, they parked my car and I waited to meet Bruce. Pretty soon he arrived. I won't say he waddled up, but he was pudgy and walked with a stride of toes-pointed-out. It was my first encounter with a young genius. My experience at Colorado had not had any talk of genius among us. We were all just bright hard-working engineering students.

Bruce had graduated from Bowdoin College in Maine at age 18 and came directly to NRL. I don't know where Bruce learned computing. Maybe he just learned it himself. I remember one day later on Bruce had loosely wired some transistors together and was applying various voltages to his little make-shift circuit. He was just holding them in his hand. Transistors were just coming on-line.

I suppose, in a way, that Bruce was as curious about me as I was about him. Later on he would refer to me as "that extra-smart ski-bum from Colorado." Certainly I did not fit the Eastern United States image of genius, geek, nerd, or intellectual. Bruce did. But we got along very well, although we never became really close friends. We did have hiking as a common denominator. Bruce and I and my girlfriend Phyllis took a long weekend to drive to the White Mountains in New Hampshire and did a two night hut trip over Mount Washington and Mount Madison. Two years later in 1961, when I had a month between my Basic Training at Fort Knox, Kentucky, and my marriage to Becky Emeis in Davenport, Iowa, in June, Bruce and his wife Betz put me up at their house some miles south of NRL on the peninsula. That was indeed an experience. I knew that Bruce just let trash accumulate, indeed, pile up in his car. He would finally take it to the gas station and pay an attendant to just haul and vacuum it all away. Their house was in about the same condition. Eating meals there was trying. We ate at the kitchen table across from a cage they had installed in the kitchen with a couple of monkeys in it.

One would just throw scraps from the table over to the cage. Sometimes the monkeys threw them back.

Like many brilliant scientists, Bruce rebelled against seemingly senseless rules. But our supervisors liked it when we volunteered to work on the computer all night. Go ahead and fill out your own time cards, they said. I see now how they needed us desperately. I see now how the nation needed us. I could have had no better teacher of pioneer computing than Bruce Wald. With our countervailing personalities, we played off each other, challenged each other. By the end of the summer, we were computing experts.

I shall always be grateful that I learned all of the basics of computing on such a primitive (by today's standards) computer. One started the LGP-30 with a small punched paper five-hole tape boot-strap program, which would then pull in the longer tape containing the machine language instructions we had coded. The arithmetic was in base 16 (hexadecimal). I could "one-op" the program, looking for bugs (coding errors), as all bits being processed could be seen sequentially on small registers at the top front of this desk-sized computer. I grew to love this little machine. I knew where every bit came from, and where it would go. Apparently there is a computer museum near Stuttgart, Germany which maintains a working LGP-30.

Fascinating as this pioneer computing and intelligence work was, with the cooling of my romance, and the almost intolerable Washington summer humidity, I started to dream about getting back to God's country – Colorado. I wanted to be in my comfort zone of Boulder and start graduate school toward a Ph.D. in mathematics. Looking back, I'm somewhat amazed at how I decided to just dump that work so vital to the United States intelligence community and head back home. The Navy offered me strong incentives to stay on. I could go to graduate school, anticipate a rapid rise in the GS salary system, the like. But the pull of my mountain kingdom was stronger; and the end of summer 1959 found me happily driving back to Boulder.

Not relenting, the Navy contacted the head of the Applied Mathematics Department, Charles Hutchinson. He called me into his office and said the U.S. Government wanted him to create a secure safe room and security safes for me to continue the military work. They would even pay for security guards. Hutch (as he was called) was a craggy old fundamentalist and he was simply incredulous. I still remember him looking at me with a mixture of bafflement and not a little resentment. How could this young pup of an Instructor have become so important? The University of Colorado at that time had no classified research capabilities. Of course I could not tell Hutch the specific intelligence task to be undertaken. The department had just acquired a small computer, a Bendix G-15, which was comparable to the LGP-30. But a moment's thought told me that I did not want to take on the onerous and time consuming machine-coding all over again on a different machine. And I wanted to start taking pure mathematics courses. Quickly putting it all together, I took a deep breath and told a relieved Professor Hutchinson, "Tell them we just cannot do it."

As recounted in the previous chapter, the 1959–1960 academic year found me successfully teaching applied mathematics, learning pure mathematics, and starting

to enjoy life as a ski-bum. Then out of the blue in the spring of 1960, I received notice from the Selective Service System that I was drafted. I was told to report for a physical exam and expect to serve four years in the U.S. Army. I could not believe it. Other university instructors my age were not being drafted. I asked Hutch if he would sign papers categorizing me as a critical skill, exempt from the draft due to national teaching needs. He demurred. I protested. He suggested that if I didn't like his decision, why didn't I try my colleagues at Naval Research? I consulted a Mr. Rhodes, the veteran's affairs advisor on campus. He agreed with Hutch: if Hutch would not sign, the only way out was if the Navy would put through the critical skilled enlistment papers. I would have to go back to Washington to work for them for four years, do a three-month Army basic training, and be in the Army Reserve for eight years. The likelihood of being called up for active duty in case of war still existed, but the probability of that was reduced by the fact that I would not have the usual additional three-months training for a specialty designation in the Army. I wouldn't be assigned to any specific Active Reserve Unit, and instead would be placed in the Inactive Army Reserves.

After a few days' thought, it seemed pretty clear. Graduate School and skiing would now have to wait. And I knew the intelligence and computer work would be fantastic. Another positive factor was that if I got my Ph.D. back East, e.g., at the University of Maryland, I might be more able to come back to Colorado permanently as professor. It is generally considered a sin for a University to hire its own Ph.D.'s, although they do it sometimes.

Thus I called my friends in the Countermeasures Branch at NRL. They were delighted and immediately started the paperwork. I was told to report immediately upon the end of the teaching semester. One has to wonder if any backroom dealing had taken place. One can never really know in the spook business.

My future wife Becky went back to her parents' home in Iowa, to work and wait until I completed the Army Basic Training, after which we would marry. I went back to Washington and even deeper into the electronic espionage game. Bruce and I successfully demonstrated our prototype codes on the LGP-30 for the submarine position fixing tasks. We were elevated to scientific officers to supervise multi-million dollar contracts to industry to build large state-of-the-art computers to be put into the military operations centers. I was placed in charge of all mathematics and software development. An electrical engineer, John Ihnat, was made responsible for all hardware aspects. John remained on this and related projects for a lifetime career at NRL. Bruce later rose to an Associate Research Director at the Naval Research Laboratory.

I have detailed elsewhere (*see* Notes) some of the mathematical tasks and scientific challenges facing me as I found myself at the forefront of this wave of computer innovation during the following four years. Bruce, John and I chose Burroughs Corporation over IBM for the contract to build the new computers. Working closely with Burroughs, we participated in the rapid hardware progression from magnetic drum to core to solid-state memories. We favored and chose Algol over Fortran for the software language and compiler. Our resulting military computer was called the D-825, and some of our ideas later appeared in the Burroughs

B-5000 and Illiac machines. We created the computing concepts of “scratchpad register” and “one-time pads” from our intelligence community culture. Similarly the fast temporary “cache memories” and “cache registers” now embodied everywhere in computing systems large and small were originated by us in analogy with espionage techniques and terminology.

I needed four LGP-30's, linked together by punched paper tapes (!), to simulate the desired larger system. To manage that configuration (and please: do not let the moving tapes tear. . .), I needed to carefully program precise parallel computing control and timing of communications between the four machines. To obtain a position fix in the minimum time possible (about 30 seconds), I optimized the flows of the data and the mathematical calculations. Such methods later were called pipelining in the computer culture. My linked four LGP-30s may have been the world's first parallel computer.

I remember driving alone nights down to the Navy top secret net-control center at Cheltenham, Maryland, to install my four-computer LGP-30 parallel computing system in 1960 into 1961. Some Naval personnel were assigned to assist me. My prototype system would triangulate the Soviet submarines' positions and would provide 95 percent confidence search regions for them, and pass these on to NSA analysts and Naval commands. I began to wonder if my Army Basic Training three-month obligation was being delayed until I had my system up and running operationally. Therefore I decided to train some talented Navy chief petty officers to run my system. Off I went to Fort Knox to suffer the purposeful sleep deprivation and humiliation of Army Basic Training. The contrast with my life as a Navy computer intelligence expert was almost comical. Essentially I was treated as an intelligence officer in the Navy and became accustomed to salutes and saluting as a habit. The Army did make me a Corporal and squad leader, however. Finally, Becky and I could get married in June, 1961.

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In the Countermeasures Branch, there was also a top-secret small satellite program under development by a small team headed by Reid Mayo. The historical origin of that potential satellite reconnaissance effort was actually the Moon. One of Lorenzen's long-time colleagues, Jim Trexler, had found that many Soviet secret electronic and communications signals could be obtained just from the reflections from the Moon back to Earth. A huge, 66-story tall moveable telescope was planned in West Virginia to collect those signals. So the Moon could be considered the world's first (natural) spy satellite! But for technical reasons only a smaller telescope was built. Nonetheless, the so-called Moon-bounce intercept capabilities stimulated Reid Mayo in 1958 to think about using man-made satellites to spy over Russia. Hundreds of pilots and technicians were losing their lives in ferret flights dodging about 200 miles in and out of Soviet border zones while trying to determine the electronic signatures of Soviet air-defense systems. Moreover, the satellite's intercept regions would be much larger than those of the ferret airplanes, and virtually unrestricted in orbits over the Soviet Union.

The United States had been relying on the U-2 spy planes to over-fly the Soviet Union until May 1, 1960, when Gary Francis Powers' U-2 was shot down.

This event had huge international repercussions and poisoned the relationship between President Dwight Eisenhower and the Soviet Union's Nikita Khrushchev. Nonetheless, the need for electronic intelligence data was so paramount that only five days after the U-2 went down, Eisenhower gave approval for Mayo's group at the Naval Research Laboratory to send the world's first reconnaissance satellite into orbit over the Soviet Union.

Shortly after I returned to NRL in 1960, I saw Reid Mayo and his associate Vincent Rose laboriously plotting circles on a map of the Soviet Union. Although I wasn't cleared for their satellite project, as I watched I had a vague idea of what they envisaged. Just chatting, I told Reid that maybe I could give them their needed trajectories and intercept circles by writing a code to do that on my little LGP-30 computer. Reid jumped at the idea and we huddled for an hour or two to discuss exactly what was needed. Reid was of the older "fly by the seat of your pants" engineering mentality, and I could tell that he was skeptical that I could achieve the desired result.

In truth, I had my doubts as well. The LGP-30 had only 4,096 memory locations to play with. But I knew that machine intimately. And I already had written code which was doing geometry and navigational spherical trigonometry on the surface of the Earth for my first project, the submarine direction finding and tracking. My boss, Bruce Wald, was away for six weeks inspecting our installations at the receiving stations encircling the Soviet Union. I was alone in Washington and could work nonstop day and night to try to implement my idea.

In a furious effort that as I recall took me less than two weeks, I wrote new code which utilized as much as possible of the subroutines I already had written for the first project, and I succeeded. I still remember vividly the amazed look on the faces of Reid and Vince as I called them in to do a sample run for them. Their astonishment turned to rapture as we then ran some of their needed trajectories, and out of my computer came the desired coordinates and intercept regions.

This became my second successful NRL project. And until now, my having done so has never been recorded anywhere.

The world's first spy satellite launched into orbit on June 22, 1960, and carried the cover name GRAB (Galactic Radiation and Background) and code name TATTLETALE. Its principal purpose was to gather radar data, and any other electronic transmissions it might record. The computer codes I wrote were used for both tracking the satellite's position as it moved along its trajectory, and determining the intercept coverage area for each point on its trajectory.

It should be remembered that in those days, one could not even conceive of satellites with onboard computers. All collected intelligence data was processed afterward. The GRAB satellites only had antennas that would collect each pulse of a Soviet radar within a pre-specified bandwidth, and transpond a corresponding signal to NRL receiving stations at ground sites within GRAB's field of view. That intelligence data was collected on magnetic tapes which were then dispatched back to NRL and on to NSA. So much useful data was collected on the GRAB I satellite that the intelligence analysts at NSA were kept busy until GRAB II went up about a year later on June 29, 1961. That satellite then collected intercept data for more than 14 months.

As quoted in James Bamford's book about NSA (*Body of Secrets*, 2001, p. 366), Reid Mayo said, "The circle that we were able to intercept from instantaneously was about three thousand or thirty-two hundred miles in diameter, depending on the altitude." The consequences of the GRAB I and II satellites were enormous. The electronic intelligence collected by them was processed by NSA and marked a turning point in U.S. Cold War strategic doctrine. The Soviet air defense system was found to be too robust for penetration by SAC's (Strategic Air Command) high and medium altitude bombers, so these were succeeded by low altitude bombers and ballistic missiles.

I will never know how NRL and NSA partitioned the workload on the processing of all the electronic intelligence captured by the GRAB satellites. I was not cleared to know. But I do remember Reid and Vince begging me to train them so that they could operate my software on the LGP-30 computer. Then I remember them putting in long hours over many months hunched over the computer, getting out their needed intercept regions. Their team received the Presidential Service Award in 1962 for the world's first electronic intelligence satellite. I was a key part of that team, although not officially because I had never been cleared for it!

I returned to my primary tasking, that of position fixing from intercepted signals. That project, as we expanded it to industrial scale, too was successful, and became known as the Bullseye project. I wrote six reports on it which are still classified and unobtainable, even to me. I never wrote any report on my high intensity but unofficial work on the GRAB project.

The Air Force had opted for a photo-reconnaissance spy satellite program, the Corona satellite. The first successful one was launched in August 1960. Evidently the U.S. government was not satisfied with the Air Force program, and created the top-secret National Reconnaissance Office (NRO) in August 1960 to take over supervision of the Air Force's spy satellite programs. When NRL failed in its GRAB III satellite in 1962, NRO also took over supervision of NRL's ELINT satellite activities in July, 1962. I was never told of NRO's existence. The satellite intercept data my computer codes help collect was, in my mind, always going to NSA or CIA.

Bamford's book (2001) is an excellent source for further dramatic instances of national significance in which my computer algorithms or their successors (on better computers) served the nation. He gives a compelling account of the Cheltenham Naval Station's role in tracking Russian submarines during the almost-nuclear war situation which arose in the 1962 Cuban Missile Crisis. There, my four-computer LGP-30 system could quickly return the Russian submarines positions, and as well, the positions of virtually all of the Russian surface ships, every time they communicated among themselves or with Moscow, at least ten times faster than the previous manual plot-by-hand Naval system. Time was truly of the essence in that nerve-wracking nuclear confrontation.

Also in Bamford's book you will find accounts of important unforeseen consequences of Mayo's GRAB program. For example, a treasure trove of electronic signatures from the Russian space program was inadvertently collected when the Russians lost critical contact with a cosmonaut and "turned on everything" to try

to re-establish contact. Additionally, the first Soviet antiballistic missile radar signatures and the locations from which they emanated were obtained by GRAB.

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This account of my life's trajectory placing me as "the right man at the right place at the right time" would have been lost from history. Only by an accident of fate is it now written.

When I left NRL in 1963, turning my attention to full-time graduate work in mathematics at the University of Maryland, my extremely brief debriefing instructions were curt and clear: "Never talk about this work." I never did. And I didn't happen to read Bamford's book, published almost 40 years after my work, on direction finding and satellite spying. Thus I had no idea that the GRAB program had been partially declassified in 1998 in order to reveal its important contribution at NRL's 75th anniversary celebration, and further partially declassified in 2006 to allow an exhibit of those early Navy spy satellites at the National Cryptologic Museum.

On a whim, I decided to go to my 50th Class Reunion here in Boulder, for the University of Colorado Class of 1958. I paid my \$125 to the Alumni Association and prepared for two days of being wined and dined by my own administrators here. Little would some of them know that they were supplicating themselves to one of their own employees! But the big surprise would be to me. As a result, I would decide to write this book.

The very first morning when I went to pick up our caps and gown to wear in the Commencement procession the next morning, within 10 minutes I walked Gordon Fink, a fraternity brother I had not seen for 50 years.

"Hi Gordon," I greeted him, as if only a semester had passed since our last meeting.

"Hi Karl," he replied, without skipping a beat.

We chatted. Gordon had risen to the very highest levels of NSA, CIA, DEA, even NRO. Somewhat in awe, I said, "Gordon, I am going to tell you something that I have never told anyone. I wrote the software for the world's first spy satellite in 1960. There at NRL. Right after Gary Francis Power's U2 was shot down over Russia."

"Karl, I have seen that satellite," Gordon replied. "The program was recently declassified. Do you want me to send you a picture of it?"

Had that chance conversation with Gordon not taken place in 2008, I might never have written this account of my role in history. For that matter, I might never have written this tale of my life. Chance is like that, isn't it? We never know what it will bring.

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Large-scale direction finding networks emerged in World War II as a counter-measure against German U-boats, which were sinking large numbers of Allied vessels in the War of the Atlantic. Our later computerized systems were still of course employed to locate adversary submarines, but were also invaluable in their use for general electronic surveillance of the Soviet Union and other potential adversaries. Now such systems can fix the locations of terrorists just from a

cell-phone emission. Such devices use line of sight propagation paths. If you have antennas of sufficiently high gain, you can detect even the weakest of signals. Transmissions from far space planetary exploration satellites are a good example. Because electronic transmissions generally go out in spherical waves, in principle they can be detected from any line of sight direction.

The Soviet launch of Sputnik and its over-fly of the United States had the unintended consequence of opening their country to satellite reconnaissance. President Eisenhower soon ordered full speed ahead on United States satellite systems to perform such electronic espionage from space. GRAB just happened to be the first spy satellite. Within the years 1959 to 1963, the world of espionage went into space.

Espionage prevents wars and thereby saves millions of lives. I like the prize-fighter analogy again. If you and your opponent can each detect the buildup by the other of potential kayo punches before they are thrown, you are both going to end up spending your 15 rounds just feinting and jabbing as you maneuver around the ring. There are no surprises and no knockouts.

I firmly believe that the advent of satellites, although originally motivated by the need to gather electronic intelligence, fundamentally and forever changed the dynamics of our human society on Earth. It took us from life in two dimensions to life in the three dimensions of space. It isn't possible now, 50 years later, to even imagine living in the pre-Space age. Human society and its promise and perils have been utterly transformed.

The GPS (Global Positioning Satellite) system now so common in our lives can serve as an example of this transformation. GPS may be thought of as direction finding in reverse. Instead of silent receiving stations waiting to triangulate a bleep from a submarine, the GPS satellites are always bleeping and you want to triangulate off them. We are all submarines now, under the great sea of space.

Notes

I have given a more detailed unclassified account of my specific mathematical and pioneer computing contributions to the primary task of tracking Russian submarines in my paper *Parallel Computing Forty Years Ago*, Mathematics and Computers in Simulation 51 (1999).

You can find more information about the 1960 satellite work and consequent further developments from a number of sources about the GRAB program, now available on the internet via Google. Also in Bamford's book, *Body of Secrets*, Random House (2001).

Some further information can be obtained from NRL Press Release 32-00r on 5/22/2000: *A Tribute to the Father of Electronic Warfare*. This was an account of the crucial role of our Branch Head, Howard Lorenzen, who died 2/23/2000, throughout his life of military electronic intelligence work.

The Crossing of Heaven

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