20 July 2008

Polaris – Poseidon –Trident
An Awesome Concept

Sea-Launched Ballistic Missile Systems
General Electric Ordnance System United States Navy

========== A Tutorial Adventure in High Technology ==========

A story about General Electric, Charles Wright and ICBM (Missile) Systems

At Charleston SC, during the Cold War era, the most terrible weapon that had ever been devised came into existence, General Electric helped develop and build it. It was the submarine-based InterContinental Ballistic Missile System or just Polaris (named in honor of the North Star). It was the single most important national venture at the time, even above Apollo. Because the capability for hiding mobile nuclear missiles in the vast oceans of the world was absolutely guarantee our nation's supremacy. As an engineer, I consider myself fortunate to have taken part in this major state of the art military venture. Each missile was about 32 feet long (weight 32,000 LB). Most of it was made up of a solid fuel rocket engine, about 5 feet in diameter. The guidance system of each missile was about the size of the average commode, the computer being the tank and the rest of the commode being the gyro portion (call it the Analog portion). The Analog portion had three gyros and three accelerometers mounted in a chunk of metal (about the size of a half gallon milk carton, with cutouts to hold these 6 cylindrical devices). Each gyro and each accelerometer was about the size of a small can of soup. The chunk of metal was mounted via ball bearings inside of a square frame (about like a square, deep picture frame). And that frame was mounted at right angles inside another slightly bigger square frame via bearings. This bigger frame was connected to the outside body of the guidance system by more ball bearings. This arrangement allowed the inner chunk of metal to rotate around in any angular position imaginable (but, in use, it actually remained "fixed", angularly, and the rest of the missile revolved about it). These frames were called gimbals and the inner chunk of metal (holding the gyros and accelerometers) was called an inertial platform (it was called "inertial", which means "fixed" because it never moved angularly in space after it was initially positioned, even though the entire missile might be making various angular movements around it while traveling to a target). The whole Analog portion (with gyros and accelerometers on the inertial platform, and the gimbals) was about twice the size of a basketball. Of course, the guidance system (the whole "commode") was bolted to the overall missile frame. GE built these guidance systems at its Pittsfield, Mass. Plant, a technical wonderland of electro-mechanical engineering. It was a vast operation and it had an additional 400 engineers and technicians out in the field.

The way the missile system worked was as follows. When the rocket engine burns, it blows hot gasses out of the back of the missile, pushing the rocket up through the sky and space to its target. These gasses are forced to go out through 4 short pipes (nozzles) called "jetavators." In flight, the jetavators can be turned slightly by the guidance system computer in any direction so that the back of the missile can be turned (guided, steered) toward the target. In order for the guidance system to "keep its balance" the gyros must keep the inertial platform (the inner chunk of metal) from moving angularly as the missile is maneuvered through the sky (something like the little sensors in your head help you keep your balance). Before the missile is launched, the inertial platform is set to a given angular position, then, as the missile maneuvers, after launch, the gyros sense if the platform starts to tilt from its preset position, and, by electric motors (operating in servomechanism loops), forces the gimbals to turn back, to keep the platform where it was originally set. Transformer-like electronic devices (called resolvers) that measure angles are located at each of the gimbal bearings, to tell the computer how much the missile has turned in every direction around the fixed inner inertial platform. This allows the computer to know exactly how the missile is pointed. As stated, the inner platform also has three accelerometers mounted on it to keep the computer informed (by sensing motion) as to just how far (and how fast) in every direction the missile has traveled since it was launched. So the computer "knows" exactly where the missile is at all times, and how it is pointed. Since the computer was "told" where the missile is intended to go, the computer can actuate the jetavators to keep the missile on the course that was mathematically programmed into the computer before launch. When the computer decides that the missile is going at the correct speed and is pointed in the right direction so that the warhead (like a rock being thrown) will hit the target, the computer cuts the warhead loose and allows it to hurtle through the sky to hit the target. At that time, the rocket engine is shut off and it and the guidance system fall to earth as expensive junk.

When I started working in the Polaris program, I was told that each guidance system cost a quarter of a million dollars. They were so valuable and secret that an engineer (courier) slept alongside each one (in a sleeping bag) on a cargo plane (I did it a few times) as the guidance system was being shipped from Massachusetts to the Lockheed plant in California. The guidance system had to be kept inside a sealed container at an exact temperature (the engineer had to manually wire into the plane's electrical system to get power for the container). I was assigned as a courier a few times so that I could write detailed procedures for other couriers who would do it regularly. Even that was a small adventure.

This guidance system, conceived by MIT, with a digital computer and an inertial section was so complicated that very few people ever understood it. As a small example, consider that the tiny gyro rotors in the gyros and accelerometers were (each) turning at 16,000 RPM in a sphere (about the size of a golf ball) that was precisely suspended in a magnetic field, so that precession bearing friction would be eliminated. I was lucky enough to be the Guidance System Specialist at Charleston SC where about 40 GE engineers had an office on the Polaris missile base, officially named Polaris Missile Facility, Atlantic (POMFLANT). The massive office building also housed the base Commanding Officer, about 125 employees from Lockheed (the missile prime contractor) and about 10 from Aerojet-General (the rocket-engine supplier), along with a myriad of Civil Service engineers and Naval Officers. There were about 900 people, contractors, Civil Service and Military working at POMFLANT.

The guidance systems had to be tested and calibrated at this base before they were put into missiles and into the submarines at Charleston. Each guidance system was not perfect---it had errors in its gyros and accelerometers that could make the missile miss its long-range target. Therefore we had to determine exactly what these errors were (e.g., like the speedometer on your car being in error by a few miles per hour). We would carefully measure gyro and accelerometer errors so that the submarine could take them into account and offset them before the missile was launched.

As a vastly oversimplified example, if the guidance errors would cause the missile to hit 10 miles to the left of the target, the submarine would apply factors to aim it 10 miles to the right. Six to eight hours were required to calibrate and test each guidance system, the intricacies involved were staggering. GE also built all the large test/calibration consoles and nearly all other support equipment, including the main missile control consoles for the submarines.

There were 16 missiles on each submarine. It was stated that each submarine was more powerful than all the bombs dropped by everyone (both sides) during World War II, including the atomic bombs dropped on Japan. It was an awesome feeling to be there, working about a block from countless atomic bombs (stored in the warheads).

The base was about 5 miles in diameter and it had a highly secret inner base about a mile in diameter. The inner high security base is where the missiles, warheads and guidance systems were kept and tested. There were armed Marine guards everywhere, it was a bit scary. The inner base was surrounded by deep swamps (even swamp panthers prowled around the wild area. I have seen them at night when I had been working late). My job was to be an expert on the "brains" (the guidance system) of the missile and to keep track of and report on reliability problems and trends and (using all the metric data being recorded as guidance systems were processed) write secret missile statistical accuracy reports (CEP) for Admiral W. Raborn (later, Admiral L. Smith and Admiral I. Galantin) who was in Washington. He was in charge of the program nationwide for the Navy. The program was completely controlled by the Special Projects office in Washington DC. Key people were identified by codes, I was SPC91 (Special Projects Charleston #91). All contractors and civilians on the base were under the technical control and auspices of a Civil Service Chief Engineer and his supporting staff, this provided continuity and it prevented chaos.

The other electronic equipment associated with the missile system at the Charleston base and on the submarine, would take one person two lifetimes to learn. I was closely involved with just one little part of it all, the guidance system (but that was the most complicated and most interesting part of the missile). The Guidance System Laboratory Building was 200 X 200 feet, 2 stories high, and was located on the inner security base.

In a (separate) Missile Assembly Building, each entire missile was laid horizontally in a berth and checked completely with a guidance system intact before being released to the Navy. GE, having a major role in the Polaris program, was involved in developing extensive documentation for myriad formal instructions, along with intricate quality control and troubleshooting measures. Everything had to be documented in great detail. Further, GE maintained a large school facility at Pittsfield for Navy personnel and GE engineers and technicians. Almost everything was in a state of cutting edge development. Sometimes I would need to interface directly with the scientists at MIT to resolve guidance system technical issues.

I would often travel to Massachusetts, Connecticut, and California on business associated with my job (being away sometimes for as long as three months). In all, it was a fantastic experience, actually breath taking. I felt at home as a civilian working on Naval bases because I understood the Navy way (I had spent many years in the active air Navy and I was still a reserve Naval Officer, going for air squadron duty each month and two weeks of every year), some people could not adapt and work well with Navy personnel.

I eventually became GE's Engineering Supervisor at Charleston, my group was responsible for everything technical associated with GE's role at the missile facility, including reliability reporting and special investigations, aforementioned statistical missile accuracy reports, training classes for our local engineers, technical requirements for new buildings and a vast amount of test and calibration equipment (and also for interfacing with other contractors who built the rest of the missile hardware). GE had two other groups of personnel at the base; one administrative group to help the Navy with logistics; and a technical group to melt-in with Civil Service and Navy people who were in long term training to eventually take over the test/calibration functions at the inner base.

While I worked at Charleston, the overall A1 Polaris system underwent 2 complete re-designs, A2 and A3 (with a smaller, lighter, improved guidance system) to increase the range from 1200 NM to 2500 NM. It then began being supplemented by a bigger and better missile system called Poseidon (God of the deep). Its guidance system actually tracked a distant star to help keep its inertial platform fixed more accurately all during flight. Poseidon was much more awesome and more powerful than Polaris. I worked in the Poseidon engineering program for a while, and then moved to Daytona Beach to embark on another adventure, the Apollo man on the moon project. A previous GE manager had transferred to that program and invited me to work with him in Florida. I'll tell you that Apollo story later.

After I left Charleston, the completely awesome Trident Missile submarines became the next generation, they are in use today. GE also played a role in their deployment. The Trident guidance system is really something!

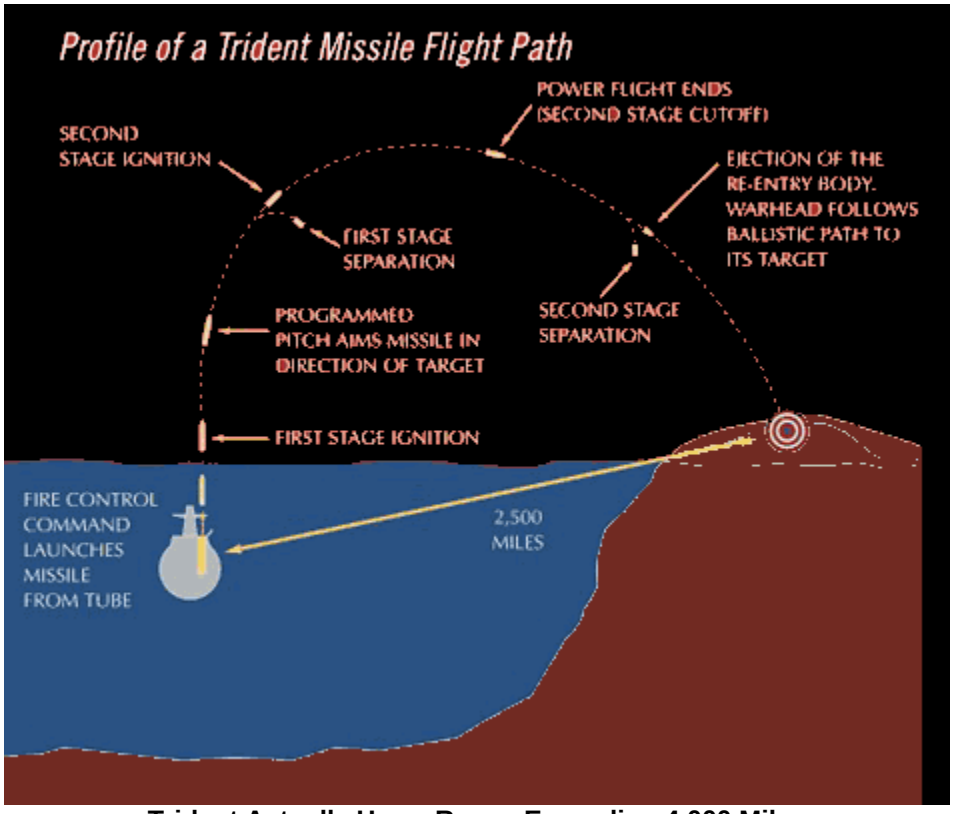
TRIDENT LAUNCH

It is interesting to note that the rocket engine of each of these submarine launched missiles Polaris, Poseidon and Trident is not ignited until it is above the sea surface. The missile is burped out of its submarine launch tube by compressed gasses, flinging it out of the water. Even though this jerks the missile around violently, the guidance system senses and records all movement and keeps its inertial platform fixed. Wow!

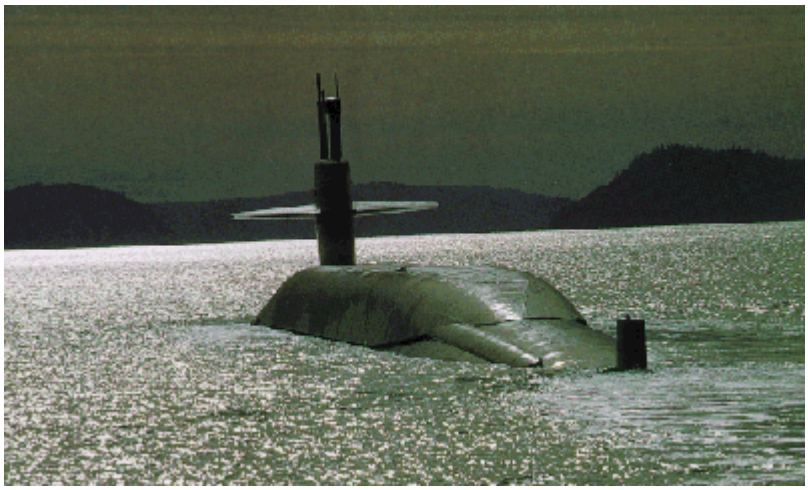
Polaris Missile Being Launched At Sea

As soon as we felt reasonably confident, we fired a tactical Polaris missile from the submerged SSBN Ethan Allen to a location 1700 miles away in the Pacific; it carried a live nuclear warhead that exploded exactly on target. This proved that the entire system worked well and it gave the USA a giant advantage in the cold war with Russia.

Polaris was an absolutely astonishing engineering accomplishment. Its progress was based on just in time technical developments. It all came together miraculously as if a divine hand were guiding it. Then Polaris set the stage for advancements to the Poseidon and Trident missile systems. I was there near the beginning phases of its development; it was an awesome fast moving adventure. It had top priority in expenditures for defense of the United States. Success of the Polaris program was due mainly to the managerial leadership of Admiral William Raborn and the nation's greatest uniformed scientist, Captain (later Admiral) Levering Smith. When the first successful Polaris was launched from the submerged SSBN George Washington, Raborn sent Smith a photograph of the rising A1 missile with his personal greetings written on the picture. After Admiral Smith died, that picture was sent to me by the manager of Smith's estate.



Trident Actually Has a Range Exceeding 4,000 Miles



A Ballistic Missile Submarine

========== POST SCRIPT==========

After we had just loaded the first Polaris submarine with 16 missiles, my colleague said, “Charlie; I know that you realize the omnipotent power of the weapon system that we have turned loose in the world. How can we justify having done such a thing?” I could only answer that I had genuine faith that my Government would never use that awesome power except as a deterrent, or as a weapon of last resort. Being a Naval Officer ready reserve at the time and knowing the men who manned these submarines, I also felt that I could trust them completely.

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