Historian's Corner

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In 1957, I was working my dream job at Ford Motor Company Engineering in Dearborn, Michigan. What could be better than being in the Experimental Engine Section of a major automotive concern for a hot-rod kid? However, I was concerned about the way the blight was spreading in Detroit. When I received an offer from the Glenn L. Martin Company in Colorado, since my wife was a Colorado girl and I loved the outdoors and mountains, I couldn't resist, so along with our one year old daughter, we moved to Denver. I had no idea what an exciting career was in store for me.

Initially, I did not understand just what a Titan was to be and with no aerospace experience, it was a great challenge to change from automotive research and engineering to this new profession. I think the only reason they offered me a position was that when asked if I had ever handled or worked with high pressure gas or cryogenics, I said my welding outfit used oxygen at 3000 psig regulated down to a working pressure, and that I had used liquid nitrogen at the Ethyl Corporation Research Lab to condense engine exhaust gas samples for analysis. About all that I knew of rockets was related to Newton's third law of motion. Apparently that was close enough to work as a propellant and pressurization engineer.

After the development of the A-bomb, new weapon delivery methods became a critical requirement for the United States. In 1955, the Cold War was in full swing and President Eisenhower announced that a Massive Retaliation (MAD) policy using ICBMs was the answer to Soviet aggressiveness. In September 1955, the Glenn L. Martin Company was declared the winner of the competition to develop an alternative to the Atlas ICBM. Things moved slowly in the next year or so with analysis, planning, and starting of the inland Martin Denver facility required as a part of the award decision. This attitude changed rapidly following the launch of Sputnik on 4 October 1957.

The Titan I program was organized such that several different "configuration lots of vehicles" were planned since decisions on necessary system capability were not firm and a large amount of critical equipment was not yet in a state of readiness. As a result, the vehicles of each lot encompassed the systems that were ready in order to keep the program moving forward and the following lots were to introduce other elements as they became available. This meant that each lot of vehicles had a separate set of engineering and there would be considerable differences between lots. Some seemingly simple changes between lots resulted in costly difficulties later on.

The Lot-A vehicles were two stage stacked vehicles, but were intended to fire only the St I engines for static test and flight, with no stage separation. The St II tanks were to be filled with water. Subsequent Titan I lots with added new components and subsystems as they became available, were to separate stage II at stage I burnout and fly to the prescribed target range.

The Denver test stands were far from being ready to test anything for most of my first year there and they did not even have an office for the small crew that was to eventually run the test stands. Initially, we were in the Cold Flow Lab with no office space and no real work assignments. Finally they brought in a semi-trailer with a small propane heater at the site of D-1. Only twice did I see the man that hired me, or any other supervisor, for several months. We spent our time observing the test stand's construction and learning what the ground facility consisted of. We also attended some Titan flight system courses that were offered at Ft. Logan, and by hanging around final assembly in the factory, we began to learn what a Titan was. The engine compartment was an array of pipes, tubes, and wires.

Photo 1. Titan I Rocket Engines

Stand activation was difficult in that equipment to deal with the high pressures, the containment of 5500 psi helium, and the temperatures associated with Liquid Oxygen (LOX), was not available. The valve shop did a wonderful job of adapting water and steam valves and the like to function under these environments. The construction workers were not accustomed to the rigid cleanliness requirements and many things had to be redone, reassembled, and retested. Most construction workers were not familiar with Mil Specs and often made inappropriate interpretations of their meaning.

In 1958, the first firing was scheduled at D-1. The test article was a set of steel "Battleship" tanks with rocket engines attached, built to prove out the facility and the propulsion system. I had been assigned to Stand D-2 that was behind D-1 in the schedule, but we kept up with the planning for the first firing on D-1. Schedule pressure became so critical they decided to press forward with two twelve hour shifts, seven days a week on D-1, and since they had only a single crew, some of us on D-2 were drafted to form the second shift. I had become familiar with the water system on D-2 and was assigned to operate the water console if the firing happened to occur on our shift. It did in about three days. Dick Lea was in charge and Les Sullivan was the Test Conductor.

The primary function of the water console was to establish the 300 psi deflector plate water flow that protected the plate from the stage I engine exhaust. The system was comprised of a thirty six inch water main coming from the storage tank on the hill, with flow controlled by a huge motor driven valve behind the plate. We had done one trial deflector plate flow on D-2 that involved opening the valve to a point that flow "looked OK" and closing the valve after engine shutdown time. On D-2, we incorporated the opening of the deflector plate water valve into the operational sequence controlled by the Master Operation Controller that controlled the countdown and firing. The other function of the water console was fire control. There were water nozzles everywhere including a system called Engine Deluge, along with a CO2 gas system. We didn't have a detailed written water console procedure and no specific pre-firing verbal instructions as to operations.

At Fire Switch 1, the TV monitor turned a brilliant white-yellow and it was obvious that we had an engine explosion and an ongoing engine compartment fire. Without waiting for a command from the test conductor, I flipped on the Engine Deluge system and it immediately snuffed out the fire. We had never talked about what to do in a mishap. A week later we had new engines and I again found myself on the water console for the firing which went off without a hitch. It was a great day.

On subsequent D-1 firings, I worked as the propellant and pressurization lead engineer and we loaded propellants directly from the transportation trucks into the vehicle tanks since the ground equipment was not yet complete and the schedule demanded we move forward. This was a very scary situation with six inch flexible LOX lines manually connected to the vehicle and lots of oxygen vapor around.

On D-2, we received the first Lot-A flight-type vehicle. Strangely enough, the second Stage would not mate to Stage I and the interface required redesign. Howard Bolton, as the initial D-2 Test Conductor, had prepared a system level firing procedure and we went through many simulated countdowns following it. Subsystem procedures were still being developed at that time. The subsystems to be tested were essentially the tankage and propulsion subsystem, the propellant loading and pressurization subsystems, electrical power, flight controls, and hydraulic subsystems.

It was only a few days until our first mishap. In a propellant loading exercise, the engineer successfully loaded both RP-1 and LOX, but on unloading the RP-1, forgot to open the tank vent valves. This resulted in the first caved-in tank dome that was experienced, only to be followed by one on D-4, and another in the transportation flight of a lot B missile to the Cape. In each subsequent case, the procedures were clear, but not properly followed. Later we modified the procedures to require the tanks to be pressurized when unloading propellants.

Much credit has to go to the operating crews, engineers, and technicians at the test stands. I became the test conductor at age twenty eight and most of my engineers were younger than I. Although several of the engineers and technicians had missile test experience from other venues such as White Sands and Edwards Air Force Base, generally on much smaller systems, but most did not. To put it mildly, we were all scared stiff at every propellant loading and firing. The majority of the test crew was new to aerospace engineering and test, having never dealt with the magnitude of the system and the severity of the environments. Some people had come from a program called the Snark at the Cape. The program was having severe difficulties with many flight articles landing just off the shore and the men often spoke of the "Snark Infested Waters". However, their experience was extremely valuable. Many times we had problems we just were not sure how to handle, and when we asked engineering folks what to do, they sometimes said they didn't know either. "Use your best judgment" was often the answer.

Vehicle subsystem elements were a major problem for the first of the Lot-A vehicles. The Three Axis Reference System (TARS) was especially difficult in that it failed over and over in pre-firing checkouts. Down it would go to the lab called the Gyro Barn, an old pioneer building updated for use until a better facility could be constructed. Imagine working on gyroscopes in a barn. Other subsystems were also difficult to get into a firing condition, and we continually related to a "Random Success" when all subsystems checked out as ready to go. Many components, valves and black boxes, were brand new designs, supplied by companies that were also new to aerospace environments and conditions, both for ground equipment and flight hardware. Many, many, little issues arose that the designers couldn't have known of during the design phase caused delays while design engineers developed solutions. Many were subsystem inter-relationship issues that wouldn't be detected until you were in an operating mode.

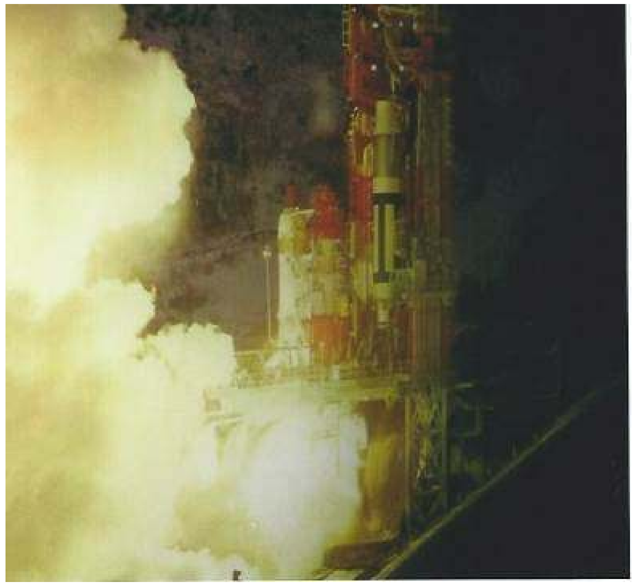

Photo 2. D-2 Static Firing

One example was experienced when attempting to pressurize the propellant tanks late in the countdown to fire the first flight vehicle. Cold flow called and asked what we were doing, since we were draining their helium supply at a terrible rate. We learned that a ground facility pressure relief valve was open and venting. As it turned out, the large dome loaded regulator that reduced the helium pressure from the 5500 psi supplied from cold flow, could not react fast enough and a high pressure surge hit a ground system relief valve. Both of these units were never designed to handle helium, which due to its atomic molecule and low density would move through a pipe at very high speed. The solution was to add another regulator in series behind the first.

Another interesting problem was that Titan Stage I with two engine subassemblies had two large standpipes to supply liquid oxygen through conduits in the RP-1 tanks below to each rocket engine subassembly. As the LOX warmed up in the engine compartment, some boiled off creating a bubble of gaseous oxygen. When this bubble grew large enough, it would rumble up the pipe, sounding like the greatest burp you ever heard. Of course this caused a pressure spike and mechanical stress, so it had to be stopped. An immediate fix that allowed us to proceed was to inject a low flow of helium into the bottom of the lines at the engines that caused small bubbles to flow continuously and not allow the large bubbles to form. Somewhat later, engineering came up with a brilliant solution. Since there were two identical standpipes, they made an inter-connection between the two in the engine compartment. One of the lines was insulated from the LOX tank all the way down to the engine; the other was left exposed to the atmosphere. The result was that the insulated pipe stayed colder than the uninsulated one and a continuous convective flow was established. Problem solved.

In addition to the component reliability problems, we had our share of dumb luck issues. We prepared for the first firing and had an excellent pre-firing checkout on all systems. The next step was to close up all equipment racks and have Quality Control seal them. Shortly after starting the one-hour count down, the propulsion system aborted. Well, no firing that day. The next day in checking the system everything checked out OK. All right, let's fire this thing. We got to the same point as the day before, and propulsion aborted. Again, everything checked out during troubleshooting. When looking at the terminal board in the propulsion equipment rack, we happened to notice that the involved pin on the terminal board protruded slightly more than the others in the rack. We looked at the rack door and saw that a stiffener was built into it that aligned with the location of the long terminal when the door was closed. Then we saw a little burn spot on the door and knew the answer. The door was always open during pre-firing checkouts and always closed and sealed for the firings. Moving the connection to another pin solved the problem and we had a good firing.

For the first firing, the main outlet valve at the LOX storage tank at the pad refused to open. I was Test Conductor at the time and went down to the pad to see what the problem was. Finally I got a non-sparking crow bar about six feet long and gently nudged the valve gate from the locked position and the operator cylinder opened the valve normally. Later we found that the installation contractor had piped in the nitrogen to the operating cylinder from the 5500 psi line rather than the 150 psi service line. Since the valve had a large tapered gate valve, it was driven into the tapered seat and locked up. Simple fix required. Actually, after the first vehicle, things got a lot better, we became more familiar with the systems and four Lot-A birds were successfully fired.

The first Titan ICBM was launched on 6 February 1959. It was Lot A number 3, and our Denver test crew was watching the launch on our consoles. When it lifted off the room exploded in cheers as the vehicle we worked so hard to test and prepare, successfully flew, burning a nice round hole in the cloud cover.

Lot B suffered from a series of mishaps. It was to be the first vehicle flown with stage II separation and burn. The program was in a tenuous state since only four Lot A vehicles had flown, burning only stage I engines, with no stage separation. At the time there were no complete Lot B vehicles ready to fly and a decision was made to marry an existing stage I of one vehicle to an existing stage II of another to prove the staging process and start a rocket engine in the vacuum of space. Many engineering changes existed between these two vehicles and the Project Directive defining the changes to make them compatible was about two inches thick. Rumor had it that continuation of the entire Titan Program rested on the success of this patched together vehicle, called B7A. The vehicle was launched, stage I burned successfully and shut down, stage II separated, and the engines ignited and burned as planned. This was the first ever successful two stage rocket vehicle flight, the first in-flight stage separation, and the first rocket engine start in space. There was no stopping of Titan from then on.

Photo 3. Titan I Launch

Many successful R&D firings were conducted at the Denver Test Stands and the many lessons learned were applied to subsequent space systems. Items such as the criticality of millisecond timing errors, how to deal with the extreme environments of temperature, pressures, vibration, shock, EMC, and acoustics were passed directly to Titan II leading to its great success. Vehicle lots C, G, J, and M followed with many more successful static firings and flights. Another issue critical to the entire U.S. retaliatory capability was to assure ICBM fleet survivability following a first strike by an adversary. This was to be accomplished by keeping the missiles in the silo until the moment of launch and to fly directly out of the silo. Titan I Lot M proved this to be possible with seven successful flights launched from the Silo Launch Test Facility at Vandenberg AFB. Titan I held the fort until the hardened, more powerful Titan II was fully operational.