Historian’s Corner

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Interesting Events and Lessons Learned in Early Aerospace Activities
By Ray Ziehm

Aerospace technology has presented American Industry with many new challenges and opportunities that most engineers, designers, and programmers had never experienced in other fields of science, engineering, and manufacturing. This is most evident in the levels of environmental issues, mechanical loads, dynamics, and of course, orbital mechanics. Temperatures, pressures, vibration, shock, radiation, and timing requirements far exceeded levels encountered by most organizations. Essentially no advanced education in the realm of aerospace was available and Aeronautical Engineering was the closest to what would be required, even though it was still a long way from adequate for aerospace. As has always been done, engineers and managers relied upon the basic laws of physics to adapt to the almost unbelievable numbers to be dealt with.

In October 1957, the Soviet Union launched the Sputnik I satellite and Americans were taken by surprise. The military immediately recognized the potential of the event and it was a wake-up call for the country in general. Sputnik I was a crude, simple vehicle that achieved only a three month orbital life and carried no scientific instrumentation, but it did beep. I got up at four in the morning on the first two days and actually saw the blinking reflection of the sun on the tumbling vehicle. Americans were stunned and felt we had already lost an unannounced, unrecognized space race. Actually, it only took a few weeks until January 31, 1958, when an American satellite with more capability was launched into orbit. This launch was the Explorer I, placed into orbit by a modified Jupiter I launch vehicle carrying an instrument complement that made an astounding scientific discovery, the presence of the Van Allen Radiation belt. The size of the belt was confirmed by Explorer III in March 1958. This discovery would place restrictions on the space industry for all subsequent manned and unmanned space launches and operations. Both Sputnik and Explorer launch vehicles were derivatives of the German V-2 rockets used in World War II. Explorer I ceased communications May 23, 1958, and re-entered the atmosphere in March 1970.

In no way did the Sputnik launch show that America was behind in space exploration, although the media and many others felt that it did. The U.S. Navy Vanguard satellite was well along in development and was much more sophisticated, both in the launch vehicle and in its instrumentation, far ahead of the Soviets. The instrument complement included cosmic ray detection, temperature sensors, thermal control surfaces, and micrometeoroid detectors. The U.S. Navy three-stage Vanguard I satellite was launched March 17, 1958, and placed into a stable orbit that was estimated to last two hundred and forty years, surpassing Sputnik a bit. Today the Vanguard I spacecraft is the longest man-made article orbiting the Earth. Indeed, the Soviets were there first, but their scientific accomplishments were almost insignificant.

As the American industry came up to speed in sufficient numbers and investigated some of the issues to be satisfied, many new discoveries were made and sometimes surprising results were found. One of the early discoveries to be made was not really new or surprising, but no-one had thought of it. Isaac Newton taught us in his first law that static or moving bodies will remain in their current state until acted upon by an outside force. This was applied to orbiting satellites and often implemented to control satellite attitude through spinning them to establish a momentum vector that would never change. Explorer I was a long vehicle relative to its diameter, spun up around its long axis in a desired attitude, and was expected to remain so. Somewhat later, the vehicle was found to be spinning with a coning movement, which surprised everyone.

At that time I was spacecraft lead design engineer of possibly the first funded Martin Denver study of a mission dedicated Earth orbiting satellite. We were investigating whether the vehicle should be spin stabilized or three axis stabilized by active thrusters to best satisfy mission objectives. Our Attitude Control Engineer was in contact with government engineers in the Aerospace Corporation, who were investigating the issue. They knew that the vehicle was initially spun about a non-principle axis and soon realized that if any energy was lost from the system, conservation of momentum would cause the vehicle to nutate such that it would eventually spin about another lower energy, but momentum conserved axis, namely tumbling end-over-end. They also concluded that any energy lost, such as a wire bundle or structural flexing or moving within the vehicle, could be the cause. The physicists understood the issue and it soon became known that moment of inertia ratios of spin stabilized space vehicles had to be carefully controlled and that they could be used to stabilize the vehicle attitude or to cause a spinning vehicle to precess to a new spin axis as the mission required, but no-one had really thought about it till it occurred. The laws of physics prevail.

Another, almost comical, experience was solving the helium line contamination problem on the Denver Static Firing Test Stands. When Stand D-2 was first activated, we were not able to pass the particulate contamination requirements of the Mil Spec. The entire high pressure line from Cold Flow to the stand was torn out, taken to the factory, and re-cleaned with an acid bath, and whatever, and reinstalled, it still did not pass. One of our test engineers, Bob Munden, who had missile firing experience at Edwards AFB and Muroc, said he knew how to fix it. He had the factory build a hollow cylinder about three feet long, and about ten inches in diameter with a two inch wall thickness with fittings on each end to fit the supply pipes. He then bought several boxes of Kotex and carefully packed them into the hollow center of the tube. The system then passed with flying colors, and similar filters were installed on all stands.

Amazing things were also happening in the factory. I-beam shaped ring frames were being bent to fit into a ten foot diameter to stabilize the Titan propellant tanks. Straight I-beam sections were fed into a stretch forming machine and pulled through a set of dies and came out with a perfect five foot radius. It was a pleasure to watch this machine in action and I cannot imagine the cost and difficulty in forming these parts in any other way. The tank welding fixture was another really super concept. It held pre-welded barrel sections in alignment and automatically welded them with a beautiful pattern as it rotated. The industry had said that ASM 2014, a very strong aluminum alloy, was not weldable, but the designers needed its high strength, and the welding engineers derived a way to successfully do it that survives today.

Some advantageous happenings have been learned in the area of orbital mechanics. One is related to affecting a circular orbit maneuver to bring a satellite on orbit into a position that will allow a rendezvous with another in the same orbit, but ahead in position. At first one might think that if you are trying to catch up with something ahead of you, the thing to do is to speed up by a thruster burn. Actually that will place you in an elliptical orbit with a higher apoapsis that will have a longer period and place you further behind. The proper thing to do is to thrust against the orbital velocity path which will change your orbit to elliptical with a lower periapsis that will have a shorter period of revolution and bring you closer to the orbiting target. When you have caught up with the target, a second thrusting burn is required to recircularize your orbit and you will have achieved a near rendezvous with the target vehicle. Of course the mission analysis folks have always been aware of this, but at first glance to the neophyte, it just seems wrong to go backwards to get ahead.

Another interesting phenomenon is the orbital swing-by maneuver used to support interplanetary missions by adding velocity to a space vehicle as it flies by a major orbiting body, normally another planet. The passing spacecraft is guided to closely fly by the larger body in a carefully designed path that exposes it to the larger body's gravitational field. The spacecraft is pulled toward the planet by the planet's gravity, but also is affected by the fact that the flyby mechanics are such that the desired spacecraft flight path is aligned with the planets velocity vector which is added to the spacecraft. As the spacecraft passes the planet and begins to move away, it now must sacrifice only the velocity gained from the gravitational pull when approaching the planet. This maneuver can add thousands of miles per hour velocity in what seems to be a free gift, but there is no free lunch in physics. The energy gained by the spacecraft is subtracted from the energy of the planet, but due to the huge difference in the mass of the two bodies, the change to the planets orbit is so small it cannot even be measured. This maneuver requires the entire mission to be programmed around this opportunity which places serious launch window constraints upon the mission. One of our mission analysis engineers, Gerald Hollenbeck, delivered some AIAA and AAS technical Papers in 1975 describing this maneuver, and his mission plan for outer planet missions was implemented on the Cassini Spacecraft mission. He was awarded the Dirk Brower Award by JPL for his effort.

Many other simple things that have sufficed for years have proven to be inadequate in space. One excellent example is the use of relays in electrical circuits. Relays often have multiple sets of switch contacts, all assumed to operate at the same time. In reality, many events need to be controlled to the mili-second in many space systems and sometimes the contacts within a relay have been found to open or close at varied times. This problem has been called a relay race.

Another issue with the use of relays in space is that the contact points in a relay are mechanical devices that can react to environmental shock and vibration by opening or closing a circuit at an inopportune time. One Titan ICBM was destroyed immediately following launch due to the orientation of the destruct system relays being such that the mechanical switch parts reacted to a shock wave from the firing of the launch bolt ordnance traveling up the structure, jolting the relay which closed the contacts, and firing the destruct system ordnance that destroyed the vehicle. Previously the relays were oriented in a different attitude; however the decision was made generally to replace relays with motor driven switches.

It's recently been said that the last fifty years have produced more technological advances than that of all previous history. Just think, we have seen it happen and even been a part of it.