50 Years in Aerospace, with 40 Years at Aerospace

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Prologue

The reason that I have the fortune of celebrating 40 years at The Aerospace Corporation and writing this memoir is: The Laser. I was ten years old when it was invented in 1960 by Theodore Maiman at Hughes Research Laboratory in Malibu. Yet the roots of the laser go back to theoretical research on the interaction of light and matter conducted by Albert Einstein and published in 1917. Building on the work of Max Planck [who theorized that light was quantized into packets whose energy (E) is proportional to the frequency (ν) of the light: ($E=h\nu$); the constant of proportionality h is known as Planck's constant], Einstein called these quanta "photons," and knew that they had the properties of both particles and waves. In his 1917 paper (in order to reconcile theoretical predictions with experimental results), Einstein reasoned that the existing concepts of spontaneous emission of light (in which an excited atom gives off a photon and relaxes to a lower energy level) and absorption of light (in which a photon can strike a relaxed atom and raise it into an excited state) needed a third phenomenon, which he named "Stimulated Emission" (in which a photon of the proper energy strikes an excited atom and makes the atom emit another identical photon in lock-step with the incoming photon). The practical application of stimulated emission would wait some 43 years when a device was invented that could generate an intense beam of coherent light, namely the Laser (Light Amplification by Stimulated Emission of Radiation).

Enrolling at The University of California at San Diego in 1967, I chose the department of Aerospace and Mechanical Engineering Sciences (AMES) for my major. One of the areas of research at that department was the heating of space vehicles upon re-entry into a planetary atmosphere. Since a great deal of the heating was by radiative transfer of energy from the compressed gasses in front of the re-entry vehicle, Einstein's equations for stimulated and spontaneous emission plus absorption were key parts of the theoretical research into re-entry physics. Since much of the AMES faculty were well versed in these equations and the same equations explain the operation of the Laser, some of the faculty were conducting Laser research as well. As an undergraduate laboratory assistant, I helped several graduate students building laser experiments and collecting data.

Upon my graduation with a Bachelor's degree (signed by Governor Jerald Brown) and with the successful thesis defenses of my graduate student colleagues, their advisor, Professor S. S. Penner asked me to be his new graduate student. I gleefully accepted, although I was aware that his mentorship would involve not only countless hours of laboratory research but intensive study of the theories that explain the experimental results. Six years later I successfully defended my PhD thesis "Laser Diagnostic Measurements: I. Particle Size Determination Using the Photocurrent Power Spectrum of Laser Radiation Scattered from Moving, Polydisperse Particle Systems, and II. Anomalous Transparency in Nitrosyl Chloride," and got another diploma, this time signed by Governor Ronald Reagan. Professor Penner then told me I had to leave the paradise of UCSD in La Jolla and get a JOB. That was the end of my ten years of education in Aerospace followed by the acceptance of a JOB offer from The Aerospace Corporation.

The Laboratory Years

My first day at The Aerospace Corporation was 18 April 1977. I was hired into the Aerophysics Laboratory to conduct fluid dynamics research using a laser-Doppler velocimeter. Jimmy Carter was President and there was an "Energy Crisis." The fluid dynamics research had to do with coal combustion (reference page 5 of the February 1, 1978 ORBITER article, whose first paragraph states "the fact that the country is undergoing an energy crisis is incontrovertible," and ironically states as an afterthought "also working on the project is Dr. Jay Bernard," even though the experiment was <u>mine</u>).

When Ronnie Reagan became President, all of a sudden there was no energy crisis and we needed particle-beam weapons, laser weapons, and kinetic energy weapons for his Star Wars project. The continuous-wave hydrogen-fluorine chemical laser was invented in the Aerophysics Laboratory in 1970 (in part by Henry Bixler) and was the focus of a great deal of research for the laser weapon (indeed, by the late 1980's, the technology had advanced to the point that TRW assembled a 2-million watt HF laser at White Sands and was shooting wire-guided missiles out of the sky). Our work involved using a ring laser resonator to extract the maximum power out of the gain medium. Tim Bixler (Henry's son) and I have a patent of a special mirror that would ensure that the beam was uni-directional. The Aerophysics Laboratory was subsequently disbanded and I became a part of the Lasers & Photonics Laboratory. In total, I worked for the ETG Laboratories for 15 years. As an aside, even though a laser weapon was never fielded (and even though I didn't always agree with his politics), it is my contention that Ronald Reagan's foresight and bluster collapsed the Soviet Union and brought down the Berlin Wall in part due to the formidable hardware developed for his Star Wars endeavor (including Aerospace's chemical laser).

Launch Vehicles

In the early 1990's, General Dynamics in San Diego decided to upgrade their Atlas IIAS Inertial Navigation Unit (INU) with more accurate gyroscopes, replacing mechanical spinning-mass gyros with ring-laser gyroscopes. When the laser gyros were exhibiting anomalous behavior, Don Huang of the Medium Launch Vehicle (MLV) Program Office looked through the Matrix Organization charts and found that I had worked with ring lasers. Some of my Laboratory colleagues and I assisted in the investigation; I went to Honeywell in Clearwater Florida to look at the test results, and we ended up purchasing one of their gyros to conduct investigations in the Guidance & Controls Laboratory in D8. Finding the INU development and the anomaly investigation fascinating, I enrolled in the Rotation Program with MLV. When the problem was solved and the new INU was ready for its first flight, I was invited to be on console at Cape Canaveral. The successful launch was so thrilling to me that I never rotated back to the Lab. At nearly the same time as the INU development, McDonnell-Douglas decided to transition to ring-laser gyros for their Delta II Redundant Inertial Flight Control Assembly (RIFCA). I participated in that development and the resolution of several interesting anomalies during qualification, and saw the first RIFCA flight in December 1995. 142 successful RIFCA flights later, there will be only two more flights (for NASA on Delta II vehicles) of that unit until it is retired.

When one counts the 104 successful flights of the INU, 142 successful flights of RIFCA, some 60 Fault-Tolerant INU flights and two flights of its successor (INCA), I have participated in over 300 missions navigated with the help of ring-laser gyroscopes. With three gyros in the INU, six gyros in RIFCA and five gyros in the FTINU & INCA, that adds up to a number approaching 1500 ring-laser gyros launched without a failure.

Although the end result is often glamorous, this Launch Vehicle endeavor is also fraught with toil, sweat, and tears. For example, in 1997 I was in Hangar AE at Cape Canaveral to monitor the launch of the GPS IIR-1 Delta II mission. For some reason, Tony Inverso and I decided to run outside at T – 0 to watch the liftoff first-hand. The spectacle of light and sound and several hundred thousand pounds of hardware thrusting itself into the sky was as spectacular as always, but then disaster struck. Roughly one-half mile above the pad, a solid rocket motor casing burned through and ignited the RP-1 / oxygen mixture it was strapped to. Whereas most fireworks soar a few hundred yards and explode into a 50-yard ball of fire, this was a half-mile high and a quarter-mile ball of fire. I was devastated. Fortunately, Tony had lived through a launch failure or two and comforted me that we would figure it out and get back into the sky.

It has been interesting to see General Dynamics in San Diego (the original developer of the Atlas vehicle) and McDonnell-Douglas in Huntington Beach (Delta) merge into United Launch Alliance in Denver and graduate to Atlas V and Delta IV, subsequently sowing the seeds for a new workhorse, Vulcan. The rise of SpaceX has also been phenomenal, changing the landscape of this business forever. NASA is as busy as ever, fostering not only exploration of our solar system and deep space, but encouraging small businesses to make launching nano-satellites into orbit much more affordable. The future promises to be at least as exciting as the past.