Random Memories of an Aerospace Career
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The Graduate

When you've graduated from college not once but twice, including graduate school, it's time to go to work. I followed this conventional wisdom as far as three interviews in the aerospace industry, including one at the Systems Division of the Avco Corporation in Wilmington, MA. In each meeting I was advised to continue my education towards a doctorate if at all possible, but at Avco, Dr. Adrian Pallone said it in his usual blunt manner: "do it now, or you'll never do it." I followed Adrian's advice, since it beat making a bigger decision to select a company, and the alternative was a very easy choice.

I had left NYU in 1958 vowing not to return to the original but now out-of-date Guggenheim School of Aeronautics. In the year I was at MIT getting a Masters degree, a visionary dean named Lee Arnold took over, and also vowed to make major changes in the faculty, curriculum, and research program. Part of his plan involved bringing back graduates like me, and he made the offer package too good to turn down. Unfortunately, Lee was more visionary than I realized, and he really couldn't deliver on some of his dreams. One of these was a job, which was critically important as I planned on getting married at the end of the summer.

My former summer employer and professor (and brief partner in the NYRA project), Gordon Strom, came to my rescue when I told him about the problem, and I was rehired by the low speed wind tunnel project until something better came along. It was an exciting and depressing summer at the same time. I prepared for a wedding, found an apartment, took graduate courses and worked on experimental aerodynamics projects (one of which involved a demonstration to the great aerodynamicist, Theodore von Karman, who was literally put to sleep by the demonstration we had prepared…but he was over eighty and there were no young women around to keep him awake).

The problem I worked on for my doctoral thesis involved a theory and an experiment, the two hopefully agreeing to some degree before my time and appointment as a research assistant ran out (Lee Arnold finally came through, by selling the Air Force another visionary scheme for neutralizing ballistic missiles, more than twenty years before Ronald Reagan announced the Strategic Defense Initiative). It involved high power microwave beams and unsteady aerodynamics, both of which Arnold had some familiarity with, but which had little chance of contributing to national missile defense). The experiments worked well enough, and produced some interesting photographs and data to analyze. The theory seemed incredibly straightforward as it was based on a famous paper on hydrodynamic instability by the equally famous Prof. Goertler of

Freiburg University. When Prof. Goertler confirmed that no one else had previously worked on this problem, I was elated, and rapidly carried out the analysis.

An obligation of the Air Force contract was a report at a workshop on missile defense at the Rome Air Force Base in upstate New York. This was my first experience briefing a customer, but Lee Arnold did not seem to be worried, and focused on cocktails and dinner the night before. I must have given a pretty good talk on my incomplete project work, because Dr. Arnold Goldburg of the Avco Everett Research Laboratory, who was in the audience, invited me on the spot to repeat the seminar in a few months at Avco, and consider coming there to work for him. The only preliminary requirement he explained, would be an interview with Dr. Bennett Kivel, a renowned atomic physicist and head of Avco's ballistic missile defense programs, and Dr. Arthur Kantrowitz, the founding Director of AERL and a world famous aerodynamicist (Arthur's thesis adviser was none other than Edward Teller, whom I encountered later in my career at AERL).

Both Kivel and Kantrowitz were in New York to attend a meeting of the American Physical Society, and they agreed to meet with me at the hotel. The questioning was all from Kantrowitz, who asked how I could hope to derive three-dimensional, vortical instabilities in my highly simplified model flowfield when the basic flow had no rotation to it. I quickly realized the critical omission and said that I was working on that problem as well,and what I had shown them was only a "warm-up," although I knew that it was probably irrelevant to the "real" problem. Needless to say, by the time they heard the story at AERL I had completed the full problem and had some results to compare to my experimental data. I got the job offer and finished my thesis, but I owed a lot to Arthur Kantrowitz. The lesson was clear: work only for people who are a lot smarter than you.

Physical Sciences Inc

The Avco Everett Research Laboratory had employed me for almost ten years when, in early 1973, something seemed not quite right. The day I was promoted to the position of Vice President for Applied Technology, with direct responsibility for almost fifty scientists, engineers, and administrative personnel, I came home feeling sick. I was just rewarded with a job I didn't seek, in a company in which I no longer had any faith. The "Lab" I had joined ten years earlier had changed dramatically. Innovative applied research carried out by a small group of brilliant industrial scientists had been replaced by "mega-projects" that demanded large investment in capital equipment, engineering, and project management. The people I had joined or hired began to leave voluntarily in significant numbers, an almost unheard of phenomenon in a laboratory that believed in the survival of the fittest. It suddenly dawned on me that I should leave as well, and try to re-establish the Lab that I once knew.

I had formed a close working relationship with Dr. Kurt Wray, a physical chemist who chaired the Atomic Physics Committee when I had the Aerophysics Committee chair, and who also led a major government project in the field of re-entry physics. I spontaneously suggested to Kurt that we have dinner one night to discuss the status of the

Lab, and what we might do about it. We met at Polcari's restaurant in Boston's North End, had our spaghetti and meatballs and a beer, and got to business. Within the first few minutes I suggested that the best path was away from Avco and towards a new, independent company that would have the best of Avco's traditions, but with a greater diversity of research interests. We would keep the company small and hire only the very best scientists, and our long-term goal would be to reach one million dollars in annual revenues with a minimum six- month backlog.

Kurt asked what position each of us would have, and I said, "I'll be President, CEO, and Chairman of the Board, and you can be Vice President of Research, a Director, and Treasurer." We would own equal shares of the company, and they would be the controlling class of stock. Kurt asked who we would hire, and I suggested turning over the placemat on the table (it was a very elegant restaurant) and making a list of whom we would like to have in the near-term. There were about two dozen names on the list when we finished, including three of our colleagues who we needed to speak with immediately. Without a second thought about how we would finance this company or support ourselves in the coming months, we also agreed to resign our positions and get started with recruiting.

The day I resigned I came home later than usual, and after dinner went into the children's bedrooms to say goodnight. Laura and Kathy were still awake, but John and Neil, then three, were not. I can clearly recall sitting next to their bunk beds asking myself "what have I done to them? " By morning I was ready to go, and let the people on our "A list" know that we were leaving to start a new enterprise. If they wanted to hear about our plans they would have to meet with us at my home on the first of April. Everyone we invited wondered if this was the beginning of a great adventure or a really complex April Fool's joke. By the day of the meeting, which all but one person attended, our top three colleagues had "signed on" and by the end of the day another five had asked to come with us. Within a month, with the addition of two more senior scientists and a secretary, we were up to thirteen. The fact that we had zero business and had written no proposals did not seem to matter. We were free!

Combining our savings and borrowings, we managed to scrape together about ninety thousand dollars, enough to pay our salaries and rent for a few months. We had been borrowing a spare office at our attorney's facility for the first month, but when we reached five and the coffee cups began to pile up, we were invited to find a new home. Even with some small consulting jobs, we were rapidly running out of funds by summer, and we cut our salaries in half to make the remaining capital last as long as possible. The breakthrough came in late September, when I received a phone call from the Air Force Office of Scientific Research, informing us that a contract for $130,000 was on the way. I leaned back in my lawn chair, put my feet up on the aluminum picnic table that served as my desk and said, "sure, we can fit that work into our schedule," and breathed a very large sigh of relief.

With my father-in-law's help, I arranged a line of credit at the Essex County Bank to finance our first contract. My business plan, which consisted of a mission statement, a

one-page cash flow projection (my first ever) and a list of personnel, was hand-typed on three pieces of my best bond paper. I walked out with a credit line sufficient to support three months cash flow, and never looked back. We were in business to stay, and as 1974 arrived we had cause to celebrate, restoring our full salaries with modest raises. Several more former Avco colleagues arrived, and our former director was mollified (we promised to take no more people), although the associate director of AERL held a bit of a grudge until we hired him, too, many years later. Avco Everett Research Laboratory continued to prosper, and survived for another twenty years, but it was never the same institution. Physical Sciences Inc., the name we had chosen on that April Fool's Day in 1973, is now more than twenty-seven years old, with annual revenues of more than $20 million and 130 employees. How did this happen?

I am convinced that we survived and lived happily ever after because we never considered another outcome. Confidence (some call this naiveté, but I disagree), wins over competence every time. Not in the long run, but certainly in the critical start-up phase of a new venture. An important corollary is the ability to learn from mistakes and take strong corrective actions to compensate for incompetence or bad judgment. A sense of humor helps a great deal, and I have always tried to keep things in perspective, even during difficult times. We had our disagreements, of course, but always worked them out for the broader objective of mutual support and business success. We always knew "who was in charge," but also learned to listen to each other. When basic principles conflicted, someone had to leave the organization to maintain a healthy, unified atmosphere. It didn't happen often, but it was still traumatic. Not until PSI grew to more than fifty employees were we able to handle departures without feeling grief or betrayal. It's still a "family" kind of company, and I hope it always will be. We may not be the largest R&D organization in the country, or the fastest growing, but we are certainly one of the best. It's all that Kurt and I set out to do, and more.

Note: Kurt left PSI after eleven years to relocate with his wife Torj, a professional potter, in the wilds of the Maine Coast, but continued to consult for the company for a number of years. He remains a shareholder and friend. Of the "originals," Mike Finson and George Caledonia are still at PSI but only as consultants; George retired last year and Mike will retire this month, leaving me as the last of the founding group. George was my successor as President and CEO, and Mike was Executive Vice President and Chief Technology Officer. We've been together so long that we can (and do) finish each other's sentences. We only hope that the next generation of managers has it so easy.

Origins of a Profession

In 1947, when I was ten, my father took me to a show at the New York Coliseum to see the private aircraft that would soon be in everyone's garage. It wasn't his technical or business background that motivated this trip downtown, but rather a desire to "get in" on a new industry as a smart investor. His involvement in the stock market is another of my earliest recollections, since I picked up the newspapers with the closing prices every

evening for him, and was invited to join him at Weingarten & Co., his broker, to watch the tape and meet his cronies. The boom times of the late forties and early fifties had begun, and the market could only go up, driven by the post-war aviation and electronics industries.

We inspected the Republic Aviation Seabee, a combined land and amphibious takeoff aircraft (with a "pusher" prop) that almost no one could house or afford, and it made a bigger impression on me than I realized at the time. We next visited Republic's airfield in Farmingdale, Long Island, I assumed to get a look at this plane and others in flight. In retrospect, I can only conclude that my dad's interest was in the thrill of seeing new airplanes, rather than discovering an investment secret. I fully shared his interest, and probably decided right there to someday become an aeronautical engineer.

It was only natural for me to build model airplanes on a small table in my room. None of these ever did fly, or at least not on a sustaining basis. A huge towed glider never soared due to a lack of wind or legs, and a gas-powered free-flight model almost always lost power as soon as it attempted a takeoff. Nevertheless, I became totally absorbed in the building of these models, and wonder today if it was the airplane glue that I was sniffing for hours that created the happiness I experienced. Not letting failure stand in my way, I built model after model, and even designed a personal helicopter that *would* fit it anyone's garage. I'm not sure if I enjoyed the "idea" of flight or the craftsmanship involved in trying to achieve it, but it was certainly a romantic and inexpensive alternative to finding a girlfriend.

A highlight of attempting to fly the latest airplane model was the walk to and from the flying field in Van Cortlandt Park, a huge flat grassy place where baseball, soccer and track events were always in progress (and still are). The possible appearance of the latest issue of Model Airplane News at the local bike/model shop on the way just added to the anticipation on a summer afternoon. I can clearly recall even the smell of that shop to this day, and can see the shelves of elaborate balsa wood models that were just waiting for my attention. It was about the best place in the world to be at that time, and I will never forget it.

What is so amazing about all of this? First, my interest in aviation continued for another five to six years until I entered engineering school to actually learn how airplanes fly and how to design them for a living. Second, through all of my undergraduate days I never learned to fly a plane myself, although I came close in an M.I.T. roommate's Cessna 172 at 3,000 feet over New Hampshire, when he turned the controls over to me for a few minutes. Third, I've never had a job in the aerospace industry, and became progressively removed from commercial aviation with each professional degree and work experience.

A career in research and development is not the same, but it became equally rewarding. Moving on to missiles and space before mastering aircraft was just a response to what was happening in the world. Sputnik in 1956, the US space program that followed, all had a profound influence on both my educational choices and professional

plans. I hesitate to think, however, about what the consequences of building model rockets could have been. My early designs, extracted from a few books I really didn't understand in the research library of the New York Public Library, would have possibly killed me if I had ever attempted to test them (I came close, but not as close as the heroes of "*Rocket Boys*," a then recent movie).

In my older years I will probably return to my first love of flight, but this takes time and concentration, and I already have too many hobbies waiting for me. Having a grandchild or two or three is a great motivator, and construction of a model railroad was a recent example of this. The best thing about grandchildren is not, as some say, leaving them to their parents at the end of the day; rather, it is the opportunity to be a kid yourself again, when it doesn't matter what anyone, particularly your own kids, think. Perhaps we're too uptight with marriage, building a career, and the raising of our own children, to really enjoy ourselves. It takes a second childhood to do that!

Going Public

The very words "going public" strike most people as the prerequisite for great wealth. To an entrepreneur, it is the ultimate vindication of a successful business plan, the transfer of ownership from the knowledgeable insiders to the trusting public. If the entrepreneur and his co-owners manage to sell some of their shares in the process, or soon thereafter, it is a mechanism to begin to "cash out" and diversify. For some, however, it is the opportunity to buy a new car, boat or house, and to imagine that they are Masters of the Universe.

Physical Sciences Inc. was nineteen years old when the opportunity to "go public" presented itself. Early in the spring of 1992, a part-time employee of ThermoElectron Corporation, then acting as a consultant to PSI, suggested that the stock market might be receptive to a "new" ThermoElectron. He added that PSI had the right "story" and he knew just the investment banking firm to sell it to the public. Unfortunately, we listened to him and began a several month odyssey in search of status, cash, and individual paper fortunes. The firm was Unterberg Harris, led by "Tommy" Unterberg, whose father had founded C.E. Unterberg Towbin, a highly successful underwriter of many "hot" high technology companies in the 60's and 70's (including ThermoElectron).

When Tommy visited PSI and was asked how difficult it is to "go public," he replied "not as difficult as the care and feeding of fifty scientists." Innocently accepting this vote of confidence in us, we agreed to the four-month schedule that would have us on NASDAQ by the end of May. John Dexheimer, a Managing Director of UH, was assigned to get the job done, and we threw ourselves into drafting a prospectus and due diligence activities, which included detailed review of our legal and financial status. The basic idea behind our proposal to sell fifteen million dollars of new stock to the public was that we had the opportunity to spin out a flock of companies built on PSI technology (which in turn had been developed with federal funding). This thesis followed the Thermo model of spinouts, in which the public money constituted a form of venture capital.

One such spinout, PSI Medical, had already been formed and had a promising minimally invasive treatment for kidney stones in clinical trial. It was projected that we'd come up with a "PSI Medical a year," and actually identified the next six candidates. This was the "sex" part of the "sex and violence" that our consultant insisted we highlight in our prospectus. I never did find out what the "violence" part was, other than what we almost did to our venture capital investors in PSI Medical. Since the first application of cash from the IPO was to fund the next phase of Medical's development, it would severely dilute the ownership of the venture capitalists. For accounting reasons, it was also necessary for PSI to own at least 51% of its subsidiary, and this ran counter to the VCs' interests (in fact, the sudden change in PSI's potential leverage as a public company was extremely disorienting to them). I learned first-hand what little respect there is between VCs and investment bankers, and how raw greed can distort the behavior of otherwise intelligent, pleasant people.

The next step in the process was to file the prospectus, or "Red Herring" as it is called, with the Securities and Exchange Commission. They had thirty days in which to approve it or request changes before permitting the underwriters to sell the stock. During this month, we were not idle, preparing a presentation to potential investors, embarking on a one week "road show" to the centers of finance in the US and Europe, and meeting one-on-one with money managers in New York City. The purpose of the trip and meetings, was not, as I had assumed, to simply provide a face to the company and its management. Rather, it was to actually convince the investors that we had a real chance of doing something useful with their money, and that the odds were better that the stock would rise above its opening price than fall below it.

We opened not in Venice, but in London, at the Armorers Guild Hall, a wonderful room filled with jolly British bankers looking for either a good deal, a good meal, or both. After an introduction from Tommy Unterberg, I gave the carefully rehearsed fifteen minute pitch and answered questions. Things seemed to go well, although with the terminally polite British one can never tell. Next came San Francisco and a disappointingly light turnout, followed by Minneapolis with even fewer in attendance. Despairing about the success of their "road show," Unterberg Harris pulled out all the stops for Boston and New York, our grand finale. It may have been the room, the free PSI Medical T-shirts ("We'll Bust Your Stones"), the grilled salmon, or an "up" day on the market, but we filled the room. With the applause still ringing in my ears, we flew home and anticipated the big day the following week when the SEC and the investment community would render their judgments.

With a green light from the SEC, it seemed straightforward to our first trade in the proposed range of $8-9 a share. At the lower end of this range we would raise over $15M, and the company would have a market value of more than $45M; not bad by the standards of the day, and worth over $5M to me personally. Something was going on in the market, however, and it wasn't good. The biotechnology industry had just gone through another boom and bust cycle, and there was suddenly a diminished appetite for any high tech IPOs. We should have seen this coming as the audiences thinned during the

road show, and as potential investors failed to line up for allocations of stock. In fact, the Unterberg Harris "book" was not even fully subscribed, much less being a factor of two or three oversubscribed as in successful IPOs.

With a touch of sadness, Tommy Unterberg informed us that we would have to reduce the number of shares offered and lower the price to a range of $5-6 a share, thereby raising "only" ten million dollars. This wasn't the first time that he had to adjust his originally rosy outlook, and it wouldn't be the last. We agreed to the change and waited. After another week, and another conference at which a final offering price of $4 was suggested, we called a halt to the process, ending our quest for public money, status and personal fortune. Having spent over $200,000 on lawyers, lunches, and limousines, Tommy took our decision well. Our own board of directors, shareholders, and employees, upon learning that we had blown over $400,000 of our own money on this adventure, did not.

Needless to add, we learned a lot about the public markets, which recovered six months later, our business and ourselves through this expensive education. We learned that there should be more than "sex and violence" behind a publicly traded stock, that timing the IPO market is crucial, and that if something is too good to be true, it probably isn't. As a precursor to the "dot com" mania of the late nineties, it should have been a valuable lesson to not get involved with greedy people who sell with "mirrors and blue smoke." As a mirror held to ourselves, it *almost* convinced us that we should remain a research and development company and leave the high finance to others.

But, like my father, I'm an optimist, succumbing again to temptation not once but twice. First in another aborted attempt at an IPO a year and a half later, initiated by an introduction from who else but ThermoElectron, and second in a one year privately-financed attempt to exploit the dot com craze with a family-based entertainment concept. I may now be cured of the "going public" disease, but, like alcoholism, you have to take it one day at a time. PSI will undoubtedly remain private and independent, as an employee-owned company, and I'll probably not risk any more of my retirement money on high-risk start-ups. Probably.

Albert Einstein and me

I am reading the latest biography of Einstein by Walter Isaacson, and am trying to understand how he came upon the concept of relativity. It seems that even Einstein couldn't quite understand how he, rather than someone else of his era, discovered relativity, but offers the observation that he was late to develop, and his child-like curiosity about nature had much to do with it. Other clues are more instructive, including the work of Henri Poincare, the great French mathematician, who declared that space, time, even geometry, are not absolutes. What Einstein appears to have done is integrate what appeared to be unrelated phenomena in the fields of mechanics, electricity and magnetism, and optics; at least, that is what he accomplished in 1905 with the publication of four seminal papers, the last of which led to "special relativity."

While Einstein was not an outstanding mathematician, he did possess an ability to visualize physical phenomena and imagine how to represent them mathematically in the simplest possible terms, but not, as he famously said, any simpler. As in the study of music, where it is necessary to have a basic theoretical foundation and a confident technique at the keyboard, theoretical physics requires a basic understanding of real-world phenomena and an adequate set of mathematical tools. Equally important is an ability to recognize what is important in a physics problem, and to ignore that which is not. When a problem yields an elegant solution, it is almost obvious that it must be correct. Einstein and the other physics greats of the early twentieth century made amazing breakthroughs with physical insights and simple models.

What does this possibly have to do with my own experience in science and technology? Actually, quite a lot. I have had a few "aha" moments when working on problems of fluid physics and aerodynamics, and they were as exciting to me as similar events must have been to Albert. The earliest of these occurred as I imagined how to explain the grooves etched in glassy meteorites. I had learned a little about the causes of instabilities in fluids, and was able to recreate these conditions in the laboratory with very simple experiments. Only then did I attempt to solve equations that more or less represented what I was seeing, and to make predictions about when meteorites should have grooves and how they would be spaced. The fact that a Nobel Prize winner named Hans Bethe was interested in glassy meteorites and their similarity to re-entry vehicles that would protect the Apollo astronauts on their return to earth, and that a German contemporary of Einstein, Hermann Goertler, wrote me a note encouraging me to work on this problem, added to the pleasure of explaining one of nature's secrets.

I recently celebrated my 70th birthday in the company of close friends from all periods of my life. As it turned out, I had many connections with them over the years theough my study of "Goertler instabilities" around meteorites. Even recently, a former associate now at NASA asked if I might agree that observations of grooves seen in experimental heat shields for the planned excursions to and from Mars could be related to Goertler instabilities. Of course, I agreed, in the hope that I could revisit the excitement of my graduate years.

Continuing my birthday celebration marathon, a more recent gathering of high school classmates was an excuse to visit the engineering school where I performed my experiments. Unfortunately, it is now a community college, and the only vestige of my lab was the outside metal cage that held bottles of highly pressurized gases for the wind tunnel I used. The lab itself was the scene of a music class, and it is unlikely that any of the students had ever looked at the engravings on the building exterior memorializing aviators from DaVinci to the Wright Brothers.