by William L. Ditto

Chaos at 35,000 Feet

It's time to call it quits! That was my exact thought in early 1997 on a flight from India to Atlanta. I was feeling deeply depleted, partly from travel but mostly from overwork. I had labored so hard to make our project and the start-up company a success that I had nothing left to give. It was with a sense of deep relief that I slumped back into my airline seat, ready to fold my small company and allow others more clever and energetic to bring the technology to market. Then came the announcement: "If you are a doctor, please contact a flight attendant immediately."

I turned and looked back. A middle-aged man had collapsed two rows behind me. To my relief, six physicians responded. They immediately diagnosed the problem as ventricular fibrillation—a condition in which the heart speeds up and its beat becomes chaotically irregular. According to the American Heart Association, ventricular fibrillation is the major cause of sudden-death heart attacks and the final event that causes one in six deaths.

Over the next 30 minutes, the doctors tried unsuccessfully to convert the man's deadly rhythm to a slower, normal heartbeat. He died just before the plane made an emergency landing. For me, his death was one of those rare moments when major life decisions get made.

It is likely the man's life could have been saved if a defibrillator (a device that delivers a large electrical current through the chest) had been available. Fibrillation is triggered when something causes a major disruption of the heart's electrical activity. Normally the heart only fibrillates because of disease—primarily various forms of heart disease—but an electrical shock or blunt-force trauma can also cause fibrillation. Sometimes, quickly delivering a strong electrical shock to the heart can restore its normal rhythm. For much of the 1990s, I had been working to develop an improved defibrillation technique. It was that effort that I had determined to abandon only minutes before the man collapsed. His death forged a new resolve in me to pursue our lifesaving technique; it felt like an obligation.

In the beginning

I was skeptical in 1992 when one of my collaborators, physicist Mark Spano of the Department of the Navy, suggested that we apply for a patent on our new cardiac-control technique, which then consisted of an algorithm and a way to implement it. Nonetheless, I agreed to find out how to obtain a patent. At the time, I was an assistant professor of physics at the College of Wooster in Ohio.

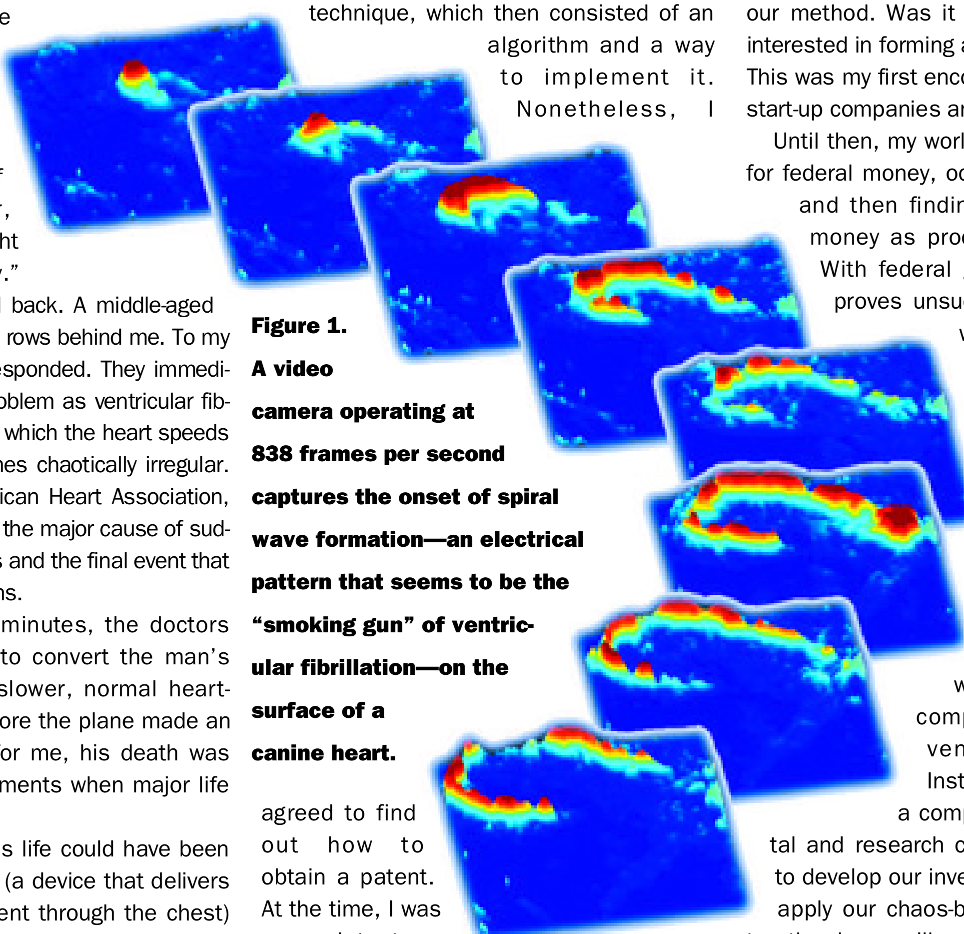

Figure 1. A video camera operating at 838 frames per second captures the onset of spiral wave formation—an electrical pattern that seems to be the "smoking gun" of ventricular fibrillation—on the surface of a canine heart.

Because of my complete ignorance of business, my decision to pursue the business side of developing an invention was hasty and had unexpected consequences. It launched me onto the turbulent waters of intellectual property laws, exclusive rights, contracts, negotiations, high-technology start-up companies—and on an extraordinary entrepreneurial journey. For a patent to be more than a resume booster, it must be prosecuted and developed with care. We were lucky in that our application sailed through the patent process fairly quickly, by glacial government standards, and about two and a half years later, our patent was granted.

Soon after our application was filed, our first paper on the cardiac-control method appeared in the journal *Science*. I immediately began getting phone calls inquiring about our method. Was it patented? Would I be interested in forming a company to exploit it? This was my first encounter with the world of start-up companies and venture capital.

Until then, my world consisted of begging for federal money, occasionally receiving it, and then finding ways to spend the money as productively as possible. With federal grants, if your project proves unsuccessful, you lick your wounds, publish your intermediate results, and move on to another effort. However, venture capitalists who are willing to give you money to capitalize on an invention want practical results, and fast. They also want to control your company. We declined all venture-capital offers. Instead, I decided to form a company and to seek capital and research contracts from industry to develop our invention. I also wanted to apply our chaos-based control methods to other human illnesses, such as epilepsy and other seizure disorders. Contrary to my expectations, however, calls from venture capitalists dramatically increased after the decision to go it alone.

While parrying venture capitalists, I was busy discussing the potential of our method with biomedical companies. This was a real eye-opener. Far from my initial views of corporate America as an evil empire, I was impressed with both the vision and idealism of the industrial managers, scientists, and engineers I encountered. My immediate

Figure 2. Spiral waves of electrical activity—shown here in the van Capelle-Durrer model of human heart tissue—are hypothesized to be responsible for the onset of fibrillation.

plan consisted of obtaining money to incorporate our method into an implantable device to control erratic heartbeats called arrhythmias in order to prevent fatal fibrillation. Current implantable defibrillators shock the heart with about 7 J, which is equivalent to dropping a bowling ball on the chest from 6 ft. This shock can result in muscle, bone, and connective-tissue damage, and extreme pain. Our approach uses a series of millijoule control pulses—whose irregular timing is based on chaos theory—to restore the heart's natural rhythm.

Little did I know that low energy was the Holy Grail of cardiac-arrhythmia control. Only as I talked to biomedical companies did I come realize the huge human and financial stakes involved in our venture. I decided I had no choice but to partner with a major company to push this technology as far as possible. Here I confronted another enduring struggle of the scientific-industrial complex—"tech transfer."

Industry–academia gulf

Something we do poorly in this country is to transfer an idea from our world-class research laboratories to industry. Often academic scientists are less interested in material gain than in getting their discoveries used. It is a common misconception among academics that giving away intellectual property rights to every company that might want them will enhance the chances that their discoveries will be exploited. Nothing could be further from the truth, as I found out. Under normal circumstances companies will spend the money needed to bring an emergent technology to market only if they can obtain exclusive rights to the invention.

I quickly learned why companies want exclusive rights. Corporate employees advance by discovering or inventing new technologies, securing the rights to the technologies, and then developing them into products and services that make money. Exclusive rights to an invention provide a company the economic incentive to develop the technology because they give the company, upon successful tech transfer, an advantage over its competition. I constantly fielded two questions: Who owns the patent, and could exclusive rights be obtained? It became clear that hopes for bringing our invention to market hinged on obtaining exclusive rights that I could option to another company, one with the financial strength and willingness to develop the technique and take it through the federal approval process.

So, while awaiting the patent and juggling an academic career, I set out to secure future rights to the patent should it be granted. I naively thought these issues would be easily resolved. I was never more wrong.

In addition to me, the Navy (because of Spano's participation), the University of California Board of Regents, and two researchers who worked with us had claims to the patent. Obtaining control of the right to grant exclusive use of the patent required reaching an agreement acceptable to all the parties. It took 18 months of negotiations to secure clear and unencumbered control of the patent rights.

As the negotiations progressed and the daily hassle grew, I began serious discussions about forming a company with two acquaintances who eventually agreed to invest money in the project. Control Dynamics, Inc., was incorporated in 1994, after the patent was granted and I had obtained legal standing to assign exclusive rights to it. I now found myself the company's president and chief scientist. In addition to running my own academic research team, I directed a small industrial laboratory devoted to pursuing practical applications of chaos theory in areas as diverse as medicine, computers, and power-generation equipment.

Importance of start-ups

An industrial scientist, especially at a start-up, must be concerned with the effective allocation of resources for both long- and short-term nurturing of new technologies. Most of a start-up's scarce research budget must go for day-to-day problems, but the budget must allow for long-term risks to prevent stagnation of the business. Risks must be taken, but too many risks and you are out of business. Thus you would prefer to get a large gain with as little risk as possible. This type of risk is where small companies make or break themselves.

Low-risk, high-gain projects are best, of course. However, there is no such thing as a free lunch, and developing new technologies often requires levels of risk that industry giants find unacceptable. Typically only a small percentage of "good ideas" pan out as novel research discoveries, and of such discoveries, only a few show potential for applications. So there is a role for small companies to fill in the gap between research laboratories and big corporations.

As a small company, there comes a time when you must "bet the farm." Fortune favors the bold, and risks must be taken. Thus, between the academic physicist and the industrial physicist there must be an entrepreneurial physicist. One key role of small companies is to develop risky technologies and survive long enough to develop an innovative technique or product. This is why my business partners and I started Control Dynamics.

Only as a start-up president did I begin to learn the constraints and rewards of being an industrial scientist. I now had total control and I could push the technology as I saw fit. Yet, I often found my basic-research side screaming "damn the torpedoes, let's take the risk," while my industrial side was weighing the pros and cons of risky research without immediate returns. As an academic, my job was to spend money in risky ventures to advance knowledge, but as an industrialist (albeit a minor one), I always ran the risk of making some decisions that could bankrupt the company.

Control Dynamics, although small, is functional. Over the last several years, we have won many contracts to develop chaos-control technology. Our patent applications for chaos-based devices have been successful, and now we are intensely working toward practical applications of our research.

One of our most promising directions is the imaging of the deadly "electrical storm" of the heart during fibrillation to understand what exactly is happening. Our visualization technique uses a high-speed charge-coupled device (CCD), developed by cardiologist Frank Witkowski of the University of Alberta in Edmonton in conjunction with Control Dynamics, and dyes that fluoresce when an electrical charge is present (such as the electrical rhythms of the human heart). With our CCD video camera (which takes 838 pictures a second versus a normal video camera's 30 frames), we visualized, for the first time, the chaotic electrical disturbances of fibrillation induced in animals (Figure 1).

To our surprise, the patterns were few in number and quite simple. These patterns are seen in many natural systems and are known as spiral waves or rotors (Figure 2). They resemble the swirling eddies that form as a rapidly moving stream surges past rocks. In humans, electrical waves swirling through the heart create the state of fibrillation. Our imaging technique may lead us to the development of new devices that could prevent or terminate fibrillation without the need for jolting electrical shocks and injury to the body.

The jury is still out on whether we will survive as a company, but the experience has been a lot of fun despite the frustrations. After almost five years in the black, our goal of saving lives (and maybe making a little money) remains at the forefront of our endeavors. Starting a company is not for the faint of heart, but the rewards are self-evident. So if you are daring enough to try to change the world, form a company. You may not succeed, but you will never be bored.

BIOGRAPHY

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