

# Foreword

This book tells the story of the Barta Building and the external world from which the Whirlwind computer emerged. It is an authoritative account about a team of individuals who pioneered technology that forever changed our world. But there is more to the story—the internal MIT environment that fostered innovation. Especially in the 1940s, MIT can be described as a free-enterprise society in which one could do anything if it was honorable and one could raise the necessary money from the outside. In this freedom of action, I believe MIT differed from almost all other academic institutions.

Such freedom to innovate resided in the Division of Industrial Cooperation (DIC) directed by Nathaniel Sage. The DIC had been set up in the 1920s to handle contracts and funds, mostly from industrial companies who wanted to sponsor specific research projects. The DIC then became the contracting vehicle for government-sponsored activities during and after World War II. The DIC was parallel to and mostly independent of the MIT academic departments and could independently hire people.

Nat Sage set the tone of the Division of Industrial Cooperation. He favored results over the restraints of contracts and bureaucracy. As the son of an Army officer, he grew up in Army camps around the world. Somewhere in that experience, Sage became a very good and self-confident judge of people. There were those at MIT whom he trusted implicitly, and those whom he would not trust farther than he could watch them. Sage trusted Gordon Brown, my mentor, and Stark Draper, famous for gyro computing gun sights in World War II and the guidance system for the moon landing. I was also on his favored list, and he was a tower of strength in tough times, of which we had many.

An incident in the later stages of designing the SAGE computers showed Nat Sage's way of dealing on our behalf with distractions. We had several engineers who had spent a stressful week in Poughkeepsie, NY, pushing the IBM engineers to design for the reliability to which we were committed. Came Friday afternoon, they wanted to be home for the weekend, and rather than face the tedious trip to New York and a change of stations for a train to Boston, they chartered a plane to take them home. When the Air Force finance officer saw the charge for the plane, he came to Nat Sage to

berate us and demand some kind of punishment. Sage was sympathetic, said he would look into it, and after the officer left put the papers in his desk. Several months later he mentioned the officer's visit to me.

Unlike most organizations, in the DIC bad news flowed upward. If there was no news, those at upper levels assumed matters were under control. The upper levels were there to assist when there was trouble, and when necessary we took problems "up stairs" for help. Also, administrative levels were not barriers to communication; everyone was free to skip levels, both up and down, to go directly to the place where discussion could be most effective.

The core team that created Whirlwind emerged from the early 1940s in the MIT Servomechanisms Laboratory directed by Gordon S. Brown. Brown was principally responsible for my career at MIT. Brown ran what at the time seemed like a chaotic organization. World War II projects came in; he turned most over to graduate students to manage, keeping a few projects for himself to manage. We, as employees of the boss, had to compete with him for resources and influence. Brown was impatient, with little sympathy for incompetence. He would "walk on" those who did not defend their positions, but respected and gave tremendous help to those who would stand up to him and demonstrate justifiable independence. I think my turning point with him came one day when I had an issue to discuss with him and went to his office door where he was sitting at a desk facing the door. I stood in the door waiting to be invited in and was sure he knew I was there. After a long time he looked up and said, "Get out!" At that point I walked to his desk, sat on the paper he was writing, and told him I would not leave until he paid attention. It was a rough environment but powerful in character building.

In developing military equipment, we gained experience in the total sequence of new products—defining the objective, innovating new ideas, studying the theory of operation, making demonstration models in the machine shop, designing for production, devising tools for factory manufacture, solving factory production problems when they arose, and going to the military field to analyze and correct failures in operation. When we started such work, MIT was without guards and military security; to fill in, I was given a City of Cambridge police badge and a pistol permit to double as a guard. At age 24, I signed drawings in the space reserved for the Chief of Army Ordnance and sent them directly to factories; such was the freedom and urgency of wartime. Here we came to a deep and abiding

faith in Murphy's Law that, if anything can go wrong, it will. That enduring belief served us well as we embarked on designing reliable computers. The Servomechanisms Laboratory under Gordon Brown trained innovators.

Today, many critics lament the lack of innovation in our society and draw the conclusion that more emphasis on teaching mathematics and science will lead to innovation. That will probably fail. Pressures in the present school systems suppress innovation. Innovation comes from repeated successes in innovating. Innovation means trying ideas outside of the accepted pattern. It means providing the opportunity to fail as a learning experience rather than as an embarrassment. It means living part of the time outside of the traditionally accepted track. An innovative spirit requires years for developing the courage to be different and calibrating oneself to identify the effective region for innovation that lies between the mundane and the impossible. Almost none of the conditions for developing innovative attitudes are to be found in today's K-12 education. In fact, the traditional school powerfully suppresses any tendency toward being innovative. Both teachers and students are driven to conform.

However, today's educational shortcomings did not exist in Brown's laboratory. Each project opened into uncharted territory. Each provided a wide range of experience that far exceeded that of most people in industry, government, and academia. It was this wealth of experience and building the personal character for innovation and entrepreneurship that produced the team that was capable of pioneering the digital frontier.

Gordon Brown had an even more crucial role by launching the activity that led to the Whirlwind and SAGE programs. The end of World War II terminated the military projects in the Servomechanisms Laboratory. I assumed that I would be leaving MIT either to find an industrial position or to start a new company to carry forward and apply our feedback system knowledge to physical engineering applications. Then, Gordon called me to his office to ask if I would like to stay and choose one of the ten projects that he had on a list.

I decided to pick one from the list. Captain Louis de Florez at the Navy's Special Devices Center in Port Washington, Long Island, had proposed it. De Florez was an uninhibited innovator. One story from his early career comes from when he worked for an oil company in Texas. Refineries were threatened by fire and explosion when a pipe eroded from the inside until the wall was weakened, and a major bursting and explosion could occur. De Florez devised a warning system by drilling small holes part way into the pipe walls. When the inside eroded to the bottom of a hole, oil would spray out as a warning. De Florez was a commanding figure with a pointed

waxed mustache. Also, as far as I know, he was the only person able to get permission to land a seaplane in the Charles River sailing basin in front of MIT. I was there once when the Metropolitan District Commission cleared the basin of sailboats; de Florez landed his plane and came to the MIT alumni reunion. After lunch, when the speeches were becoming dull, he left in a roar from his water takeoff that overwhelmed the loud speakers at the reunion.

The de Florez project was to go beyond the existing flight trainers for pilots, which were tailored to the characteristics of a known airplane. The project was to create a cockpit that would exhibit the characteristics of a proposed plane, based on wind tunnel data of a model of the plane. Thus started the sequence described in this book.

Although the Division of Industrial Cooperation was outside of and parallel to the MIT academic departments, projects did have a tenuous connection to a relevant department. Almost always, there was a faculty member who bridged between a DIC project and an academic department. Gordon Brown played the role of connecting the digital computer activity to the MIT Electrical Engineering Department.

We did have frictions in trying to awaken a traditional electrical engineering department, devoted to power generation, to the arrival of computers. At one point we presented, with only partial success, a lecture trying to convince the electrical engineering faculty that it was not only possible but also desirable to use binary arithmetic for computation.

Our relationship to the Electrical Engineering Department gave me access to incoming graduate student applicants to become full-time research assistants. They were allowed to take two subjects per term toward their degree. By reviewing applications myself, I effectively had first choice of those applying to MIT. We accumulated an impressive group. Many graduate applicants were coming back from military service with a maturity and real-world experience that is unusual for students. They were ideal recruits for the coming information age. Their M.Sc. theses on aspects of computers qualified many to present papers at the national and international technical conventions.

Because of the continuing budget pressures in the early phases of the Whirlwind computer, we were subjected to annual reviews by panels appointed by the Office of Naval Research. Most of these were a distraction from our mission, but occasionally a point was raised that improved our thinking. An especially important advance came when ONR appointed a mathematics professor, Francis Murray of Columbia University, to be inquisitor-of-the-year. Murray came on a Saturday and we met in my office.

At one point he asked, “What are you going to do about the electronic components that are drifting gradually and are on the edge of causing mistakes? Any little random fluctuation in power, or streetcars going by, will cause circuits to sometimes work and sometimes not.” This was a very perceptive and powerful question. Inexplicably, we had done nothing about it. It was such a pointed question, and obviously such an important one, that I felt an immediate answer was essential. I said to him, “Well, we could lower the voltage on the screen grids of tubes to change their gain and convert behavior from a marginal to a permanent failure and then it would be easy to find.” He thought it was a good solution and so did we. The next week we started designing such capability into Whirlwind. The “marginal checking” system in Whirlwind carried over into the SAGE Air Defense system, adding another factor of ten to the reliability.

During the design of Whirlwind, we were strongly criticized for the amount of money we were spending to develop entirely new circuits and devices that would be reliable. The total Whirlwind cost over some seven years was four and a half million dollars; it would not be long after until individual production line machines were costing that much. The matter of cost was one of the things that the outside world understood least. Whirlwind was being judged in the context of mathematical research, in which the salary of a professor and a research assistant was the standard by which projects were measured. We were spending way beyond that level and were seen as running a “gold-plated operation.” Although the gold plating might occasionally have been excessive, in retrospect, I think there was reason for it.

An organization has great difficulty maintaining two contradictory standards. If you’re going to have high performance and high quality in the things that matter, it is very difficult to have low quality and low performance in the things that, perhaps, don’t matter. The two standards bleed into one another to the detriment of both. For example, at an early demonstration for important people, we didn’t want them sticking their fingers into the high voltages in the circuit racks of Whirlwind. I asked somebody to get rope to put along the aisles so visitors wouldn’t walk among the vacuum tubes. A nice-looking white nylon rope was procured and installed. During the demonstration, I saw some of our critics fingering this beautiful rope and looking at one another knowingly as if to say, “That’s what you would expect here.” It may not have cost any more than hemp rope, but it reinforced that impression of an extravagant operation. Another example was the Cape Cod display scopes built into cabinets made of mahogany-faced plywood. Although our cabinetmaker made these quite inexpensively,

people looking at those mahogany cabinets were reinforced in their thinking that we were extravagant. Eventually we solved this problem by spending additional money and painting the cabinets gray.

We came out of the Servomechanisms Laboratory with a central group that understood the full potential of teamwork. Of course, later, the team unity was reinforced as we stood together on the computer frontier to repel critics. There was complete sharing of information. In a bi-weekly report, distributed to everyone, each person reported on progress and difficulties. There was little jockeying for personal advantage. Every person has strengths and weaknesses. A team must have a shared vision of the future, a sensitivity to political matters, the capability of developing people, technical competence, the courage to transcend adversity, salesmanship, integrity, the ability to put long-range goals ahead of the short term, and a shared understanding of the individual strengths and weaknesses within the group. We had those characteristics well represented, scattered throughout our group. No person had all these skills. For every person there would be a glaring hole in one or more of those dimensions.

Yet, it was a group that understood each other well enough to use people in situations where their strengths prevailed and have others compensate for their weaknesses. Out of that came an organization that was able to be much more effective than most of those we see around us in technology and corporations at the present time. It was an organization possessing power based on a clear vision and consistency that could dominate the military and corporate structures that grew around the North American air defense system.

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