

Introduction
“We Were Heavily Armed, and We Had Crystals”

Private First Class Irwin Gottlieb joined his unit in France on June 9, 1944. Trained as a machine gunner, he was assigned to the First Reconnaissance Cavalry Troop of the First Infantry Division. From D+3 till VE Day, Gottlieb and his unit saw almost continuous action, often miles ahead of the rest of the division. It was not uncommon for German troops to avoid contact with the thirty-man troop; possibly confusing them for the head of a much larger armored column, or at the very least hoping to prevent disclosing their position to the recon unit. Firefights did erupt, however; Gottlieb himself was wounded during the last days of the war. In later life, when asked how his unit defended itself against often-times much larger German units, Gottlieb would invariably reply “we were heavily armed, and we had crystals.”¹

Being “heavily armed” is easy to understand: with an assortment of .30 and .50 caliber machine guns, 37 mm cannon, and 60 mm mortars, they could give as good as they got. The meaning of “and we had crystals” is not quite as obvious. What he meant by this was that his unit possessed quartz crystal-controlled radio equipment. The saga of how such equipment came to be regarded by a front-line combat veteran as a weapon as vital to survival as machine guns and mortars is the object of this work.

What made their radio equipment such a powerful weapon were the quartz crystal units which controlled their transmitting and receiving frequencies. Comprised of little more than a fingernail-sized wafer of quartz, these crystal units provided the operating stability which ultimately allowed instant and dependable radio communications to be taken for granted by the men in the fields, the tanks, and the airplanes.

Though the outward appearance of the quartz crystal unit suggested a very simple device, their manufacture required methods of exacting standards and extreme precision. So much so that prior to WWII they were produced one at a time, by hand, in a small number of companies across the country. The entire output of the crystal “industry” in 1941 was only 100,000 units. However, by the end of the war, a full-fledged industry numbering nearly 150 manufacturers was turning out over two million units *per month*.

Quartz crystals went from a 19th-century scientific curiosity to the focus of a massive military and industrial program during the Second World War. The largely untold story of this transformation is one of science and technology and the problems of peace-time military planning. It deals with the conflict between the established arms of the military and the rapidly evolving and expanding ones born of the previous World War. It involves unprecedented cooperation among and between various government agencies, independent branches of the military, and private industry in order to design, build, supply, and support a war-time mass production industry where none had existed prior to the attack on Pearl Harbor.

In this book I divide the story of the quartz crystal industry into five sections. The initial section serves as an introduction; covering the history and the science of the piezoelectric effect of quartz, its use in radio electronics, and the ultimate acceptance of this mode of frequency control by the U.S. Army Signal Corps, the branch of the Army with overall responsibility for communications and its corresponding technologies. Sections 2, 3, and 4 address what I refer to as the “Three Crises.” The first is the crisis brought on by America’s abrupt entry into the Second World War. Suddenly faced with enormous needs for reliable military communication equipment, the country had no mass production industry to produce the crystal units needed for frequency control. Worse still, there existed no mass production techniques or equipment to be utilized even if an industry could somehow have been conjured up immediately from thin air. Being the primary agency involved with the development of new communications technologies, the solution to this problem fell to the U.S. Army’s Office of the Chief Signal Officer.

The second crisis involves the problem of supplying the crystal industry with the unprecedented amounts of raw quartz needed for manufacturing the crystal units. The only sources of “radio grade” quartz available during the war were within the interior regions of Brazil. Defined by Congress to be a “strategic and critical” material, the problems of how to increase the production, purchase, and transport of quartz to the United States were faced primarily by the departments of the Executive Branch of the civilian government. The third crisis came about after it appeared that the first two had been overcome by the Signal Corps and the government. It had to do with something known as the “Aging Problem,” an inevitable failure of the crystal units due to the manner in which they were manufactured. Representing a communications research and development challenge, the solution of this problem came primarily from those most experienced in this field, the scientists and engineers of the Signal Corps laboratories.

The final section of the book attempts to put the story of the quartz crystal unit into context with much more well known industrial and scientific contributions to the war effort. In terms of rapid industrial growth and dramatic increases in output, this story is not unique. A great many industries (such as aircraft and ship manufacturers) grew in size during the war. A great many other sectors of industry (such as the automotive industry) retooled their plants for the production of war materiel. Completely new industries (particularly the synthetic rubber industry) were created in this country by scientists, engineers, and industrialists where none had existed before. What is truly unique about the crystal industry is that it was *invented from scratch*. There was no mass production industry to expand. To enter the crystal business took much more than a simple “retooling” of manufacturing plants; in early 1942, no one really knew *how* to mass produce crystal units. Even the synthetic rubber industry, essentially a new entity in the US, was built along the lines of existing programs in other countries. No such blueprints existed for the quartz crystal industry.

The complete story of this wartime effort has never been told in any unified way. Though a handful of reports and conference presentations have been produced which recount the history of particular groups involved with the quartz crystal industry, this

book, based on hundreds of primary documents, correspondence, and interviews, is the first to attempt to portray the entire enterprise.

This story more than anything else is one of invention. At its heart, this book is about the quartz crystal oscillator; a product of pure research that was almost instantaneously embraced by the amateur radio community. However, the invention theme encompasses much more of the story. It also involves the inventiveness of the early pioneers of the crystal industry, developing the tools and techniques needed to manufacture the crystal units. It includes the work of the Signal Corps and the U.S. government to invent a mass production industry for an item whose crucial importance to the military was never fully realized until the war began. The new methods of business cooperation and the ways of confronting the age-old problems of supply and demand that were developed with respect to the crystal industry can also be considered inventions. Overall, this is a story of an interconnected web of inventors (scientists, industrialists, basement hobbyists, and military administrators) and inventions (material objects, techniques, and ideas). The overall success of this wartime program can quite possibly be linked directly to the fact that it essentially had no history; no previous modes of thought and action that could inhibit the free-thinking and inventiveness on the part of the participants.

I intend to show that the crystal program played just as important a role as radar or the atomic bomb in terms of its scientific and engineering contributions to the war effort and as any other sector of industry in terms of its rapid response to the challenges brought on by the war. Furthermore, the development of a mass production industry for quartz oscillators during WWII had far-reaching effects on late twentieth-century technology and society. Today, nearly everything that requires some type of timing or frequency control depends on a quartz oscillator. This includes cell phones, color television, computers, watches and clocks, wire-based multi-signal telephone technology, and many other items upon which our modern society depends. In fact, it can be argued that the move toward crystal control, with its reliance on a truly 20th-century, solid-state technology, presaged society's coming dependence upon the transistor and the integrated circuit and marks the very beginning of the evolution from an analog to a digital world.

“Pass not the shapeless lump of crystal by,
Nor view the icy mass with careless eye:
All royal pomp its value far exceeds.

And all the pearls the Red Sea’s bosom breeds,
This rough and uniform’d stone, without a grace,
Midst rarest treasure holds the chiefest place.”

Claudius, 14 A.D.²

“We have faith that future generations will know that here, in the middle of the twentieth century, there came a time when men of good will found a way to unite, and produce, and fight to destroy the forces of ignorance, and intolerance, and slavery, and war.” -
Franklin Delano Roosevelt