The year 1977 was expected to be a pivotal year for General Electric’s Medical Systems Division (referred to as GE Med). GE Med was on the verge of introducing its long-delayed CT Scanner into the medical equipment market, which had seen rapid growth in CT Scanner sales in the United States since EMI Ltd. had pioneered the market in 1973. EMI had sold 69% of the 650 high-priced scanners that were installed worldwide and held the top position in market share followed closely by Technicare’s Ohio Nuclear Division, which was second to EMI in machines sold and installed in 1975-76.¹

Several years previously, Walt Robb, GE Med’s General Manager, had authorized the development of CT Scanner that would try to leapfrog EMI’s technology using fan beam X-ray technology that could theoretically provide faster scans of patients and therefore better images. However, such technology was complicated, unproven and had been rejected by EMI’s scientists as unfeasible. Indeed, Robb’s boss at GE, Jack Welch had told him “You’re betting your job!” by betting GE Med’s market position in CT scanning on this technological direction.²

Therefore, GE Med was in a position of trying to overcome the established market leaders in the CT Scanner market. EMI had over a three-year lead on GE Med in installed scanners. However, with both a long history in the diagnostic imaging business and a new technology that could leapfrog the existing dominant scanner design, GE Med was a competitor that other scanner manufacturers had to take seriously.

GE Medical Systems Background and Position in Medical Imaging

GE Med was a division of General Electric (GE), which was a large US based, publicly-traded conglomerate. GE was ninth on the 1976 Fortune 500 list of US-based Corporations with net sales of $13.4 Billion and net profit of $581 Million.³ Its vast operations spanned the globe and included major positions in a number of industries including natural resources, consumer electronics, industrial machinery, power systems and jet engines. Approximately, 30% of GE’s revenues and 53% of its net earnings came from outside the United States.⁴
GE, due to its size and vastly complex operations, was usually considered to be a slow mover in the various industries where it competed. However, GE compensated for its relative lack of speed by bringing strong manufacturing, marketing and R&D skills to its various businesses. GE had recently upped its commitment to R&D by increasing corporation-wide expenditures on research and development despite weakened margins and profits in many of its businesses due to inflationary pressures in the 1970s. It’s projected 1977 R&D spending would exceed $1 Billion, including contract work for various governmental agencies. Many of GE’s older businesses were mature and R&D was seen as a way of establishing strong positions in emerging businesses.

GE Medical Systems was a GE division based in Milwaukee, Wisconsin whose primary business was X-ray equipment sales and service. GE was one of the world’s oldest suppliers of X-ray equipment having entered the market in the late 1890s shortly after X-rays were discovered. GE Med had the strongest X-ray market position in United States selling approximately 30% of all equipment in the country. International X-ray companies Picker, Siemens, Philips and Westinghouse divided another 40% of the US market while a host of smaller specialized companies like Continental X-ray and Standard X-ray competed for the other 30 percent. The market for X-ray equipment, supplies and service in the United States was estimated to be around $1 Billion in 1976. GE Med had also recently entered the US electrodiagnostic and nuclear imaging equipment markets, but these businesses were dwarfed by its X-ray operations.

By 1977, a high level of commitment existed at the highest levels of GE to invest in the medical systems business as a future growth and profit opportunity. While there had been some discussions of GE divesting the X-ray business in the late 1960s due to legal concerns about the long-term effects of x-rays on patients and possible lawsuits, GE Med’s GM at the time, Julien Charlier, convinced top corporate management and GE board that considerable growth opportunities existed in the health care diagnostic field. Indeed, by the early 1970s, GE Med mostly due to its strong position in the X-ray market had been designated as a ‘star’ in GE’s portfolio of businesses. Star businesses were those with high growth prospects, which were slated for investment. As such, GE invested heavily in its medical systems business in the early 1970s including making acquisitions companies in nuclear imaging, thermography and ultrasound along with dramatically expanding and updating GE’s X-ray equipment manufacturing facilities in the Milwaukee area.

GE Med held about 15% of the global market for X-ray equipment. Its strongest positions outside the United States were in European countries with a minor market position in Japan. This pattern of lower market share outside a firm’s home country was common in the X-ray market where large multi-national firms such as Siemens (Germany), Toshiba (Japan), and Philips (Netherlands) tended to have greater market share in certain regions of the world where they were headquartered or had a large employment presence. Government management of many health care systems around the world reinforced this market share pattern as governments preferred to buy medical equipment from their own ‘national champion’ firms. Despite, GE
Med’s smaller global market share, it had manufacturing and direct distribution presence in a number of regions of the world. It was also expected that the X-ray market would become more global in coming years with competing firms increasingly trying to penetrate the geographic strongholds of their international competitors.

GE Med’s position in the US X-ray market was based on having a strong product line that was sold by GE’s direct sales force of 300 people and backed with 1200 service technicians. This direct sales force was targeted at Radiologists within hospitals and medical research institutions. Radiologists were the physicians who performed X-ray procedures on patients in hospitals and interpreted the resulting X-ray films in consultation with the physicians treating the patients. Because of their position within hospitals, Radiologists had a strong influence over what type of X-ray equipment was installed. While capital equipment tended to be purchased by hospital administrators, Radiologists were extremely influential in the decision process due to their knowledge of X-ray equipment. Also, Radiology Departments tended to be profit centers in hospitals performing numerous procedures per day that were billable and covered by Medicare and private insurance plans. Because Radiology Departments were profitable, there was an incentive for every hospital, except for the smallest institutions, to try to establish Radiology Departments equipped with the most up-to-date equipment in order to attract strong physicians and perform many procedures.

Radiologists tended to purchase X-ray equipment based on the technical characteristics of the equipment and service capabilities of the equipment’s manufacturer. Service capability was extremely important because X-ray equipment was complex and equipment downtime represented lost revenue for both doctors and hospitals. As a result, Radiologists often had established strong relationships with particular equipment manufacturers (and their respective sales forces and service technicians), and hospitals or institutions sometimes purchased almost all of their X-ray equipment from a single manufacturer. Prices were generally negotiated with hospital administrators with elite institutions such as the Cleveland Clinic and medical schools being able to get discounts. Medical equipment placed in these institutions served as a method of promoting sales to hospitals.

GE Med had invested heavily to try to become the service leader in X-ray technology in the United States. In addition to its large service force, the company had built the GE Medical Systems Institute in Milwaukee. This training facility, conveniently located near the Milwaukee airport was the largest corporate training facility in the diagnostic imaging industry worldwide. The GE Medical Systems Institute provided ongoing training for all GE X-ray service technicians plus offered training to the employees of the hospitals and clinics where GE X-ray equipment was installed.

While most X-ray sellers did not report detailed financial results of their businesses (i.e., they were often part of larger, diversified corporations), the X-ray business was assumed to be highly profitable in the US market. Equipment sellers usually received service contracts with the sale of
equipment. These contracts were speculated to be more profitable than the sales of X-ray equipment.\textsuperscript{17} X-ray companies also sold consumables, in particular X-ray film, to their installed base which further increased profitability. Indeed, 50% of X-ray expenses in the US were for supplies.\textsuperscript{18}

Outside the US Market, the X-ray business was less profitable. In government controlled health care systems such as throughout most of Europe, capital equipment purchases were controlled centrally by administrators. Decisions on equipment often were made using system-wide cost-benefit analyses that included the cost and maintenance of the equipment. X-ray equipment was also rationed to various hospitals and clinics to avoid having too many machines that might go underutilized.

**GE Med and the CT Scanning Opportunity**

**Late to the Market**

For GE Med, the road to bringing a CT scanner to market had been bumpy. Because of CT scanning’s use of X-ray technology to generate diagnostic images, entry into the product category would be a natural product line expansion for GE Med. However, the division had been slow to enter the market for a number of reasons. Initially, when EMI revealed its CT Scanner technology to the world, GE Med was heavily investing in several new X-ray lines that focused on making the positioning of X-ray patients vis-à-vis the x-ray camera much more precise. These machines allowed for high quality X-ray images for radiologists of, for example, patients’ heads. However, because the resulting images were only two dimensional, the technology was quickly surpassed by CT Scanning.\textsuperscript{19} Second, despite GE Med’s top managers having several conversations with EMI’s executive board about GE purchasing EMI’s scanner business (that were rebuffed by EMI), the early projections about how large the CT Scanner market would grow were quite varied and some GE Med executives wondered if the market would be more than 30 installed machines.\textsuperscript{20}

The explosive growth of CT scanner orders in the US after EMI’s first installation in 1973 had shown strong acceptance of the product in the medical profession. The fact that CT scanning was also replacing traditional X-ray procedures in diagnosing many patients made the development of a CT scanner an extremely high strategic priority for GE Med.\textsuperscript{21} By early 1974, GE Med found customer orders for X-ray equipment starting to decline in the USA as hospitals and clinics shifted more of their capital expenditure budgets toward the purchase of CT Scanners.\textsuperscript{22}

It was during this chaotic period that Walt Robb was appointed General Manager of GE Med in December of 1973.\textsuperscript{23} Rob had been a profit-center manager for only two years at GE but had worked for a number of years as a research scientist in various capacities and at GE’s Corporate
R&D Center in Schenectady, New York. Robb held a Ph.D in Engineering from the University of Illinois and founded the Medical Development Operation at GE’s Corporate R&D Center. In a few short years, this organization had developed a number of inventions and patented innovations in thin membrane technology that could be used in organ transplants.\textsuperscript{24}

One of Walt Robb’s initial moves in the CT Scanner market was to dispatch a team of several engineers to the Mayo Clinic, which had agreed to let GE examine the installed EMI scanner. These engineers reported back that GE could probably produce a similar product in about nine months following EMI’s technical direction. At this time, Robb contacted GE’s Corporate R&D Center for assistance and discovered that scientists and engineers in Schenectady had been working on CT Scanning concepts since 1972 unbeknownst to engineers and managers at GE Med.\textsuperscript{25} However, the scientists in Schenectady has been working on an advanced fan-beam scanner concept that was technologically more advanced than EMI’s scanners but was unproven in terms of whether it could be turned into a real product that could be feasibly manufactured and serviced.

After meeting with the scientists at GE’s Corporate R&D Center and examining their research, Robb authorized the development of a fan-beam technology scanner and put together an R&D team that would develop prototype fan beam scanners, which after field testing, could be hopefully be developed into GE Med’s main CT Scanning product line. This team would be based at GE’s Corporate R&D Center but would also draw heavily on engineering talent from GE Med in Milwaukee. While this move would delay GE’s entrance into the field relative to following a product design that more mimicked EMI’s technology, Robb hoped that success would allow GE Med to leapfrog EMI in terms of technology.

**GE Med’s Scanner Research & Development**

By the beginning of 1977, almost three years had passed since Walt Robb authorized the development of a fan-beam scanner. Much of GE Med’s delay in commercially introducing a CT scanner came from their effort to leapfrog existing CT scanner technical standards with a ‘third generation’ of technology. CT scanning technology was already in its second generation despite CT scanners having been commercially available for less than four years. EMI’s initial scanner design had been based on a single rotating X-ray source and detector. Second generation machines, introduced by Ohio Nuclear and quickly copied by EMI, had multiple rotating X-ray sources and detectors.\textsuperscript{26} While such changes may seem modest, they enabled shorter scanning times, which generally increased the quality of images generated. A major source of blurred images in CT scanning was movement by the patient during a scan.

By the end of 1976, EMI had been able to reduce scan time from 4 1/2 minutes to 20 seconds in their second generation machines.\textsuperscript{27} The reductions in scan time were appreciated by both patients and Radiologists. Because a typical brain scanning procedure often required around ten separate full scans to complete, a patient on a first generation machine had to remain relatively
immobile for around 40 minutes for a scanning procedure to be completed. The same scan could be completed in less than five minutes on a second generation machine. Besides the diagnostic benefit of producing less blurry images, scan time reduction meant that a CT scanner could perform many more procedures in a single day and thus produce more revenue for hospitals and Radiologists.

GE Med’s concept of a fan-beam scanner would try to drastically again reduce scanning time. A fan beam scanner would have a single source of X-rays that would fan out going through the patient to a wide array of detectors on the opposite side. Both the generator and the detector would rotate around the patient (see Figure 1).

![Figure 1](image)

While conceptually possible, third generation fan-beam scanners represented technological and manufacturing challenges. Technologically, a fan-beam scanner would have to be much more powerful and require some component changes from existing scanner designs. For example, a fan-beam scanner would require hundreds of detectors to capture x-rays as opposed to one or a handful in first and second generation scanner technology. As a result, the expensive silicon-oxide detectors in existing scanners would have to be replaced by less expensive, off-the-shelf analog to digital converters. For these converters to work properly, they would have to be encased in xenon gas. Reconstructing the data received from the hundreds of detectors into useful diagnostic images would require data processing power about 100 times greater than what was required by EMI’s first generation CT scanners and involve much more complex software and mathematical algorithms to turn detector data into three dimensional images displayed on a CRT.

From a manufacturing perspective, fan-beam scanners presented significant problems. Existing CT Scanner manufacturers had already discovered how difficult it was to assemble even simpler first-generation CT Scanners, which had resulted in a huge backlog of orders in the industry.
While conceptually, manufacturing a CT scanner was an assembly operation requiring no massive capital investments, components needed to be tested rigorously before assembly and then various subsystems needed to be constructed into a reliable scanning system. After construction, the CT Scanner needed to be tested substantially at the factory and then partially disassembled for shipment to hospitals or clinics. Once the CT scanner arrived at its destination, it needed re-assembly, more rigorous testing and calibration before customers could be trained in using the machine. Failures in this process needed troubleshooting until the system worked as designed and mistakes in subcomponent assembly or defects in parts could cause failure at any point in the process. Fan-beam scanners amplified these manufacturing problems because they dramatically multiplied the number of detectors that could fail or be out of alignment. Any detector failure or misalignment caused poor quality images or create artifacts (non-existent visible elements) on a patient’s scan.

In terms of technological direction, EMI's research staff had tested and rejected the idea of fan beam scanner in the mid-1970s because they had difficulty producing high quality images with the technology. They also believed that the X-ray generator and detectors needed for such a scanner would make its price prohibitively expensive. Indeed, Sir Godfrey Hounsfield, EMI’s chief scanner scientist and Nobel Prize winner believed that a fan-beam scanner would not work because the concept was “three orders of magnitude more difficult than engineering could solve.”

GE Med's experience with third generation technology seemed to support EMI's research staff's conclusions. In 1975, GE Med developed a prototype breast-only CT scanner based on fan beam technology targeted toward the early detection of breast cancer. However, the product was never marketed because it failed to produce clear diagnostic images in clinical trials. However, GE Med managers were encouraged enough by the trials to embark on a full body scanner (head and/or body) based on fan beam technology. By early 1976, GE Med had installed a prototype head and body scanner at the University of California at San Francisco Medical Center for testing. While the machine performed well in full body scans, it had image quality problems in scans of patients’ heads. Much of the GE Med’s R&D team’s time in the second half of 1976 had been dedicated to hardware and software fixes attempting to fix the image quality problem.

By the start of 1977, GE Med's managers believed that their scientists and engineers were close to solving the image quality problems. Indeed, the production of some CT Scanners had begun as early as March of 1976. The GE Med marketing and sales staff had been told to inform customers that a GE scanner would be ready for delivery at some point in 1977. Sales staff had been informing customers of a machine that would reduce scan times to under 5 seconds with images displayed on a CRT screen at 320 x 320 pixels resolution. Orders were being accepted for $15,000 to reserve a place in GE Med's manufacturing queue. However, Radiologists were aware of GE Med's scanner development set backs and were waiting to for a finished scanner to be installed.
GE’s Scanner Marketing and Manufacturing

GE Med planned to market their CT scanner around the world using their existing X-ray sales force. While early enthusiastic advocates on CT scanning in hospitals and medical institutions were Neurologists, Radiologists had become the primary physicians in hospitals that were interpreting the results of CT scans for diagnostic purposes by the end of 1976. Scanners would be serviced by GE Med's existing X-ray service force, which would be supplemented by technicians trained in servicing scanners as needed.

GE Med would assemble CT Scanners in a new facility in suburban Milwaukee. X-ray tubes and the detector array would be manufactured in-house at GE Med’s long-time Milwaukee plant. The image reconstruction software would be developed and continually updated at GE’s Corporate R&D Center in Schenectady with help from Milwaukee as needed. The only major subsystem that was outsourced was the computer hardware (i.e., a minicomputer) that would run the image reconstruction software.

Market Uncertainty in 1977

Heading into 1977, tremendous uncertainty existed in CT scanner market. While orders and placements of CT scanners had grown explosively since EMI's first sales in 1973, it was unclear what the actual size of the market would be in the US (see EMI & the CT Scanner (B) case for more details). The US government was also concerned about what they saw as a large oversupply of CT scanners in the United States. Because hospitals used CT scanners as showpieces to attract new doctors and to compete on prestige with other hospitals, regulators worried that too much money was being spent on high-tech CT scanners and that Medicare and private insurers were therefore subsidizing, through billable procedures, hospitals' purchases of CT scanners that might not be needed. Indeed, the US government had been encouraging regulators at the state level to reject hospital requests for purchases of new scanners under Medicare's "Certificate of Need" program and some states such as California had put a moratorium on new CT Scanner purchases by the end of 1976. Therefore, the possibility of scanners sales cooling off or even decreasing in the US market was very real.

Insiders within GE Med felt they were better positioned to withstand any decrease in demand due to the Certificate of Need issue. Both EMI and Ohio Nuclear had little presence in medical equipment outside of CT Scanners. It was unclear how much patience their corporate parents would have for losses or declining profits in the scanner business. GE Med as a multi-product company with strong position in x-ray equipment and supplies could survive a drop in CT Scanner demand for a number of years despite the amount that had been invested in developing their fan beam scanner. It was believed that the Certificate of Need issue would disappear after several years because the technical advances in scanners would put pressure on politicians to allow hospitals to purchase the latest technology.
Markets outside the US had developed more slowly. However, because regulators often controlled the purchases of scanners in centrally-run government health plans, this market was expected to be less profitable on a per-capita basis than the US market.\textsuperscript{44}
Endnotes

8 Ibid.
10 Ibid, pp. 75-82.
15 Ibid.
17 Ibid.
23 Ibid, p. 93.
24 Ibid, p. 93.
25 Ibid, p. 94.
27 Bartlett, op. cit., 1983b p. 3.
29 Figure 1 and text description are from http://www.medcyclopaedia.com/library/radiology/chapter04/4_2.aspx accessed on 2/26/2010.
32 Lynn et al., op. cit., 1996 p. 16.
34 Ibid, p. 97.
38 Ibid, p. 86 and 103.
39 Ibid, p. 103.
40 Ibid, p. 528.