An Engineering Disaster: Therac-25

Introduction

Technological advancement is a result of the upcoming 21st century. But is it possible, with all these new gidgets and gadgets that disaster could strike? In fact, a costly and deathly mistake? As some wise, old man once said, " To err is to be human". But is there really such a thing as an "accident"? These so-called accidents and mistakes are really just cases of human inattention.

In a period where computers have become part of everyday living, the technology has been increasing at an alarming rate. And with this rate of innovation, human mistakes are bound to occur. Between the period of 1985-1987, such an error did occur, costing six innocent people their lives. Six people too many. This mistake was known as Therac-25; the name of the machine used in radiation therapy for cancer patients. It is the biggest and most disastrous case of human error relating computer controlled radiation and human death to date.

Therac-25

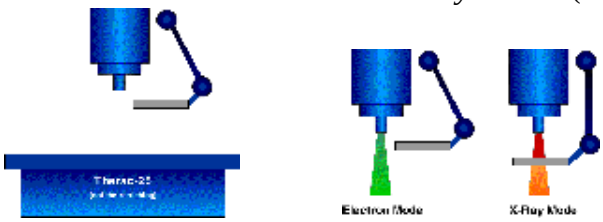
Background Information

The Therac-25 was a medical linear accelerator, a linac, developed by the AECL (Atomic Energy of Canada Limited) and CGR, a French company. It was the newest version of their previous models, the Therac-6 and Therac-20. These machines accelerated electrons that created energy beams that destroyed tumours. For shallow tissue penetration, the electrons are used; and to reach deeper tissue, the beam was converted into x-ray form.

The Therac-25 was a million dollar machine built to give radiation treatments to cancer patients. Most of these patients had already undergone surgery to remove the majority of the tumour, and were receiving the radiation to remove any leftover growth. This high energy radiation machine was computer controlled from a separate room to protect the operator from any unnecessary doses of radiation. Patients usually came in for a series of low energy radiation treatments to gradually and safely remove any remaining cancerous growth.

The Therac-25 had two main types of operation: a low energy mode and a high energy mode. The first mode consisted of an electron beam of 200 rads that was aimed at the patient directly. The second, higher energy mode, used the full power of the machine at 25 million electron volts. When used on patients, a metal plate was inserted between the beam and the patient, which would transform the beam into an x-ray.

The Therac-25: Electron and X-Ray Modes (click on pictures for full-sized images)



http://www.smi.stanford.edu/people/felciano/research/humanerror/humanerrortalk.html

There are some features of the Therac-25 that are necessary to review in relating the machine to the accidents. The Therac-25 was designed to be solely computer controlled. The previous versions were related to other machines. Another feature was that the software used had more responsibility in controlling safety. Again, the previous machines had separate pieces of machinery and hardware to monitor safety factors. The designers believed that they could save time and money in the Therac-25 by using only software safety control. A final feature was that some of the old software used in Therac-6 and Therac-20 was used in the Therac-25. A "bug" that was discovered in Therac-25 was later also found in the Therac-20.

The Failure of the Therac-25

In 1986, Ray Cox went into the clinic for his usual radiation treatment in his shoulder. The technician mistakenly typed "x" into the computer, which signified x-ray beam, then immediately realizing the error, changed the "x" into an "e" for electron beam, and hit "enter", showing the machine that they were ready to start treatment. This sequence occurred in less than 8 seconds. (This particular sequence, in this time frame, was never tried in the original testing of the machine.) The computer gave the signal of "beam ready", and the technician pressed "b" to deliver the beam to the patient. But then the computer responded with an error message. Usually this message meant that the treatment had not been delivered. So the technician repeated the process and delivered another beam to the patient. And yet again, an error message occurred. Meanwhile, Ray felt sharp stabbing pains in his back, which was much different than his usual treatments, and removed himself after three shocking attempts.

Because the commands were changed in such a short period of time, the computer did not respond properly. The metal plate moved away showing the technician that it was in low energy electron beam mode. But the beam that actually came from the machine was a blast of 25 000 rads with 25 million electron volts, the maximum setting, which is more than 125 times the regular dose.

Ray's health quickly became worse, and he died 4 months later from complications of major radiation burns.

The Therac-25 at full power. (click on picture for full-size image.)

www.smi.stanford.edu/people/felciano/research/humanerror/humanerrortalk.html

Ray was not the only unlucky victim of the Therac-25. At least 5 more similar incidents occurred in that fateful two year span from 1985-1987. Nobody knew why patients were having such adverse reactions to the supposed low energy electron beam. Little did they know, that patients were being exposed to many times the normal dosages of radiation, leaving terminal effects. And when someone finally discovered the real problems, it was too little too late, and six innocent lives had already been lost.

Causes of the Disaster

Some of the possible causes of the failure of the Therac-25 are:

- failure to properly assess the old software when using it for new machinery
- not well designed error and warning messages
- did not fix or even understand the frequent recurring problems
- should have installed proper hardware to catch safety glitches
- manufacturer would not believe that machine could fail
- lack of communication and organization between hospitals, government and manufacturer

How they Solved the Problem

On February 10, 1987, the Health Protection Branch of the Canadian government along with the United States Food and Drug Administration (FDA) announced that Therac-25's were dangerous to use, and were to be shut down until permanent changes could be made. Finally on July 21, 1987, after many revisions, some final recommendations were given by the AECL on how to repair the Therac-25 to no longer be a health threat . Some of these recommendations are:

- operators cannot restart machine without re-entering information
- ensuring that metal plate is in place if x-ray beam is selected
- error messages will be made clearer
- dose administered clearly shown to operator
- limiting editing keys to limit any accidental type ins
- all manuals rewritten to reflect new changes

Conclusions

These six people, their families and friends went through tremendous pain and heartbreak through no fault of their own. To not know why their loved ones were so ill, and deteriorating rapidly, when they really should have been recovering from their cancer, this was the hardest part to deal with. And then to discover, that through human error, their lives had been changed forever. In many senses, a computer had killed their mother, father, son, daughter, or whoever was

closest to their heart. It is hard to believe that through simple human error, an unnecessary loss of lives could take place. It has happened, and may happen again in the future. Therefore, it must be our goal to never let such a tragedy as Therac-25 take place again.

References

Felciano, R.M. *Human Error: Designing for Error in Medical Information Systems*. Text version of talk given at graduate seminar at Stanford University School of Medicine. 1995-1997. http://www.smi.stanford.edu/people/felciano/research/humanerror/humanerrortalk.html

Leveson, N., Turner, C.S. *An Investigation of the Therac-25 Accidents*. Reprinted from *IEEE Computer*, Vol.26, No.7, July 1993, pp.18-41. http://ei.cs.vt.edu/~cs3604/lib/Therac_25/Therac_1.html

Leveson, N. *Therac-25 Accidents: An Updated Version of the Original Accident Investigation Paper*. In Adobe Acrobat format and downloaded from website. http://www.cs.washington.edu/research/projects/safety/www/therac-25.html

---

Done by Joanne Lim
October 1998.