extensive understanding of user interfaces and human factors I was able to reconstruct the accident with uncanny accuracy. On the basis of this reconstruction, I came to the conclusion that it was the interface design and not the admittedly flawed software which should be viewed as the culprit in this case.

Despite my finding, Prosecuting Attorney Jane McMurdock insisted on pursuing the case against Randy Samuels. I believe that any competent Computer Scientist, given an opportunity to interact with the Robbie CX30 simulator, would also conclude that the interface designer and not the programmer should be charged with negligence, if not manslaughter.

2. Shneiderman's 'Eight Golden Rules'

My evaluation of the Robbie CX30 user interface is based upon Shneiderman's 'eight golden rules' (4). I also used other techniques to evaluate the interface, but those will be published in separate papers. In this section, I offer a brief review of Shneiderman's eight golden rules, a subject which would be more familiar to computer interface experts such as myself as opposed to the robot hackers who read this obscure journal.

The eight golden rules are:

1. Strive for consistency. As we shall see below, it is important for a user interface to be consistent on many levels. For example, screen layouts should be consistent from one screen to another. In an environment using a graphical user interface (GUI), this also implies consistency from one application to another.
2. Enable frequent users to use shortcuts. Frequent users (or, power users) may be turned off by overly tedious procedures. Allow those users a less tedious procedure for accomplishing a given task.
3. Offer informative feedback. Users need to see the consequences of their actions. If a user enters a command but the computer does not show that it is either processing or has processed that command, this can leave the user confused and disoriented.
4. Design dialogues to yield closure. Interacting with a computer is somewhat like a dialogue or conversation. Every task should have a beginning, a middle and an end. It is important for the user to know when a task is at its end. The user needs to have the feeling that a task has reached closure.
5. Offer simple error handling. User errors should be designed into the system. Another way of stating this is that no user action should be considered an error that is beyond the ability of the system to manage. If the user makes a mistake, the user should receive useful, concise and clear information about the nature of the mistake. It should be easy for the user to undo his or her mistake.
6. Permit easy reversal of actions. More generally, users must be permitted to undo what they have done, whether it is in the nature of an error or not.
7. Support internal locus of control. User satisfaction is high when the user feels that he or she is in control and user satisfaction is low when the user feels that the computer is in control. Design interfaces to reinforce the feeling that the user is the locus of control in the human-computer interaction.
8. Reduce short-term memory load. Human short-term memory is remarkably limited. Psychologists often quote Miller's law to the effect that short-term memory is limited to seven discrete pieces of information. Do everything possible to free the user's memory burden. For example, instead of asking the user to type in the name of a file which is going to be retrieved, present the user with a list of files currently available.

3. Robot console overview

The Robbie CX30 operator interface violated each and every one of Shneiderman's rules. Several of these violations were directly responsible for the accident which ended in the death of the robot operator.

The robot console was an IBM PS/2 model 55SX with a 80386 processor and an EGA color monitor with 640x480 resolution. The console had a keyboard, but no mouse. The console was embedded in a workstation which included shelves for manuals and an area for taking notes and for reading manuals. However, the reading/writing area was quite a distance from the computer screen, so that it was quite awkward and tiresome for the operator to manage any task which required looking something up in the manual and then acting quickly with respect to the console keyboard. The operator's chair was poorly designed and much too high relative to the console and the writing/reading area. This placed much strain on the operator's back and also caused excessive eye strain.

I cannot understand why a sophisticated system such as this would not include a better device for input. One can only conclude that Silicon Techtronics did not have much experience with user interface technology. The requirements document (5) specified a menu-driven system, which was a reasonable choice. However, in an application where speed was of the essence, especially when operator safety was at issue, the use of a keyboard for all menu selection tasks was an extremely poor choice, requiring many keystrokes to achieve the same effect which could be achieved almost instantaneously with a mouse. (See the paper by Foley et al. (6). Actually, I had most of these ideas before Foley published them, but he beat me to the punch.)

The robot operator could interact with the robot and thus impact upon its behavior by making choices in a menu system. The main menu consisted of twenty items, too many in my opinion, and each main menu item had a pull-down submenu associated with it. Some of the submenus contained as many as twenty items - again, too many. Furthermore, there seemed to be little rhyme or reason as to why the menu items were listed in the order in which they were listed. A functional or alphabetical organization would have been better.

Some items in the pull-down submenus had up to four pop-up menus associated with them. These would appear in sequence as submenu choices were made. Occasionally, a submenu choice would cause a dialogue box to appear at the screen. A dialogue box requires some kind of interaction between the operator and the system to resolve some issue, such as the diameter of the widgets being lowered into the acid bath. The menu system presents a strict hierarchy of menu choices. The operator could backtrack up the hierarchy by pressing the escape key. The escape key could also terminate any dialogue. The use of color in the interface was very unprofessional. There were too many colors in too small a space. The contrasts were glaring and the result, for this reviewer, was severe eye strain in just fifteen minutes. There was excessive use of flashing and