factors like handbooks (and how well they are written), access to system designers, attention paid by the management to the point of view of the operators, extent of training, and many others.

Human factor scientists have - rightly - pointed out these problems. But human-computer interface scholars are not free from responsibility. In their strict focusing on the interface alone, they indirectly contributed to grow the impression that new user interfaces, colour screens, supervisory control, were a panacea to solve many problems at once. We lacked a word of warning right from the beginning about the limits for the applicability of their results.

A final word about the change in the role of process operators. Some voices are raised - especially from Scandinavian countries - that process operators should be more directly involved in the control of a plant, taking over economic planning and management functions. Olsson and Lee (1992) suggest to couple process data with economic parameters and give the process operators actual budget-related targets.

I agree in principle on this point, but I am sceptical that such a change will be brought about with a conscious and explicit decision by anybody. If change will be, it will be forced by the emergence of new technology and how this technology is used. In recent times the personal computer has contributed much more to challenge the power structure in large organisations than any other factor could do. At the beginning of the Renaissance, Gutenberg's invention of the press stripped the Church from much of its power; for centuries, and in vain, European kings and emperors had tried to the same - without success. And finally, in most recent years even the fall of communist regimes in Eastern Europe was accelerated by information about the western lifestyle: the decision to air "Dallas" on Soviet TV had much more impact on Soviet society than all trade sanctions of the cold war.

Back to plant organization, process operators will have more saying about how plants are run when (1) there will be tools for them to control the plants by taking in management aspects (the tool could well be computers) and (2) there will be an implicit need to do it (e.g. to keep production costs low). If we want a change, then we must *invent something that provides the conditions for this change*. And if there is a need for change, then it will happen by itself.

In this Thesis, current experimental results about human cognitive capabilities were revised and put in perspective to indicate how computers can be used most effectively. Some tasks (pattern recognition, drawing conclusions from different clues) are more easily solved by humans; others (mathematics, simulation, fast logical operations) are more easily solved by computers. Computers should then be used to *enhance*, not to *replace*, human capabilities where these are not sufficient to perform the envisioned tasks.

The complexity approach gives indications for design, but has its own drawbacks. There is no general definition and metric for complexity to allow a critical analysis and evaluation of different design alternatives beforehand. Here is where human understanding and capacity for problem structuring are essential. The computer can reduce complexity only after a systematic analysis of the information delivered by a process, and only human ingenuity can succeed in this task. In addition, due to the fact that all workable definitions and measures for complexity involve tests with human subjects, practical tests and prototyping can give indications about usability and acceptance of a solution directly and without an explicit complexity analysis.

In this work we have also examined practical guidelines for the design of the "external" part of the user interface in relation to basic cognitive capabilities. The theory was then used in the evaluation of an actual system, the monitoring and control of a satellite ground control centre. This case study confirmed the fact that many solutions that are based on tradition or common sense, and that are carried out with user participation, can lead to acceptable results as if they had been based on formal theories of human-computer interaction.

There is no "standard" user profile. Some people are knowledgeable about computers, curious, show a positive attitude, and always want to learn more. Others are afraid of computers, or just unmotivated, and do not care much. But normally, and especially when a control system is built to retrofit an existing plant, users are technicians with good knowledge of the process under control. They mistrust the computer programmers who ignore the details of the industrial process. The computer system is accepted by the user when it is seen as a tool not to disrupt but to enhance the plant control operations. And the design of the user interface is just a part of the whole picture: For the user, the interface is not limited to the human-computer interaction in a strict sense, but includes other

6 Conclusions

In this Thesis we have examined some of the cognitive principles that are of relevance in human-computer interaction, and to what extent these principles can be used in the design of user interfaces.

Much work has been done (and is currently reported in the literature) about the "visible" or "external" design of the interface. Issues like keyboard layout, size and colour of characters on screens, handling of window interfaces, have been thoroughly investigated and many results are available. These aspects are undoubtedly very important, but cover only part of the problem at large. Mental models, expectations, and motivation by the user are equally important factors in the use of a system, but very few theories are available to describe and put these facts in perspective.

In this Thesis was presented a new approach based on the following assumption. A technical process to control can be considered in terms of its *complexity* reflected by its intrinsic information requirements (type and quantity of data, timescales, delays). If these requirements do not match normal human cognitive capability, then a computer monitoring and control system can be used to act as *complexity interface*. This approach indicates what the computer is supposed to do and what kind of complexity reduction must be carried out on the original data. This approach is also useful to define the scope for the use of computers: If a process can be fully handled by humans with no cognitive overload, then computers should not be used as user interfaces, unless there are special reasons for doing so.

The aspect of the user interface is therefore ultimately determined by the human cognitive capabilities and limits, the technical process to control, the goals to achieve, and how work is performed. It must *not* be the other way around, that the interface determines the operations or - even worse - that the interface actually increases the original complexity of the process. Cases where operators must "trick" the computer to do what they want are a sign of mismatch between user, task, and computer interface (on the other hand, they are an healthy indication that people, after all, are smarter than computers).