Computer-Based Research by Disabled Engineers: A Case Study

VIVIEN MORRIS, MA, DPhil
Senior Research Assistant, Department of Fluid Engineering and Instrumentation, Cranfield Institute of Technology, Cranfield, Bedford

It is well known that unemployment is particularly common among disabled people[1] and even highly trained graduates are often unable to find work appropriate to their qualifications. However, recent advances in computer technology mean that, in this area at least, it may be possible to mitigate the physical handicaps imposed by disability. Consequently, disabled people should be better able to achieve their vocational potential in computational work than in many other professions.

Objectives
The aim of the project was to allow a small number of severely disabled technology graduates with skills and interests in computing to work professionally for industry by providing them with training and technical equipment. Initially it was hoped that the group would become self-financing, but, in practice, constraints were identified which suggest that a small amount of external funding will probably always be necessary for a group of this kind.

Participants
It took longer than expected to find suitable participants, probably because highly-trained specialists were needed and such people are not numerous even among the able-bodied. Publicity on TV, in the national and local press, relevant technical journals and appropriate conferences[2], together with approaches to UK universities and polytechnics, professional institutions, associations concerned with disabled people[3], regional health authorities, spinal and rehabilitation units, etc., led to contact with four graduates with appropriate interests and abilities. Their background training covered mechanical engineering, electronic and electrical engineering, mathematics/computer science and civil engineering, and their respective disabilities were tetraplegia, congenital deafness and limited speech, blindness, and a rare form of muscular disorder.

Organisation
Cranfield Institute of Technology is a postgraduate university which works closely with industry, earning approximately half of its income from contract research. Much of the work of the Department of Fluid Engineering and Instrumentation (DFEI) on the analysis of flow is carried out for industrial clients so that it is particularly suitable for an enterprise of this kind, which requires industrial collaboration.

Work undertaken by participants was linked to research in progress at DFEI, but a period of training was generally necessary before they were able to begin working on commercial contracts. The management of the project was shared between several members of DFEI staff. It would have been preferable to appoint a full-time co-ordinator to arrange training programmes, select and modify computing equipment, liaise with industry, organise contract work, manage financial matters, as well as make some contribution to technical work. In practice, it proved impossible to find such a co-ordinator, possibly because those with relevant technical skills were unwilling administrators. It was particularly disappointing when the appointment of a disabled co-ordinator for a trial period was unsuccessful, though this may have been largely due to factors connected with his illness (multiple sclerosis).

Each participant lived and worked as seemed best suited to individual circumstances. Only one of the four was able to live on campus where there is close contact with academic staff and easy access to well-maintained computing equipment. Two participants worked from home, using microcomputers or telephone links to the mainframe computer at Cranfield. The civil engineer’s disability required residential care and he lived in the Part III accommodation associated with the Spastics Society’s Professional Workshop in Milton Keynes. Nevertheless, he found it difficult to endure the short taxi journey to Cranfield.

Equipment
Each participant was provided with a microcomputer and accessories but it was sometimes necessary to modify this equipment to take account of disability. The tetraplegic engineer operated his microcomputer very effectively with a mouthstick (Fig. 1) though slight modifications were necessary, e.g. to the shift key. He was also able to load and unload floppy discs by means of a specially designed rack. Small programs, or sections of large programs, were developed on this computer but access to the mainframe computer became necessary at a later...
stage to link individual sections together. A commercial company, CASE (Computer and Systems Engineering), kindly donated additional equipment to allow him to operate a telephone link to the mainframe computer at Cranfield. In addition, a large working surface was installed in his home, allowing access from a wheelchair, with a vertical section to support textbooks, manuals, etc., so that pages could be turned with a mouthstick (Fig. 2).

Fig. 2. Raised working surface with access from wheelchair.

Fig. 1. Tetraplegic engineer operating microcomputer with mouthstick.

Fig. 3. Computer operation by means of large-scale CCTV magnification system.

2) Manipulation of heavier items was difficult and a microfilm reader was purchased jointly with Imperial College so that he could access large amounts of information stored on film, according to his particular requirements, without handling paper copies.

Major problems with computing equipment were experienced by the blind mathematician. Although registered blind, he used his residual vision to operate a large scale CCTV magnification system (Fig. 3). The screen had to be continually switched between cameras focused on the VDU and on notes, as a split screen gave insufficient magnification, so the assimilation of information was slow and laborious. A voice synthesiser was attached to his microcomputer to give an audible record of input and output, but this by no means solved the problem. After discussions with the Royal National Institute for the Blind, the Manpower Services Commission (MSC) provided financial support to allow a sighted assistant to read aloud for 10 hours a week and, at a later stage, supplied a Braille link machine. This machine could be used independently to record and store information in Braille, or with the microcomputer (or telephone link to a mainframe) to provide a tactile record of computer input and output.

In view of the laborious process required to access information, it was not surprising that the mathematician worked much more slowly than a sighted person might have done. Research work at Southampton University[4] has suggested that blind subjects using a voice synthesiser take 3-6 times as long as sighted people to obtain information from a Prestel system. A much larger time factor would probably be appropriate if the user were attempting to assimilate complicated technical ideas. It remains to be seen whether the tactile Braille display proves to be more helpful than the audible record from the voice synthesiser or the visual image from the CCTV. At present, it seems appropriate to restrict the work to relatively short programs which can be retained mentally without too much difficulty. No special modifications to computing equipment were necessary for the two remaining participants.

Research Topics

During the period covered by this report, the DFEI undertook a major contract for a commercial manufacturer of electromagnetic flowmeters. The exact nature of the work is confidential but it accounted almost exclusively for about 18 months of the electronic engineer’s time and produced substantial income for the project. This
work also formed the basis for his MSc thesis, which was successfully submitted towards the end of 1983. Two other participants also carried out varying amounts of computational work linked to this contract and the company was charged for their time at DFEI's normal rates.

The mathematician undertook calculations connected with the design of specially shaped electrodes in an electromagnetic flowmeter for a project funded by the Science and Engineering Research Council (SERC) and began work linked to a flowmeter project carried out jointly by Cranfield and the University of Salford.

SERC provided some support for the civil engineer's work on computer modelling of systems of drains which become full during flooding. At the time of writing, this work is not complete so commercial exploitation is not yet feasible.

Other research topics involved developments of earlier work by members of DFEI staff and were not supported by external funds. This category includes work on an existing computer program to predict pressure surges occurring in the cooling system of a power station on the Isle of Grain. Recent tests allowed the actual pressures to be measured so that comparison of empirical and theoretical values became possible. The mathematician modified the original program so that it could be used on modern microcomputers.

The mechanical engineer was co-author of a report on the effects of installation on a 12-inch turbine flowmeter. The detailed nature of the work is confidential but it involved examination of the effects of sudden changes in flow on the meter's performance. Experimental values of various parameters were compared with theoretical predictions obtained from a computer program developed by this participant. The client was charged for his time at DFEI's normal rates. Since then, various aspects of the work have been developed beyond the scope of the original contract.

Output

The length of training required before participants were sufficiently expert to cope with work for commercial contracts varied enormously. In some cases, contract work was possible almost immediately, but in others it was still not feasible even after two years of training. Three of the participants registered for higher degrees and continued working for them in addition to contract work. Cranfield's close links with industry mean that thesis topics are directly related to industrial problems and results of contract research can often be used as the basis for a thesis. When necessary, the university accepted registration for a higher degree on the basis of part-time work from home. At the time of writing, the registration periods required for the two PhD programmes are still incomplete, while the author of the successful MSc thesis has begun work on a more substantial topic suitable for a PhD. This participant's deafness accounted for his enviable ability to concentrate on the task in hand despite the distractions of a noisy environment and, apart from speech therapy and help with telephone calls, little was needed to compensate for his disability. He was the only member able to work a full working week with normal efficiency. For various reasons, the other three all had restricted outputs. Difficulties in accessing information reduced the blind mathematician's efficiency to a tenth or a twentieth of that of a fully sighted graduate, and although the tetraplegic engineer worked effectively, his disability quickly produced exhaustion, so that he was able to spend only about ten hours a week on computational work. The fourth graduate suffered continual periods of sickness, some of which required hospital treatment, so that he made very little progress. It also seemed possible that the powerful drugs required by his disability may have affected his concentration. These restrictions inevitably led to a lower earning capacity than had originally been estimated.

Finance

The main source of income, apart from the two grants from charitable foundations, was from fees charged to industrial clients for whom research was undertaken. DFEI's normal practice is to charge customers overheads of more than 100 per cent, in addition to charges for time, and the same procedure was followed in this case. Thus, the major factor affecting income was the amount of work which could be satisfactorily completed in a given time.

There were many sources of expenditure. The initial cost of computing equipment was high, with the possibility of extra charges for specialised items to overcome disability. The graduates were paid for their work, but this was not administratively straightforward and the details varied between participants. It was sometimes possible to pay a student bursary to cover the initial training period, and to replace this with a salary as expertise developed. Alternatively, participants were paid as each piece of work was completed. Rates were based on commercial levels applicable to fully able graduates, regardless of the time actually taken to complete the work. Whenever necessary, payments conformed to DHSS requirements for disabled people in receipt of social security benefits. These sometimes seemed to be unnecessarily harsh and to actively discourage disabled people from working at home. At present, those whose earnings just exceed the £22.50 a week allowed as 'therapeutic' earnings are heavily penalised by withdrawal of benefits. The financial loss can amount to two or three times the earned income. Unless disabled people are able to guarantee earnings which exceed the benefits by at least £22.50, they lose money by working. The restricted working hours sometimes associated with severe disability mean that it may not be possible to overcome this financial barrier. At present, the DHSS does not recognise partial incapacity for work. The assumption is that one is either able to work, or completely unable to work, and no provision is made for those whose disability restricts potential earnings to the difficult band where earned income would exceed 'therapeutic' earnings but fall short of state benefits.

Additional charges for time, travel, etc. were incurred by members of staff who provided advice and guidance.
for disabled participants, co-ordinated research work, modified equipment, managed financial affairs and dealt with other administrative aspects.

Table 1 summarises income and expenditure throughout the four-year project. The figures show that a substantial proportion of costs was recovered as the project progressed. However, a large part of the income in 1982 and 1983 arose from one particular contract and it is almost impossible to achieve a steady flow of contract work. A shortage produces a corresponding drop in income, but an excess is undesirable if high standards are to be maintained. Consequently, it would not be realistic to expect to recover as high a proportion of costs as in 1982 and 1983 on a regular basis, particularly if numbers of participants increase. Each new recruit requires additional expenditure on computing equipment and this may not be offset by an increase in earning capacity until after an initial training period.

### Discussion

The therapeutic value of the work was apparent throughout. Participants stressed the frustration of unemployment and the fulfilment associated with the opportunity of undertaking interesting and stimulating work despite severe disability. During the period of the work, activities such as the International Year of Disabled People produced an increase in general awareness of the problems faced by disabled people and the discrimination to which they are often exposed. The Manpower Services Commission (MSC) now administers several schemes to assist disabled workers, e.g., fares to work, aids to employment, etc., but provision in the UK still falls short of that in countries such as the Netherlands and Sweden.[5]. The MSC has always been sympathetic to the work but the present group of graduates are highly trained professionals whose needs do not seem to be effectively served by government-sponsored schemes, such as Sheltered Industrial Groups, which cater for workers with a wider range of less specialised skills. This is particularly regrettable, as professional people may well be less handicapped in their work by physical disability than manual workers. Nevertheless, help was sought from the MSC, whenever possible, so that precedents and contacts could be established for use in the future when external funds from charitable sources might not be available.

The original aim of a self-financing consultancy group was not achieved for the following reasons:

1. Training periods were generally required before commercial contract work could be undertaken. These were sometimes unexpectedly long.
2. Severe disability sometimes restricted working hours, e.g. only 10 hours a week were possible for the tetraplegic engineer. Periods in bed or hospital reduced output.
3. Disability sometimes reduced working efficiency, e.g. difficulty in assimilating and retaining information was associated with blindness. Specialised equipment to counteract this is relatively expensive, e.g. a Braille computer terminal costs £5,000. In addition, drugs needed to overcome disability may reduce working ability.
4. Some degree of isolation was associated with work from home. Repairs to computing equipment took longer to arrange and there were sometimes delays while waiting for visits from academic advisers. There was a tendency to spend too long wrestling alone with a particular problem before seeking advice.

Nevertheless, the work suggests that it would be realistic to expect to recover a substantial proportion of costs. The percentage recoverable by disabled people in intellectual disciplines almost certainly exceeds that achieved by similar workers with less specialised skills. For example, Remploy, a government-sponsored organisation in which about 80 per cent of the workers are mentally or physically handicapped, trades in areas such as textiles, furniture, packaging and assembly. In 1981/82 it recovered just under 50 per cent of its costs[6], a figure exceeded by a comfortable margin in the present project.

### Conclusion

It appears that the external funding required to enable these engineers to work professionally is relatively low, probably of the same order of magnitude as the state aid which would automatically be paid if they were unemployed. However, the returns in terms of self-fulfilment are high and, in addition, are associated with useful contributions to engineering research. It might well be desirable to modify existing government-sponsored schemes to allow a nationwide network of such groups, possibly based in universities, so that computational research could be undertaken by severely disabled professionals in other parts of the country. Although the interests of the original group were confined to industrial fluid mechanics, there seems to be no reason why the concept should not be extended to computer applications in other disciplines.
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References

1. Kettle, M. (1979) Disabled people and their employment. Banstead: Association of Disabled Professionals.
2. Enever, K. J. (1981) Distech '81. Proceedings of a conference at Sussex University, March 30-April 3. London: The Spastics Society.
3. Baker, R. G. and Morris, M. V. (1981) Contact, No. 30, p.15. London: Royal Association for Disability and Rehabilitation.
4. King, R. W. (1983) Personal communication.
5. Greaves, M. and Massie, B. (1977) Work and Disability. London: Disabled Living Foundation.
6. Marsh, P. (1982) New Scientist, 95, 218.

Sloane Deaf

Sir Hans Sloane, Bart., MD, was President of the Royal College of Physicians from 1719 to 1735 and President of the Royal Society from 1727 to 1740. He was first physician to King George II, and the British Museum was founded as a result of his generous will. His name is remembered in Hans Place, Sloane Street and, most famous of all, Sloane Square. Sloane Square is the focal point of a stratum of British society described in The Official Sloane Ranger Handbook[1]. The people and their way of life are described, respectively, as Sloanes and sloane, and the male type case is known as Henry. Intriguingly '... Henry goes deaf, one ear at a time[2].

Dr Henry X, a 28 year old medical man who enjoyed rough shooting, noticed that tete-a-tete dinners were best conducted with the girl to his right otherwise he found it difficult to hear the higher pitched sibilants, ‘c’ and ‘s’. He was, with his left ear, unable to hear his watch tick and found telephone conversations easier with the receiver held to the right. Medical students are taught that fine pulmonary crepitations are like the sound of hair being rolled between finger and thumb: he was unable to appreciate this with the left ear where the sound lacked sharpness. As a medical student, he had served for two years in the Honourable Artillery Company and had not worn ear defenders when exposed, at close quarters, to the sound of rifle and artillery fire. Ear, nose, throat and general physical examination were normal but audiograms demonstrated left-sided high-tone sensorineural loss characteristic of noise trauma deafness (NTD) (Fig. 1).

Boilermakers develop bilateral NTD. Henry and other users of rifles and shotguns develop unilateral NTD. Usually, it is left-sided because a right-handed person holds a gun to the right shoulder with the head lying at an angle to the gun. The left ear is nearer the muzzle and the noise trauma, while the right ear faces the stock and is protected by the 'head shadow effect'.

If shooting in Britain is mainly a sloane pastime[3], is Henry 'sloane deaf'?

References

1. Barr, A. and York, P. (1982) The Official Sloane Ranger Handbook. London: Ebury Press.
2. Ibid., p.21.
3. Ibid., pp.149-150.

C. M. E. ROWLAND PAYNE