# Numerical Analysis at the Victoria University of Manchester, 1957–1979*

Joan Walsh

2004

The development of Numerical Analysis in Manchester was stimulated by the pioneering work on automatic computers which started in Manchester in the late 1940's. The research group on computers was led by F.C. Williams and T. Kilburn in the Department of Electrical Engineering; the Manchester Mark 1 machine came into operation in 1948, followed by the Mark 2 (prototype Mercury) in 1954 and the Atlas in 1962. At the same time the Mathematics Department was expanding considerably under Max Newman, Sydney Goldstein and James Lighthill. Newman was a strong supporter of the computing project, foreseeing its importance for many areas of mathematics as well as for other fields. In 1957 he appointed Dr C. B. Haselgrove (who had been working on the first computer at Cambridge) to promote research in mathematical computing in Manchester. Some of the applications of computers were immediately obvious; many well-formulated problems in science and engineering which required numerical solutions could benefit directly from faster computation. This was particularly true in astronomy, a classical area for numerical work, where the research at Jodrell Bank called for major computing support. But there was also the prospect of using automatic machines to solve analytical and logical problems in new ways, which were not simply accelerated versions of existing methods

Brian Haselgrove's research interests ranged over many areas of mathematics both pure and applied. At Cambridge he had collaborated with J. C. P. Miller on table- making (for the Riemann zeta function), and at Manchester he published papers on Dirichlet functions and the Riemann hypothesis, ray paths in the ionosphere, numerical integration using quasi-random numbers, two-point boundary-value problems, and some geometrical puzzles. The paper on boundary-value problems (*Comp. J.*, 4. 1962, p. 255) illustrates an early stage of what was to become a major interest of numerical analysts at Manchester and elsewhere, the development of general algorithms. This work involves the elucidation of classes of mathematical problems which are suitable for solution by a standardised approach. The solution methods have to be studied analytically and tested on an extensive range of problems, to determine their applicability and limitations. In the early 1960's the potential for general solvers was becoming apparent, but the programming languages available did not provide enough flexibility for implementation.

On the teaching side, Haselgrove initiated a postgraduate Diploma in Computing in 1959 in collaboration with Tony Brooker and other members of the Computing group. In 1964 Computer Science became a separate Department, and the postgraduate course (which became an M.Sc. in 1965) began to concentrate on the more mathematical aspects of computing, retaining some options from Computer Science. Student numbers were relatively small at first, but the course provided a source of research students in Numerical Analysis. Haselgrove also introduced an undergraduate course in numerical methods and computer programming, but it was not possible to include realistic practical work until autocodes were designed.

*This article originally appeared in [1].

The Department supported the expansion of activity in numerical mathematics by providing further posts in the 1960's. Joan Walsh was appointed from CEGB in April 1963, and Geoffrey Shearing and Will McLewin (who were already in Manchester) in October 1963. Brian Haselgrove died after a short illness in 1964. The group began to arrange short courses on effective numerical computation for users across the university, with the help of colleagues from Physics, Engineering, and Computation at UMIST. It was soon evident that widespread use of the computer by non-specialists would require the "packaging" of mathematical expertise into easily-applied programs, and contacts with users showed the main areas of demand. A prime mover in this direction was J. H. Wilkinson at the National Physical Laboratory, who produced highly developed methods for many basic problems of linear algebra. Another requirement among chemists and physicists was the accurate computation of special functions, which created a minor industry in the area of Chebyshev approximation. These and other advances in mathematical computation were brought together at an IMA conference in Birmingham in 1965, which attracted a large audience and promoted the value of good mathematical methods in numerical work.

The range of topics covered by the Manchester group was broadened by additional appointments: George Hall in 1965, Christopher Baker in 1966, and Ian Gladwell in 1969. (Geoffrey Shearing had earlier moved to Newcastle.) At this time the main users of numerical computation were scientists and engineers; applied mathematicians had a strong tradition of pursuing their problems by classical analysis as far as possible, and resorting to the computer only when all else failed. But many problems in science and engineering were quite intractable without computers, and large-scale numerical modelling of physical situations became feasible and popular as machines became more powerful. Leslie Fox (then at Oxford) was concerned that basic mathematical research in Numerical Analysis should not be neglected, and he advocated a special initiative by the Science Research Council (now EPSRC) to encourage greater research activity in the theory of numerical computation. The SRC eventually made special grants in the early 1970's to three institutions (Oxford, Dundee and Manchester), to strengthen their research groups by supporting research students, fellows and visitors. This helped to raise the profile of the subject, and to improve links with overseas workers, particularly in the U.S.

When standard computer languages were introduced in the 1960's, it became possible to address the need for high-quality algorithms. In linear algebra, where the problems were relatively easy to classify, a series of Algol procedures were published by Wilkinson and others in the journal *Numerische Mathematik*, and collected into a Handbook in 1971. This material then had to be implemented on particular computers, and translated into Fortran for general use. Wider distribution showed that difficulties could arise from variable word-lengths and computer arithmetic, and that strict language standards were needed. In 1970 a group of institutions which had common computing hardware (ICL 1906A machines) agreed to form a consortium to work on a library of algorithms, the original members being Nottingham, Leeds, Oxford, Birmingham, Manchester and the Atlas Laboratory at Chilton. The aim was to collaborate in the development of a comprehensive mathematical library, with high standards of testing, documentation, and maintenance. The first edition of the library was issued in Sept 1971, and within a few years, by careful attention to word-length problems and language variations, it became possible to make it available for most machine ranges. The consortium attracted support from many academic and research groups, and it was incorporated as the Numerical Algorithms Group (NAG Ltd) in 1976. The Manchester group was involved in the NAG project from the beginning, providing contributors, testers, and validators. A particularly significant contribution was made by Ian Gladwell, in the section on ordinary differential equations. The project received financial help from the Computer Board (a Government agency) for several years, until it was able to support itself by commercial sales of the software. The material was expanded and revised continuously, with the help of contributors and critics from Britain

and abroad. Some areas, notably partial differential equations, were difficult to handle in the library format, but eventually specialised packages became available for these problems, and the library was further enhanced by links to graphical facilities.

Staff appointed at Manchester in the 1970's were Jack Williams in 1971, and Len Freeman in 1976. The special SRC grant for Numerical Analysis supported a number of visitors, including Louis Rall from Wisconsin (1973), Harry Robertson from ICI Runcorn (1973–74) and Charles Van Loan, a postdoctoral fellow who went on to work at Cornell (1974–75). SRC also provided more research studentships, and 22 Ph.D. students began their courses in the years 1970–79. Towards the end of this time the SRC introduced CASE studentships for projects linked to industry, and the Manchester group used these to establish closer collaboration with local firms such as Rolls-Royce and ICI. The number of students on the M.Sc. course increased; a part-time M.Sc. was started in 1973, but the demand was not sufficient to maintain it. Another activity which aimed to disseminate advances in Numerical Analysis was a series of Summer Schools, which were organized jointly by the numerical analysts at Liverpool (under L. M. Delves) and Manchester. The first one, on boundary-value problems, was held at Liverpool in 1971, and succeeding Schools covered integral equations (1973), initial-value problems (1975), partial differential equations (1978), nonlinear problems (1980), and advances in algorithms (1984). The lecturers at these meetings included leading external contributors, and the proceedings of the last five were published by O.U.P. The link with Liverpool also led to cooperation over industrial consultancy and projects; on the Manchester side this work involved mainly Ian Gladwell and Len Freeman.

By the end of the 1970's the position of Numerical Analysis as a branch of Mathematics was well established in undergraduate syllabuses; the number of specialist journals and conferences had increased greatly, and computation was playing a significant role in areas of pure mathematics, as Newman had anticipated in 1948. Computer use became almost universal when powerful desk machines were introduced in the 1980's, and the work which had been done on numerical methods and algorithms provided a good basis for general software packages.

## References

[1] Manchester Centre for Computational Mathematics. Annual report: January–December 2003. Numerical Analysis Report No. 449, Manchester Centre for Computational Mathematics, Manchester, England, May 2004.