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Computing in Britain During World War II

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A country at war requires accurate artillery and active research into new weapons and defence mechanisms. At the outbreak of World War II Britain needed both to increase its ballistic table production and to provide the resources to support the one-off mathematical investigations frequently required for the development of new weapons and for other research projects. Just as the government had been recruiting suitable staff and equipment into GCHQ and radar research before the war, they had also recognised that additional skilled personnel and computing resources would be needed.

As early as 1938 the Nautical Almanac Office had been asked by the Ordnance Board to advise on the practicality of applying National Accounting Machines to trajectory calculations. The Royal Society also undertook a survey of the computing resources and personnel available in academic institutions and, when war was declared, many of these machines were requisitioned and the staff hired.

This paper will describe how the service ministries expanded their computing capacity both at the start of the war and during hostilities. The institutions and individuals involved will be considered along with and the kind of computing technology they employed. While they did have implications for computing in the

post war period, the Colossi, Bombes and other machines built at Bletchley Park during the war will not be included in this summary which will be confined to scientific computing within the service ministries.

L.J. Comrie and the Scientific Computing Service

L.J. Comrie (1893-1950) was the acknowledged king of the British mathematical table making community in the 1930s – a reputation he enhanced during the war[1]. Comrie was a New Zealander who had served with the New Zealand Expeditionary Force in France during the First World War where he had lost a leg. While recovering Comrie attended some classes in practical computation given by Karl Pearson at University College, London and it was here that he learnt how to use a Brunsviga calculator . After completing a Ph.D in astronomy from Cambridge, Comrie taught in the US for a couple of years before returning to England and a post in the Nautical Almanac Office. The main task of the Nautical Almanac Office was to compute the astronomical tables published annually in the Nautical Almanac used for both navigation and astronomy. Comrie was appointed Superintendent at the Nautical Almanac Office in 1930 and he revolutionised the computing methods employed there. When he joined the Office, the bulk of the calculations were done by hand using logarithms – by the time he left in 1936, the Office was using a range of calculating machines including Brunsvigas, Burroughs Machines and National Accounting Machines, and, on a more limited scale, Hollerith punched card machines[2].

Comrie did not restrict his computational activities to the Nautical Almanac Office. As one biographer put it Comrie "spread the gospel of mechanised computation"[3]. As a result people began to consult him about their computational

difficulties and, where he could, Comrie helped out. For example in 1934 Comrie used Nautical Almanac Office staff and machines to carry out triangulation calculations for the Geographical Section of the War Office. The Admiralty, Comrie's employer, did not approve and instructed him NOT to carry out any more external work. However, Comrie continued and in 1936 undertook some sound ranging work for the War Office. The Admiralty found out and Comrie was dismissed[4].

However this was just the impetus Comrie needed. In 1937 he set up the Scientific Computing Service as a commercial scientific computing bureau – the first of its kind. He assembled a wide range of calculating machines and a competent staff and offered his services to the scientific community. The SCS (as it became familiarly known) was to become one of the major computing resources for government during the war[5].

Comrie liked to tell the story of how at 2.00 pm on Sunday September 3rd 1939 – three hours after war was declared – he was telephoned at home by a Major from the War Office. The Major asked him if he and his staff could prepare fire control tables for anti-aircraft guns; the Major's own staff had said it would take a month to prepare one of the three tables necessary – could Comrie do one in three weeks? Comrie accepted the task and the SCS made two of the three tables in only 12 days – including seeing the tables through press and checking the proofs[6].

This was to be the beginning of a very fruitful relationship between the SCS and the service ministries. The SCS was involved in many war time jobs including helping to locate German radio guidance transmitters as described in R.V. Jones's book *Most Secret War*[7], the preparation of wind graphs for sound ranging analysis, making bombing tables for the US Air Force and on going triangulation calculations for the War Office.

The Ministry of Supply

While service ministries had access to the SCS on the commercial basis it could not possibly undertake all of the extra computing generated by the outbreak of war. As far as I am aware, and you may be able to tell me differently, the Ministry of Supply was the first service ministry to make special provision for the increased demand for scientific computation.

The Ministry of Supply was created on 1st August 1939 and took over the supply departments of the War Office and the Air Ministry (MAP – Ministry of Aircraft Production was not created until May 1940). It also incorporated the Ordnance Board and the Research departments of the War Office. The Ministry of Supply thus became responsible for most of the ballistics research being carried out in Britain at that time. In 1938 changes had been made to the theory governing the air resistance of cylindrical projectiles which had the effect of making most of the trajectory calculations and ballistics tables for existing weapons obsolete. In addition, new weapons were coming into production which also needed ballistics tables before they could become effective in the field. Hence the War Office's phone call to Comrie.

While the Ordnance Board already used National Accounting Machines to compute trajectories, these were insufficient to meet the sudden increase in demand. Consequently the Ministry of Supply began to look around for additional computing resources and, on 1 September 1939, 2 days before the outbreak of war, the Ministry of Supply External Ballistics Department took over the Cambridge Mathematical Laboratory under a lease agreement.

The Cambridge Mathematical Laboratory

The Cambridge Mathematical Laboratory had been created by John Lennard-Jones as a centralised computing resource for scientists at Cambridge University[8]. Lennard-Jones was Plummer Professor of Theoretical Chemistry at Cambridge University. He was seconded to the Ministry of Supply in 1939 and served as Chief Superintendent of Armament Research and, in 1945, as Director General of Scientific Research to the Ministry of Supply. The Cambridge Mathematical Laboratory was equipped with a model differential analyser, several desk machines, and the Mallock Machine (an electrical simultaneous equation solver). What most attracted the Ministry of Supply was that the Mathematical Laboratory was expecting delivery of a full sized 8-integrator differential analyser from Metropolitan-Vickers in late 1939. A Differential Analyser is an analogue device consisting of a set of interconnected disk and wheel integrating mechanisms which can be set up in such a way as to describe and solve differential equations – the most common method of output was a graph plotter. It looked very much like a big Meccano set and many of the model differential analysers made in the 1930s were indeed constructed largely from Meccano.

Under Lennard-Jones the Ministry of Supply built up a team of young mathematicians including E.T. "Charles" Goodwin, James Wilkinson, and Tom Vickers to carry out ballistics calculations for guns and rockets, research into high explosives theory and sound ranging. While the prospect of having access to the Differential Analyser had been the main motivation for taking over the Cambridge Mathematical Laboratory, the External Ballistic Department team soon found that, while the machine was excellent for research work and for understanding problems, its accuracy was too low for the routine calculation of trajectories – a conclusion the Aberdeen Proving Ground in the United States also came to[9]. While the Differential

Analyser was kept busy on research, the bulk of the work in the Cambridge Mathematical Laboratory was carried out using desk machines. The staff there worked mainly on ballistics problems and the facility was only occasionally used by outsiders.

Other computing centres: Manchester, Oxford and the RAE

In contrast the Manchester University Differential Analyser which Douglas Hartree had installed in 1935[10] was used during the war for consultancy work and was open to almost anyone who required it. Like Lennard-Jones, Hartree began to work for the Ministry of Supply almost as soon as the war started and he built up a small but effective team to operate the differential analyser. This team eventually became part of the Headquarters Section of the Ministry of Supply while Hartree himself joined the Projectile Development Establishment at Fort Halstead. The Manchester Differential Analyser was used by a wide range of people from both inside and outside the Ministry of Supply and its work included the calculation of heat flow in rocket tubes, a study of servomechanisms in fire control equipment, the propagation of blast waves and many other investigations.

Scientists and mathematicians at other universities also contributed to the war effort either by performing computing work or by acting as mathematical consultants. One such example was R.V. Southwell. Southwell, Professor of Engineering at Oxford, established a research group working on solving large numbers of simultaneous equations using his well known relaxation methods[11]. Like Hartree's group, Southwell's team acted primarily on a consultancy basis and worked especially closely with the Air Ministry.

While the service ministries were keen to acquire or make use of outside computing facilities, most research departments had some, albeit limited, computing resources of their own. Many had desk calculating machines, a few had National or Burroughs Accounting Machines and some, such as the Armament Research Department at Woolwich and the Coast Artillery Experimental Station had model differential analysers. Very few scientists had punched card machines at their disposal.

As R. A. Fairthorne, a member of staff at the Royal Aircraft Establishment at Farnborough during the war, recalled:

> "All devices for calculation, large or small, were almost unobtainable even in government establishments and certainly so far as junior officers were concerned. During one part of the war I had to do some calculations using my personal copy of Peter's Multiplication Tables because I would have had to cycle some miles to queue up to use a desk calculator. All punched card machinery was tied up for essential statistics and logistics"[12]

However, this did not stop the staff at Farnborough trying to improve the computational facilities available to them. In particular the Royal Aircraft Establishment pressed for permission to install Hollerith punched card machines in their structural and mechanical engineering department, to help to solve the large sets of simultaneous equations arising from their work on structural stress in aircraft bodies[13]. They already had a limited number of desk calculating machines, as Fairthorne has indicated, and were using Southwell's relaxation techniques. They had also tried, with little success, the Mallock simultaneous equation solver at Cambridge. They pressed the Aeronautical Research Council for a Hollerith installation but one

was not installed until 1945 when the pressure on the supply of such equipment began to lessen.

The Nautical Almanac Office

Unlike the other service ministries, the Admiralty already had a well equipped and knowledgeably staffed computing centre in the form of the Nautical Almanac Office. While before the war the Admiralty had sacked Comrie for taking on outside work, when war broke out the Admiralty recognised that it had an extremely valuable resource which it came under pressure to open up. Donald Sadler, Comrie's successor as Superintendent, began to take on outside work in autumn 1939[14]. In the first two years of the war the Nautical Almanac Office took on ballistics table work for the Ordnance Board, the Air Ministry and the Ministry of Aircraft Production as well as more specialist one off pieces of research work for various Admiralty research establishments; one example was a calculation involved in mine design.

To add to the pressure on the Nautical Almanac Office its own work had increased. Before the war the computation of star positions had been jointly shared between several countries. The war had terminated those agreements and the Nautical Almanac Office had now to calculate all its own astronomical data for the annually published Nautical Almanac – now an even more critical publication for navigational purposes. However, it was not until July 1941 that Sadler received an extra member of staff to help cope with the ever increasing work load.

Because of Sadler's unique position in running a major computing facility to which many service ministries were applying for help, he could see a need for a large, central computing facility to which all of the armed forces and the scientific civil service could have access. In 1941 he wrote a formal proposal for the creation of just

such a facility but the suggestion came to nothing as the ever increasing crisis of computing resource had not yet been recognised by those in power.

A suggestion from another quarter to centralise computing within the Admiralty did, however, bear fruit.

The Admiralty Computing Service

In 1942 John Carroll, Professor of Natural Philosophy at Aberdeen became Assistant Director of Scientific Research at the Admiralty's Scientific Research and Experiment Department (SRE). The role of SRE was to administer naval research establishments and act as a means of communication and liaison between them. It also had a role in keeping Admiralty establishments briefed on scientific developments taking place outside the ministry. Before joining the Admiralty, Carroll had had a keen interest in mathematical tables and desk machine computation and had consulted Comrie about the purchase of machines for use by his students.

When Carroll joined the Admiralty SRE Department he soon became aware that a significant amount of time was being spent by Admiralty experimental staff in performing calculations. Many calculations were inseparable from their experimental background and many were brief but Carroll was concerned about scientific effort being wasted by staff performing long, repetitive calculations – particularly in cases were specialized knowledge or machinery could achieve the same, or better, results much more quickly.

Later the same year, 1942, John Todd, a pure mathematician but later to become a well known Numerical Analyst at the US National Bureau of Standards and at the California Institute of Technology, joined Carroll at the Admiralty SRE Department. At the beginning of the war Todd had been assigned first to a degaussing

range and then to the Mine Department of HMS Vernon where he had been employed doing minor calculations concerning electrical circuits. He late recalled

> " I realized that pure mathematicians, such as I, could be more useful in dealing with computational matters and relieve those with applied training and interests from what they considered as chores"[15]

As a result of Carroll and Todd's feelings they asked Sadler to prepare a report on the possibility of centralizing computing within the Admiralty[16]. The main points given in Sadler's report were

a) Some computation with Admiralty establishments could, with advantage, be centralized.

b) Research and experiment work give rise to a proportion of work unsuitable for centralization and there will always be a need for some local computing facilities.

c) Centralization would speed up large calculations and make possible complex calculations for theoretical research which were not possible at the local level.

As a result in early 1943 the Admiralty Computing Service was created. It was administered by John Todd in Whitehall through which all requests for computing were to be fed. Todd would then decide whether to pass the investigation on to one of a number of senior mathematicians that the Admiralty Computing Service employed on a consultancy basis (such as N. Aronszajn, W.G. Bickley, L.J. Comrie, A. Erdélyi, P.P. Ewald, J.C.P. Miller, E.H. Neville and S. Vajda) or send it to Sadler at the Nautical Almanac Office which was to be main computing facility of the Service. This official recognition that the Nautical Almanac Office was acting as a computing

centre meant that Sadler got extra computing staff, many of them university trained mathematicians, to ease the computational burden. Those whom Sadler managed to recruit to Admiralty Computing Service included Goodwin who had been a member of the External Ballistics Department group at the Cambridge Mathematical Laboratory, Leslie Fox who had been a student of Southwell's at Oxford, and many others including F. Olver, K. Blunt, and H.H. Robertson.

From 1943 to 1945 the Admiralty Computing Service performed a wide range of jobs including an investigation into the theory of supersonic flow, some trajectory work, work on stresses in turbines, and a statistical investigation into the night vision capabilities of naval personnel. They also produced reports on many of the jobs they completed and, while some of them only reported on the mathematical theory without explaining the particular classified application, the reports helped to increase the understanding of what could be achieved by numerical computation and, in particular, what Admiralty departments could gain from using the Service.

The Influence of the Admiralty Computing Service

Within a year of the Admiralty Computing Service becoming operational Carroll, Todd, and others within the SRE Department realised that the degree of centralization that the Admiralty Computing Service offered did not go far enough. It was not running on a sufficient scale to make it economically feasible to install punched card machines or a differential analyser. Carroll proposed to Sir Edward Appleton, secretary of the Department of Scientific and Industrial Research (DSIR), that a national computing organization be set up. Their proposal called for the creation of a large government sponsored computing bureau and also recognised the need for research into new computing methods and machines. The idea was taken on board by

the DSIR and a consultative Committee was set up. The result of the Committee's deliberations was the creation of the NPL Mathematics Division established in 1945 as a National Computing Centre[17] and which became one of Britain's three main centres for electronic computer research in the post war period.

The list of people who sat on the DSIR Committee set up to consider the creation of the NPL Maths Division is interesting as many had been intimately involved with computing problems during the war.

- Sir Charles Darwin was Director of the NPL and knew of the computing needs there. He was also a friend of Lennard-Jones and the two are know to have discussed the need for a national computing centre as early as May 1943.
- Sir Harold Spencer-Jones was the Astronomer Royal and knew of the work of the ACS.
- Carroll, Sadler and Todd had, of course, run the ACS.
- Frank Yates was from the Rothamsted Agricultural Station which had carried statistical work for the government during the war.
- Prof. W.J. Duncan and S.H. Hollingdale represented the Ministry of Aircraft Production and knew of the efforts with the Royal Aircraft Establishment to increase their computing facilities.
- J.R.N. Stone came from the War Office Statistical Unit
- A.W. Taylor was from Customs and Excise
- Dr. Christopherson and Dr. David came from the Ministry of Home Security
- Hartree had installed the Differential Analyser at Manchester and was an official Ministry of Supply representative

- J. W. Maccoll, was all a Ministry of Supply representative who worked for Lennard-Jones in the External Ballistics Department and at Fort Halstead.
- J.R. Womersley (who went on to be Superintendent of the NPL Maths Division) had worked in the Armament Research Department at Woolwich and the Ministry of Supply Statistical Advisory Service.
- Major General G. Cheetham represemted the Ordnance Survey Office
- Major E.H. Thompson was from the War Office Military Survey Department.
- Goldstein was the official DSIR representative.
- And A.W. Mattocks and G.F. Peaker were Treasury officials.

When the NPL Mathematics Division was established in 1945 senior Admiralty Computing staff (Goodwin, Fox, Olver, Blunt and Robertson) were gradually transferred into the NPL as were some External Ballistics staff from Fort Halstead, such as Jim Wilkinson and Tom Vickers. Along with Alan Turing from Bletchley Park they formed the core staff of the NPL Mathematics Division which, over the next twenty years, not only provided a computing service to government and industry but also became of centre for research into numerical analysis and electronic computers.

This paper represents a snap shot of the computational landscape of war time Britain. There were other small scientific computing centres active in Britain during the war and I am still in the process of researching them. If readers know of any I have missed I would be very glad to hear about them.

Acknowledgments

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Endnotes

[1] Biographical information concerning Comrie is given in M. Croarken, "L.J. Comrie: A forgotton figure in the history of numerical calculation", *Mathematics Today*, August 2001, Vol. 36, no. 4, pp. 114-118; W.H.M. Greaves, "Obituary Notices: Leslie John Comrie", *Monthly Notices Royal Astronomical Society*, 1953, Vol. 113, no. 3, pp. 294-304; H.S.W. Massey, "L.J. Comrie", *Obituary Notices of Fellows of the Royal Society*, 1952, Vol. 8, pp. 97-107.

[2] L.J. Comrie, "Computing the Nautical Almanac", *Nautical Magazine*, July 1933, pp. 33-48. L.J. Comrie, "The Nautical Almanac Office Burroughs Machine", *Monthly Notices Royal Astronomical Society*, 1932, Vol. 92, pp. 523-541. L.J. Comrie, "The application of the Hollerith tabulating machine to Brown's tables of the Moon", *Monthly Notices Royal Astronomical Society*, 1932, Vol. 92, pp. 694-707.

[3] H.S.W. Massey, "L.J. Comrie", *Obituary Notices of Fellows of the Royal Society*, 1952, Vol. 8, pp. 97-107, p. 100.

[4] See M. Croarken, "Case 5656: L.J. Comrie and the origins of the Scientific Computing Service", *IEEE Annals of the History of Computing*, 1999, Vol. 21, no. 4, pp. 70-71.

[5] M. Croarken, *Early Scientific Computing in Britain*, Oxford: Clarendon Press, 1990. See chapter 4.

[6] "Mathematics in War", 1948 Radio Broadcast by L.J. Comrie, transcript in "New Zealand Revisited and Australia Visited 1948", Scientific Computing Service internal publication. Recording held in the Royal Society archives AV R.6.

[7] R.V. Jones, *Most Secret War*, 1978, London: Hamish Hamilton.

[8] M Croarken, "The Emergence of Computing Science Research and Teaching at Cambridge, 1936-1949", *IEEE Annals of the History of Computing*, 1992, Vol. 14, no. 4, pp. 10-15. Also M. Croarken, *Early Scientific Computing in Britain*, Oxford: Clarendon Press, 1990, chapter 5.

[9] "Ministry of Supply Advisory Council on Scientific Research and Technical Development: Ballistics Committee" Report – no date. Public Records Office WO 195/5015.

[10] D.R. Hartree, "The Differential Analyser", *Nature*, 1935, Vol. 135, pp. 940-943.

[11] R.V. Southwell, *Relaxation Methods in Engineering Science*, Oxford: Clarendon Press, 1940.

[12] Letter from R.A. Fairthorne to M. Croarken, 11 June 1983. In possession of M. Croarken.

[13] M. Croarken, *Early Scientific Computing in Britain*, Oxford: Clarendon Press, 1990, p. 106-109.

[14] M. Croarken, *Early Scientific Computing in Britain*, Oxford: Clarendon Press, 1990, pp. 66-67.

[15] Letter from John Todd to M. Croarken, 26 July 1983 and 28 July 1983. In possession of M. Croarken.

[16] The details of the formation of the Admiralty Computing Service are given in M. Croarken, *Early Scientific Computing in Britain*, Oxford: Clarendon Press, 1990, chapter 6.

[17] M. Croarken, "The Creation of the NPL Mathematics Division – a Central Mathematical Station", in J. Copeland, *ACE 2000: Proceedings of a conference held in May 2000*, forthcoming by Springer London in 2003. Also M. Croarken, *Early Scientific Computing in Britain*, Oxford: Clarendon Press, 1990, chapter 7.