# Disseminating electronics: Bell Telephone and the emergence of electronic computing expertise in post-war Belgium, c1945-c1960

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***Abstract*** **— We explore the role of Bell Telephone Mfg Co, hereafter 'BTMC', a major European provider of electronics and switch technology from the 1910s onwards, in the emergence of electronic computing expertise in post-war Belgium. In 1951, BTMC entered into collaboration with two national research funding bodies, the FNRS and the IRSIA, towards the construction of a Belgian electronic computer, the Machine mathématique IRSIA-FNRS. We explore the ways in which the running of, and people involved in this project, among others Vitold Belevitch (1921-1999), led to the dissemination and appropriation of Anglo-Saxon electronic computing know-how in Belgium.**

***Index Terms*** **— Computer industry; Electronics industry; Ferrites; Magnetic materials**

## I. Introduction

From the 1910s Bell Telephone Mfg Co, hereafter 'BTMC', has grown as a major European firm in electronics and switch technology. BTMC is as such part of the history of science and technology in Belgium for its impact and role upon Belgian telecommunications [2-3, 42]. Although it is lesser known, BTMC participated to the emergence of electronic computing expertise in Belgium too. From c1950, BTMC participated to the construction of a Belgian national computer alongside Belgian scientific research funding bodies, the FNRS, the Fonds National de la Recherche Scientifique, and the IRSIA, the Institut pour l'Encouragement de la Recherche Scientifique dans l'Industrie et dans l'Agriculture. The construction of this computer, the Machine mathématique IRSIA-FNRS, hereafter 'MIF', made BTMC a platform for the dissemination and appropriation of Anglo-Saxon know-how in electronic computing.

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In this paper we explore the ways in which the running of, and people involved in this project, e.g. Vitold Belevitch (1921-1999), led to a process of appropriation of Anglo-Saxon electronic computing know-how in Belgium. We explore Belevitch's role at BTMC and the CECE, the Comité d'Etude et d'Exploitation des Calculateurs Electroniques, a subsidiary of the IRSIA and FNRS set up in 1955 towards the exploitation of the MIF and research in electronic computing-related issues. Methodologically, by and large, the information interpreted in this paper originates in an oral history programme on Belgian computing history at the Facultés Universitaires Notre-Dame de la Paix, Namur [1].

## II. Catching up with Anglo-Saxon wartime science and technology advances

By Anglo-American standards, the state of science and technology in post-war Belgium was quite poor due to years of stagnation under German occupation. This state of affairs pervaded most continental Europe. For military and economic reasons, it was felt in political milieus that action was needed to catch up with Anglo-Saxon wartime advancement in science and technology. Backwardness issues were identified e.g. in electronics, by then an emerging domain of research. Yet electronics was also central to the recent boost to the development experienced in the US and UK by the physical sciences, most notably in nuclear physics [4-7]. Especially, this was due to that electronics research was the provider of components towards high-speed electronic computing machineries. Electronic computing machines are indeed a side-product from World War II, the first such machine being the ENIAC unveiled in 1945. Thereafter, engineers in the US, UK and Europe deployed efforts towards realising high-speed electronic stored-program computers, developing designs inspired by von Neumann's 1945 *Report on the EDVAC*. These efforts led to computers such as the 1948 Manchester Baby, the 1949 Cambridge EDSAC, the 1951 Manchester Ferranti Mark I, and Aiken's Harvard Mark computer series, 1950- [8-11].

In Belgium, at hearing about the ENIAC and the progress of the physical sciences in the US, the FNRS and the IRSIA joined forces and set some financing for stays for Belgian researchers in the US. In 1946 researchers in the physical sciences were thus sent spending time in the US to collect information on American research in the physical sciences and electronics [12]. Charles Manneback, a physicist at the Université de Louvain (1894-1975) [13], then participated to the Harvard Symposium on Large Scale Digital Computing Machinery, held in January 1947 at the Harvard University Computation Laboratory. The symposium was a show-off of the state of the art on American electronic computing devices, as the 1949 EDSAC conference would be for British electronic computer design. This meeting included sessions on storage techniques and technologies, on structural conception, on input and output devices, and on programming and coding. Sessions also included guided visits of Aiken's machines too, e.g. the Harvard Mark I and Mark II. Manneback was one rare European at the symposium, and left impressed. Before the year was gone, he had penned reports on how electronic digital technology held the key to the future of computing technology and possibly that of all practices dependent upon the performing of massive number-crunching tasks [14-17].

Such reports by Manneback contributed to reinforce in Belgian universities and at the FNRS and IRSIA, that electronic digital computing – although costly financially, c50,000 dollars [18], as well as in staff and technical expertise – was a direction of research to pursue in priority. Also, in the UK and the US, publications were flourishing that argued how electronic computing technology was a feasible technological development crucial for the future advancement of the physical sciences [19-24]. Hartree, in particular was touring UK and US universities, praising electronic computers as crucial due to "the possibilities which th[eir] speed opens up as practicable" [25-27]. There were also reports coming from France, Switzerland, Germany or the Netherlands, that argued likewise electronic computing as a necessary direction of engineering research. In a few words, electronic computers were a development Belgium had to find a way to participate to [28-40].

## III. Constructing an Electronic Brain for Belgium with the Help of BTMC, 1950-1955

In 1950, Henry, director of the IRSIA, suggested pursuing the construction of a Belgian national electronic digital computer. BTMC was approached as the technical industrial partner in the project. Technically, BTMC was at the time one of Europe's leading producers of telephone switches and relays. BTMC had a reputation of delivering reliable and cutting edge products, the latest being the invention of the transistor in 1947. Also, politically, BTMC was well introduced for cultivating privileged relationships with the state-owned Régie des Télégraphes et des Téléphones [2-3, 41-42].

The project was officially launched in 1951, with the justification that it was by far time for Belgium to work on getting its own of these 'mathematical machines' about which gossips had become so rife during recent years. Beyond the popular interest, due to "these characteristics of [mathematical machines] that make people awe so much, that is, their faculty of memory, their amazing speed at calculating," there was also the many reports arguing on the "practical importance" of the technology for the physical sciences, the industry and economy and the modernisation of society [43].

Oddly for a project funded by the FNRS, traditionally rather a backer to university-based research [59], oral histories and primary papers fail to reveal any collaboration with university departments, even in electrical engineering [43-49]. Universities acted as observing participants to the project, which shows in the composition of the committee set up in 1951 to guide the project. This committee, that one would expect composed of electrical engineers, rather included high-ranking academics representing their universities. The practice of the project was entrusted to BTMC, represented on this latter committee by Van Dyck, president of BTMC and, on the technical side, by William Pouliart, head of BTMC electronics laboratories. The only academic member of the committee later found involved in the practice of the project was Marcel Linsman, a chef de travaux at the Université d'Etat de Liège [50]. This situation reflects the relative weak presence of 'électricité des courants faibles', as electronics was called, in Belgian universities. The habit was rather to prefer mining and metallurgy due to the enduring predominance of the coal and steel industry in Belgian economic structures [51-53].

The research on the design of the MIF and the actual construction were located at the BTMC offices, in the centre of Antwerp. Work started in 1951 along lines imported from the US: the first plans were drawn out of blueprints of the Harvard Mark IV architecture brought back from a visit by Linsman and Pouliart to Aiken at Harvard [45, on pp.5]. The project was to be run, if with more than usual top-down supervision due to the cost and political importance of the endeavour, as an almost routine project. By and large, in 1951, electronic computer research was no longer adventurous electrical engineering. The techniques and methods to construct computers, and the problems likely to be encountered, were known and described at length in an increasingly flourishing literature [19-25]. BTMC moreover through its special relationship with Aiken at Harvard was well equipped to foresee most of the major technical problems that plagued other European national computer projects, for instance in France [54].

The project was thus pursued as a production than research endeavour. This fact shows in the planning of the machine, especially as regards to the design and organisation of the logical circuits of the machine. These were carefully prepared by two BTMC engineers trained at the ETH, the Swiss Federal Institute of Technology, Frédéric Iselin and Fritz Wiedmer. They drew structural maps on large sheets, later reprinted in several exemplars installed on large movable tables easily transportable towards use by technicians. As time went by, these circuit maps were completed and kept available on large moveable tables during the construction of the machine. For being located at BTMC, the machine IRSIA-FNRS project was thus pursued as if the construction of yet another Anglo-Saxon electronic computer, which delivered. A half-size U-shaped prototype – 17 racks instead of the 34 of the full machine – was delivered early 1955, barely four years after decisions were taken to engage into the project. This prototype was impressive, with dimensions of about 2.5 meters in height and width, and 7.5 meters in length (figs. 1 and 2) [45].

Fig. 1: Front view of the Machine mathématique IRSIA-FNRS, c1954-1955. Courtesy: N. Rouche. This photograph is also reproduced in [45].

On the front view of the machine (fig. 1), the central section visible on the left-hand side underneath the supporting bridge contained the rapid-access magnetic tape storage unit. Throughout cabling is hidden and organised behind the covers on the top, bottom and edges of the structure. The second view (fig. 2) shows the inside of the U-shape of the machine, revealing the backside of the racks. At the centre of the photograph sit the two magnetic drums where numbers and instructions were stored separately imitating the architecture of the Harvard series Mark machines. The arithmetic unit sat behind the photographer. This first machine was a technical achievement: although a prototype, it was equipped with its full storage capacity, and functioned reasonably reliably.

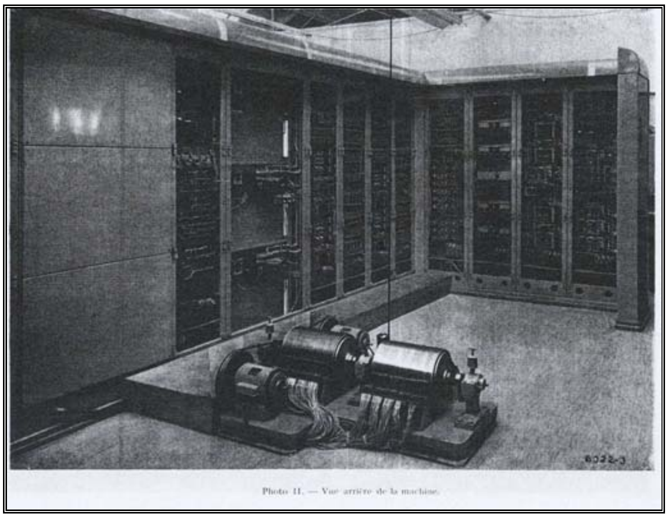

Fig: 2: View of the inside of U-shape of the Machine mathématique IRSIA-FNRS, c1954-1955. Courtesy: N. Rouche. This photograph is also reproduced in [45].

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| *Dimensions* | Height: c2,5 m; Width: c2,5 m; Length: c7,5 m for the 1955 half-size prototype; c13 m for the full-size machine |
| *Arithmetic unit* | Or "groupe calculateur," constituted of triodes and gas tubes, nested in several registers |
| *Control unit* | Or "circuits de commande," made of, e.g., gas tubes and triodes |
| *Input* | Via a keyboard punching data and program on tape |
| *Output* | Electrical printer |
| *Digital coding technology* | Shift registers made of 4 gas tubes<br>1 decimal digit represented by 8 gas tubes, 1 instruction by 4 gas tubes |
| *Storage* | High speed storage unit made of 9 columns of shift registers, with shift registers made of<br>• flips-flops (4 flips-flops equivalent to 1 register), each flip-flop being made of triodes (about 3000), with reliability issues,<br>• and/or gas tubes (about 1000) used towards asynchronous transfers between drums and magnetic tapes<br>Medium speed storage unit made of two twin magnetic drums coated in nickel, one for data, one for instructions<br>• Capacities of 2000 decimal numbers and 4000 instructions<br>• Rotation speed: 4000 revolutions/minute<br>• Dimensions: 50 cm in diameter, by 1m long<br>• Covered with tracks distant by c3 mms, each comprising 1440 magnetic dipoles, distant from one another by 1 mm<br>• Dipole writable in 10 µs<br>• Access via about 100 reading heads<br>• Word length of 18 decimal digits, coded in binary tetrads of 72 bits, or two instructions<br>• Addresses identified via four-digit code<br>Slow speed storage unit made of six endless hundreds of meters-long magnetic tapes about 6 mms large; these were mostly used<br>• towards access to sequential data, for instance programming instructions, or data input,<br>• and as temporary storage units to allow the re-synchronisation and circulation of data flow between drums and shift registers |
| *Cycle and speed* | Clock frequency: 100 kilocycles/sec<br>Addition time: 3 msec<br>Multiplication time: 15 msec |

Fig. 3: Technical characteristics of the Machine mathématique IRSIA-FNRS [40, on pp.2; 43-49; 55-58]

The technical characteristics of this machine were quite cutting edge (fig. 3), especially on three aspects. First, the main central part of the storage was made of two twin magnetic drums coated in nickel, drums being a quite recent storage innovation. One was reserved for data and the other for instructions, an architecture resulting from inputs by

Aiken [45, pp.5; 60-61]. Second, as regards to electronic storage, the machine was mostly equipped with gas tubes instead of triodes, advantageous for their better reliability and their lesser release of heat while used. Third, the machine was user-friendly in terms of its arithmetic and coding. Although internally treated in digital coding, users manipulated numbers as series of decimal digits. Also, the machine was provided with a hybrid arithmetic unit allowing for floating or fixed-point arithmetic depending on the preferences on the user [45]. An additional fourth interesting feature is that, with the MIF being constructed at BTMC Antwerp offices, its construction also resulted somehow from the interaction between Anglo-Saxon know-how and the more European background and expertise of the non-American staff of BTMC. In time, this led to, at least, the learning, dissemination and appropriation of Anglo-Saxon electronic computing know-how among these European electrical engineers and researchers.

## IV. BTMC Antwerp, c1951-1955: Disseminating Anglo-Saxon electronic computing know-how

A large part of BTMC staff on the project was made of young Belgian and European – Iselin and Wiedmer were trained at the ETH – engineers and graduates in physics and mathematics. Most of them had been attracted to BTMC following on the influence of BTMC head hunters, such Thonus, who toured Belgian universities. Also, BTMC, as one of Europe's largest firms in electrical engineering, was an attractive employer to career-minded engineers, especially so due to its New World aura.

Among the staff working at BTMC and attached to the IRSIA-FNRS project were Iselin, Wiedmer and André Fischer, from the ETH, Henri Castelijns, Jacques Loeckx, at Bell from 1957 to 1962, André Thijs, Jean Toussaint, as well as a certain Vandevenne who succeeded to Pouliart, and many others whose names are still to be recovered, e.g. van Mechelen, and Michiels. Most were electrical engineers trained in one of the Belgian universities, Vandevenne from the Université de Bruxelles for instance [57].

A most major figure as regards to the IRSIA-FNRS project was Vitold Belevitch who joined BTMC in 1942. Born in 1921 [62], Vitold Belevitch had read electrical and mechanical engineering at the Université de Louvain, before joining BTMC in 1942. Belevitch there also started reading towards a doctoral dissertation on circuit theory, submitted in 1945. As the war receded, Belevitch's status was already high at BTMC, due to rumours on his technological intelligence: by c1950, Belevitch was BTMC's local genius. Belevitch became involved with the IRSIA-FNRS project in 1951 representing, from as early as 1952, the project in electrical engineering circles, publishing on the combination of electrical and electronic engineering involved in the construction of the Machine IRSIA-FNRS. By 1952 Belevitch was already au fait of most of the technical problems to be solved while at constructing the MIF: issues with number and instruction coding procedures, with the structure of the arithmetic unit, with coordination and synchronisation of the various storage systems, with the implementation of the hybrid floating and fixed-point arithmetic [47-48].

Belevitch is central to the dissemination of Anglo-Saxon electronic computing know-how out of BTMC. Besides his position at BTMC who opened him the doors of industrial milieus, he also cultivated useful part-time lecturer positions in universities and technical colleges. Besides providing him with further audiences whereto present his research, these also allowed him looking out for staff. It is through this teaching that he hired for instance Claude Fosséprez, an enthusiast for analogical calculators (1933 -). Fosséprez proved a crucial staff, with a strong sense of practicability that allowed him rapidly assimilate the basic and lesser so principles of electronic computing technology. He worked among others on flip flop circuits towards storage and the calculating unit. Moreover, he was central to the design and gradual improvement of the storage systems, among others drums and the magnetic tapes. Fosséprez became so central to the engineering of the IRSIA-FNRS project that, as time went by, Belevitch gradually returned to giving his full attention to circuit theory. This was also rendered possible by that BTMC technical staff took over the more routine task related to the design of the MIF thanks to its stocks of components (relays, triodes, cables). A crucial help came in this respect from the ladies of BTMC cabling workshop as the MIF contained hundreds of meters of cables.

The construction of the IRSIA-FNRS machine for taking place at BTMC also benefited from a strong productivity impulse. The project seems to have been run under a quite strict top-down management: staff organised in departments, intensive 9-5 shifts, limited breaks, smoking ban in the laboratory to avoid damage to the circuits. With BTMC and its Belgian staff delivering the 17-racks prototype as early as spring 1955, the project was also a political success. With a birth date in 1955, the IRSIA-FNRS machine was one of the first computers to emerge out of State-sponsored research in electronic computing. It came after the 1951 London Pilot ACE, and the 1953 Swedish MMN, but ahead of many others for instance the 1956 Amsterdam ARRA and ARMAC, and much ahead of any of the French unachieved endeavours in the matter. [54].

## V. Appropriating Anglo-Saxon electronic computing know-how, 1955-1962

By January 1955, the MIF, quite physically impressive, functioned well enough for engineers to let it go for a show off. Its inauguration took place in February 1955 in the presence of King Baudouin, with unexpected machine failures forcing the use of the emergency fake tapes pre-prepared for the demonstration's results [40, pp. 2]. The overall lesson was that the MIF was not to be trusted to be reliable. Unreliability was due to that the functioning of the machine was sensitive to its internal temperature. When cold and just switched on in the morning the machine worked considerably slower. When the machine was at its ideal temperature, these optimal conditions as regards to temperatures caused other troubles: blowing up of triodes, and, especially, dilatation effects within the drums and scratching of their coating. Unreliability was palliated by an alarm instruction, and tracked through by reading of the shift registers so as to identify which of the thousands-odd components was the naughty one. Still, exploiting the MIF meant constant reminding of the complex electronics it was made of. Before even the prototype to be dismantled, staffs were then allocated tasks of testing components, characterising causes of unreliability and researching improvements. Also programs of instructions were devised for the implementation of complex mathematical functions as the MIF was only capable of the basic operations of addition (and subtraction) and multiplication [43, on pp.7]

Soon, a subsidiary, the CECE, for Comité d'Etude et d'Exploitation des Calculateurs Electroniques, was created with Belevitch as director. The CECE was aimed first at the exploitation of the MIF, that is, as interface between users and the MIF. Secondly, the CECE was to explore issues with the programming and engineering of the MIF and the problems experienced with its usage. Besides Belevitch, the CECE gathered together staff coming from BTMC, especially those had worked on the construction of the MIF. For instance Fosséprez transferred as head of the new machine room. Others staff transferred were Fischer, Iselin, and Van Mechelen. The other CECE staffs mostly arrived due to Belevitch's outside contacts in universities. In 1955-1956 staff at the CECE included at the least Belevitch, Fosséprez and Fischer, from the MIF construction stage, Paul Dagnélie, an engineer from the Université Libre de Bruxelles, François Servais and a certain R. Broeckx, mathematicians. There was also a secretary, Arlette Toubeau and Jean Meinguet, an engineer from the Université de Louvain fascinated by Belevitch's technical intelligence. He joined in 1956 after his 18-months military service. Staff increased in time. From 1957, the CECE was joined by Marguerite Liétaert, a mathematics graduate of the Université de Louvain, Marc Noé, Ivan Ottelet, Jacques Neirynck, again an ex-student of Belevitch at Louvain, a certain Peters and Roderick Gould, arriving from Harvard sent by Aiken. From 1955, the CECE also welcomed as short-term staff, young physicists, mathematicians and engineers on military service, picked out after their initial training period at the Ecole Royale Militaire. Among these there were 'Freddy' Storrer, a mathematics graduate from the Universiteit te Gent, in 1955 at the CECE, and, in 1957-1958, Pierre Macq, a physics graduate of Manneback [49, 57].

Research activities at the CECE were of two types, oriented towards the completion of the 34-racks MIF. Fosséprez, Dagnélie, Fischer and other engineers were directed towards that direction. The other part of the CECE activities was devoted to the problems generated by the usage of the MIF, that is, with its programming and with the optimisation of the implementation of complex mathematical problems. Although the machine was technically put into exploitation from 1955-1956 onwards [69], research activities at the CECE did not reach full pace before the full-scale MIF was released in 1957. Most of the CECE staff was untrained in electronic computing. Engineering know-how had started accumulating since 1951, and there was a good experience shared by those who had participated to the MIF 1955 prototype. Such experience was however nil as regards to what the programming and the computational exploitation of the computer might entail. If anything, the few months spent early 1955 at implementing instructions for the computations of Bessel functions – this was the program demonstrated at the February inauguration – had been revealing of the lack of know-how at BTMC in programming as well as in matters of the implementation of numerical mathematics operations on the MIF.

To palliate this problem, Belevitch set up a large library budget to import the relevant Anglo-Saxon literature. By 1956, the CECE library already included most classics of the times in computer design and in numerical analysis, for instance the issues of *Mathematical Tables and others Aids to Computation*, books by mathematicians on numerical analysis (e.g. Hartree, Goldstine, von Neumann, Lanczos, Rutishauser, Speiser, Wilkinson, Stibitz, or Larrivée), on computer design (e.g. by Wilkes, Williams, the Harvard Computation Laboratory, Aiken), and on programming (e.g. by Wilkes, Wheeler and Gill and programming on the EDSAC) [74-81].

Thanks to this literature at their disposal, Belevitch, Storrer and Servais managed to start publishing as early as 1956 detailed and critical methodology papers on the practice of the implementation of complex mathematical functions in digital computing technology. These papers developed very down-to-earth and yet expert understanding of the limitations of electronic digital technologies towards numerical usages [48-49, 66-67]. Especially revelatory are Storrer and Belevitch's exploration into the implementation of transcendental functions on the MIF. Their work displays in-depth understanding of the procedural intricacies with the evaluation, spread, and containment of numerical and digital error management while at performing numerical operations on an electronic computer. Comments included mentions of the additional risk due to machine failures. Like their contemporaries on the Manchester Mark I, Storrer and Belevitch argued that the safety of numbers required for all operations performed at the least twice, preferably using alternative formulations [48, 66, 88-89].

Besides having his staff read, Belevitch also worked at exposing them directly to forefront expertise. This shows in the coaching of Meinguet, whom he put on an extensive numerical analysis reading programme. Belevitch also took Meinguet to the 1956 Paris Congrès International de l'Automatique, 18th-24th of June, before testing his skills with programming the MIF. Realising that he was better skilled to numerical analysis research, he then arranged for Meinguet to be sent for a year round c1957 to the ETH, home of Rutishauser's research on numerical analysis [63, 82-83].

With Belevitch orienting the CECE towards the use of the MIF rather than further electronic engineering research, the CECE had decreasing connections with BTMC. There was also no reason to keep housing it at Antwerp: the MIF was the Belgian national computer. During 1957, the MIF, once completed and tested, was then dismantled for its relocation at the first floor of the Institut National de Statistiques, rue de la Croix de Fer, central Brussels. The CECE engineers took care of the move. Fosséprez in particular coordinated the reassembling of the MIF, and the construction of an optimal machine room. Special floorings were installed to allow for easier storing and access to cabling. Other staffs were busy writing down programming and numerical analysis papers and textbooks to assist in optimising and rendering more agreeable the usage of the machine [55-56, 70-71].

These textbooks embody the increasing mastery by the CECE of the electronic computing know-how they were confronted with at using the MIF. More interestingly, maybe, these writings reflect how the CECE was developing its own independent rhythm of research, which delivered at the same level of expertise as Anglo-Saxon contemporary laboratories. By and large, the 1957 *Manuel de programmation* and 1958 *Pseudocode manual* resemble in contents the Autocode programming manuals developed around the same time at the Computing Machine Laboratory of the University of Manchester. These works display similar kinds of concerns for users' difficulties to deal with programming in machine code [55, 70, 78, 80-81]. The CECE publications on numerical techniques were no catching-up either of developments taking place in the UK, the US or the ETH. The discussions on computational error evaluation and containment procedures resemble those developed during the same period by, e.g., Wilkinson in the UK. The similarity is striking in the discussions on propagation of digital, rounding-off and algorithmic series truncation errors. Also, these writings reveal a level of grounding in the actual experimenting and practices of calculations that made Wilkinson's reputation [87].

## VI. CONCLUSION

In this paper we have explored how, for being performed by local staff, the work and research performed at the Antwerp offices of BTMC towards the construction of a Belgian national computer have led to the gradual emergence of indigenous know-how and expertise in electronic computing. With the MIF being constructed at BTMC, occasions emerged to learn dealing with the practical engineering issues raised by the construction of such a machine. This materialised in the gradual emergence of local engineers expert at maintaining the MIF but also deconstruct, and rebuild it at the Institut National de Statistiques. With the MIF completed, occasions also multiplied for the dealing with the more theoretical issues raised by the programming of the MIF and its usage towards complex computational operations.

This emergence of indigenous know-how originates in the gradual appropriation of Anglo-Saxon know-how and knowledge in these domains as they percolated through various interfaces. One first such interface as regards to engineering issues was BTMC, which housed Belevitch and, later, Fosséprez's learning process of electronic computing know-how. In matters of more use-focused issues such as programming and implementing computational operations on the MIF, these interfaces were made by the CECE and Belevitch. This role of the CECE was due to that, as emancipated from BTMC, the CECE was first well-prepared and second forced to find solutions to its own technical issues. Belevitch has again to be mentioned here. As director of the CECE, he played on all the cards he could towards getting the CECE on its tracks through his choice of staff and their training, and especially through the establishment of instruments for the continuing percolation of Anglo-Saxon know-how (library, training in foreign universities, participation to conferences).

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## REFERENCES

[1] The oral histories and oral communications used toward this paper are not referred to in individual references. This is to avoid flooding as their use is recurrent throughout the paper. These oral histories includes recorded interviews of Jean Meinguet (23/11/2007, 11/01/2008), Nicolas Rouche (03/12/2008), and Claude Fosséprez (10/12/2007, 14/01/2008), and multiple communications between the authors, the interviewees mentioned above as well as with Jacques Loeckx, on the phone as well as by e-mail. All these people have been closely involved with MIF project from either very early on (Claude Fosséprez, Nicolas Rouche) or later – from about 1955 – once the MIF was on the way to completion (Jean Meinguet, Jacques Loeckx). All these communications and interviews have included the taking of notes. These, as well as transcripts, are currently being compiled into a *Belgian Computing History Compendium* by the authors. This interview program also entails the collect of originals or copies of contemporary documents, for instance those referred to under [66-72]. Information on this oral history program on Belgian computing history is available with the authors.

[2] P. Verhoest, ed., *Openbare telecommunicatie (1798-1998)*, Brussels, VUB Press, 2000, pp. 74-107.

[3] J.-P. Vercruysse, P. Verhoest, Y. Punie, *Politique belge des télécommunications, 1830-1991*, Ophain, SYNEDI, & Brussels, VUB Press, 1995, pp. 87-146.
[4] J. Krige, *American hegemony and the postwar reconstruction of science in Europe*, Cambridge, MA, and London, MIT Press, 2006.
[5] P. Marage, "La physique nucléaire et la physique des particules élémentaires," in R. Halleux, ed., *Histoire des sciences en Belgique, 1815-2000*, *Vol.2. De la science nationale aux réseaux planétaires,* Bruxelles, La Renaissance du Livre, 2001, pp. 85-108.
[6] P. Marage, *La Belgique et la coopération scientifique européenne*, s.l., 2005, at http://homepages.ulb.ac.be/~pmarage/coop_intern_Bq.pdf
[7] On the economic and military motives behind American support for the reconstruction of Europe: M.J. Hogan, *The Marshall Plan*, Cambridge, Cambridge University Press, 1987.
[8] P.N. Edwards, *The closed world: Computers and the politics of discourse in Cold War America*, Cambridge, MA, MIT Press, 1996.
[9] W. Aspray, *John von Neumann and the origins of modern computing*, Cambridge, MA, and London, MIT Press, 1990.
[10] P.E. Ceruzzi, "'Nothing New since von Neumann': A historian looks at computer architecture, 1945-1995," in U. Hashagen, R. Rojas, eds., *The first computers. History and architectures*, Cambridge, MA, MIT Press, 2000.
[11] B.S. Park, 2003, "The 'hyperbola of quantum chemistry': The changing practice and identity of a scientific discipline in the early years of electronic digital computers, 1945-1965," *Annals of Science*, 60, 2003, pp. 219-247.
[12] A similar occurrence of travel is that of Louis Couffignal to the US by the French CNRS in c1946-c1948. See in J. Pérès, "Les grandes machines mathématiques. Introduction," in J. Pérès, L. Brillouin, L. Couffignal, *Les grandes machines mathématiques*, Paris, Revue d'Optique, 1948, pp.6.
[13] P. Radelet, "Charles Manneback," *Revue des Questions Scientifiques,* 161, 1990, pp. 289-308.
[14] J.H. Curtiss, "A symposium on large scale digital calculating machinery," *Mathematical Tables and Other Aids to Computation*, 2(18), 1947, pp. 229-238, on p. 234 about Charles Manneback's participation.
[15] Cambridge University Mathematical Laboratory, ed., *Report of a conference on high speed automatic calculating machines, 22-25 June 1949*, Cambridge, Cambridge University, University Mathematical Laboratory, & London, HMSO, 1950, in Renwick Papers, Cambridge University, Cambridge University Library, CSAC 84.2.8, Box 1 – File D2.
[16] C. Manneback, L. Brillouin, *Les machine mathématiques aux Etats-Unis*, Namur, Facultés Universitaires Notre-Dame de la Paix, Archives Dockx, Typed-script report, [1947].
[17] A similar report by Brillouin is: L. Brillouin, "IIIe partie. Les machines américaines," in J. Pérès, L. Brillouin, L. Couffignal, *Les Grandes Machines Mathématiques*, Paris, La Revue d'Optique, 1948, pp.6 *ff.*
[18] $50,000 corresponded then to about 7 millions French francs. See on Ref. 16, p. 12.
[19] F.C. Williams, "A cathode-ray tube digit store," *Proc. Roy. Soc.*, A 195, 1948, pp. 279-284.
[20] D.R. Hartree, M.H.A. Newman, M.V. Wilkes, F.C. Williams, J.H. Wilkinson, A.D. Booth, "A discussion on computing machines," *Proc. Roy. Soc.*, A 195(1042), 1948, pp. 265-287
[21] M.V. Wilkes, "Electronic calculating-machine development in Cambridge," *Nature*, 164, 1949, pp. 557-558
[22] M.V. Wilkes, W. Renwick, "The EDSAC – An electronic calculating machine," *J. Sci. Instr. and of Physics in Industry*, IV(30), 1949, pp. 385-391
[23] J.H. Wilkinson, "The Automatic Computing Engine at the National Physical Laboratory," *Proc. Roy. Soc.*, A195, 1948, pp. 285-287.
[24] D.R. Hartree, "Recent developments in calculating machines, *J. Sci. Instr.*, 24(7), 1947, pp. 172-176.
[25] B.S. Jeffreys, "Douglas Rayner Hartree (1897-1958)," *Comments At Molecular Physics,* 20(4), 1987, pp. 189-198.
[26] D.R. Hartree, *Calculating instruments and machines,* Urbana, University of Illinois Press, 1949, pp. v, 54-56.
[27] D.R. Hartree, *Calculating machines: Recent and prospective developments and their impact on mathematical physics*, Cambridge, Cambridge University Press, 1947, in Hartree Papers, Cambridge University, Christ's College Library, Ref. CSAC 45.9.76, Box II Continued – file 14, pp. 10, see also on pp. 7.
[28] H. Rutishauser, A. Speiser, E. Stiefel, *Programmgesteuerte digitale Rechengeräte (elektronische Rechenmaschinen)*, Basel, Birkhäuser, 1951
[29] J. Pérès, L. Brillouin, L. Couffignal, *Les grandes machines mathématiques*, Paris, La Revue d'Optique, 1948.
[30] J. Pérès, "Les grandes machines mathématiques," *Annales des Télécommunications*, 2, 1947, pp. 330.
[31] L. Brillouin, "Les grandes machines mathématiques. Les machines américaines," *Annales des Télécommunications*, 2, 1947, pp. 331-346.
[32] E. van Oost, G. Alberts, J. van den Ende, H.W. Lintsen, eds., *De Opkomst van de Informatietechnologie in Nederland*, Amsterdam, Kluwer, 1998.
[33] J. van den Ende, *The turn of the tide. Computerization in Dutch society, 1900-1965,* Delft, Delft University Press.
[34] P. Mounier-Kuhn, *History of computing in France: A brief sketch*, s.l., 1989, at http://www.icfcst.kiev.ua/SYMPOSIUM/Proceedings2/Mounier-Kuhn.rtf
[35] P. Mounier-Kuhn, "The Institut Blaise-Pascal (1946-1969). From Couffignal's machine to artificial intelligence," *IEEE Annals of the History of Computing,* 11(4), 1989, pp. 257-261.
[36] P.E. Ceruzzi, H. Petzold, K. Wohlfarth, "Kolloquium '50 Jahre programmgesteuerte Rechenmaschine'," *Deutsches Museum, Wissenschaftliches Jahrbuch*, 1992/93, 1992, pp.169-209.
[37] R. Rojas, H. Dorsch, F.L. Bauer, H. Petzold, G.-A. Thurm, eds., *Die Rechenmaschinen von Konrad Zuse*, Berlin, Springer, 1998.
[38] A.P. Speiser, "The relay calculator Z4," *IEEE Annals of the History of Computing*, 2, 1980, pp. 242-245.
[39] K. Zuse, *The computer, my life*, Berlin, Springer-Verlag, 1993.
[40] J. Loeckx, *Computer design and software development in Belgium before 1970: A personal retrospect*, March 2007 (Draft paper prepared towards G. Alberts, G., ed., forthcoming, *Proceedings of the conference "Pioneering Software in the 1960s in Germany, The Netherlands, and Belgium, 2-4 November 2006"*), pp.1.
[41] On Bell, the transistor and electronic research: F.M. Smits, ed., *A history of engineering and science in the Bell System*, Indianapolis, AT&T Bell Laboratories, 1990.
[42] S.A. Christensen, *Switching Relations. The rise and fall of the Norwegian telecom industry*, Oslo, BI Norwegian School of Management, PhD dissertation, 2006, pp. 27-87, and *ff.*
[43] M. Linsman, W. Pouliart, "La machine mathématique IRSIA-FNRS en construction à la Bell Telephone Mfg Co," *Industrie*, 8, 1953, pp.1-7, on pp. 1 (our translation).
[44] M. Linsman, "Les machines mathématiques," *Technique et humanisme*, 6, 1954-1955, pp. 279-294
[45] M. Linsman, W. Pouliart, *La Machine Mathématique IRSIA-FNRS*, Antwerp, BTMC, 1955.
[46] M. Linsman, W. Pouliart, "Principales characteristiques de la machine IRSIA-FNRS," *Nachrichten technische Fachberichte*, 4, 1955, pp. 66-68
[47] V. Belevitch, "Machines mathématiques électroniques," *Revue des Ecoles Spéciales de Louvain*, April 1952, pp. 111-120.
[48] V. Belevitch, "Le trafic des nombres et des ordres dans la machine IRSIA-FNRS," *Nachrichten technische Fachberichte*, 4, 1955, pp. 69-74
[49] V. Belevitch, F. Storrer, "Le calcul numérique des fonctions élémentaires dans la machine IRSIA-FNRS," *Bull. Acad. Roy. Belg.*, XLII, 1956, pp. 543-578.
[50] The members of this committee were: Chair: Charles Manneback, Université de Louvain; Members: Frans van den Dungen, Université Libre de Bruxelles, Henri Van Der Linden, Universiteit te Gent, Georges Boulanger, Faculté Polytechnique de Mons, Marcel Linsman, Université d'Etat de Liège, Leo Van Dyck, President of BTMC, Technical consultancy: Howard Aiken, Harvard University, Secretary: William Pouliart, director of the electronics division at

BTMC. The committee was later joined by a representative of the Ministère de la Défense Nationale (see Ref. 44, on p.5).
[51] This contrast to British universities where electrical engineering became routinely researched from the 1930s. See for instance in T.E. Broadbent, *Electrical engineering at Manchester University*, Manchester, University of Manchester Press, 1998.
[52] On Belgian economic structures and the coal and steel industry: R. Halleux, *Cockerill*, Liège, Perron, 2002.
[53] On Belgian economic structures and its long-term tendencies: K. Bertrams, *Universités et entreprises. Milieux académiques et industriels 1880–1970*, Brussels, Le Cri, 2006, *passim* and esp. pp. 270-320.
[54] P. Mounier-Kuhn, "L'enseignement supérieur, la recherche mathématique et la construction de calculateurs en France (1920-1970)," in F. Birck, A. Grelon, eds., *Des ingénieurs pour la Lorraine – Enseignements industriels et formations technico-scientifiques supérieures, XIXe-XXe siècles*, Editions Serpenoise, 1998, pp. 251-286, esp. on 252-256 and 277-286.
[55] CECE, *Document Nr 1. Manuel de programmation pour la machine IRSIA-FNRS*, Brussels, CECE, 1957, pp.41*ff*
[56] CECE, *Progress Report N.1*, Brussels, Comité d'Etude et d'Exploitation des Calculateurs Electroniques, 1957.
[57] P. Dagnélie, "L'informatique à l'Expo 58," *DataNews*, 16, 2 May 2008, pp. 6.
[58] C. Fosséprez, *Les Fondements de l'informatique et des télécommunications. Cours de l'Université des Aînés de l'Université Catholique de Louvain*, Louvain-la-Neuve, Université Catholique de Louvain, 2002, Courtesy: C. Fosséprez, *passim*, and esp. pp. 6-23.
[59] R. Halleux, G. Xhayet, *La liberté de chercher. Histoire du Fonds National belge de la Recherche Scientifique*, Liège, Editions de l'Université de Liège, 2007.
[60] T. Thomas, *Recollections of magnetic drum storage for the Mark I (1948 - 1951)*, 1998, at www.computer50.org/mark1/gethomas/manchester_drums.html.
[61] S.H. Lavington, "Manchester computer architectures, 1948-75," *IEEE Annals of the History of Computing*, 15(3), 1993, pp. 44-54.
[62] A. Fettweis, "In Memoriam. Vitold Belevitch (2 March 1921 - 26 December 1999)," *IEEE Transactions on Circuits and Systems*, 47, 2000, 613-614.
[63] For details on the 1956 Paris conference: P. Remaud, *Une histoire de la genèse de l'automatique en France 1850-1950*, Paris, CNAM, PhD thesis, 2004, pp. 62-72.
[64] G. van Mechelen, "De automatische digitale rekenmachines," *Technische wetenschappelijke Tijdschrift*, 1955.
[65] V. Belevitch, "L'apport de la théorie moderne des circuits électriques à la dynamique générale," *Bulletin de la Société Française de Mécanique*, 21, 1956, pp. 27-30.
[66] F. Servais, "Sur l'estimation des erreurs dans l'intégration numérique des équations différentielles linéaires du second ordre," *Annales de la Société Scientifique de Bruxelles*, 1956, pp. 5-9.
[67] F. Storrer, "Amélioration du procédé de division numérique utilisant l'itération de Newton-Raphson," *Bulletin de l'Académie Royale de Belgique*, XLII, 1956, pp. 30-33.
[68] V. Belevitch, "*Mathematics and computers*, by G.R. Stibitz and J.A. Larrivée," *Revue des Questions Scientifiques*, 5th series 128(18), 1957, pp. 305.
[69] CECE, *Liste des problèmes traités par le CECE*, Antwerp, CECE, [1956].
[70] CECE, *Document Nr.2: Pseudocode Manual for the IRSIA-FNRS Computer*, Brussels, CECE, 1958.
[71] CECE, *Document Nr.3: La résolution des problèmes d'algèbre linéaire sur la calculatrice IRSIA-FNRS*, Brussels, CECE, 1958.
[72] CECE, *Document Nr.4: Analyse numérique et programmation des transcendantes élémentaires pour la calculatrice "Mk-II" (Bell Telephone Anvers)*, Brussels, CECE, 1959.
[73] CECE, *Document Nr.6: Eigenvalues and eigenvectors of symmetrical matrices by Lanczos method*, Brussels, CECE, 1960.
[74] B.V. Bowden, ed., *Faster Than Thought*, London, Pitman, 1953.
[75] M.V. Wilkes, "The use of a 'floating point address' system for orders in an automatic digital computer," *Proc. Cam. Phil. Soc.*, 49, 1953, pp. 84-89.
[76] M.V. Wilkes, "Solution of linear algebraic and differential equations," *Proc. Cam. Phil. Soc.*, 52, 1956, pp. 758-763.
[77] M.V. Wilkes, *Automatic digital computers*, London, Methuen, 1956.
[78] M.V. Wilkes, D.J. Wheeler, S. Gill, *The preparation of programs for an electronic computer, with special reference to the EDSAC and the use of a library of subroutines*, Los Angeles & San Francisco, Tomash, 1982, 1st ed. 1951.
[79] M.V. Wilkes, J.B. Stringer, "Micro-programming and the design of the control circuits of an electronic digital computer," *Proc. Cam. Phil. Soc.*, 49, 1953, pp. 230-238.
[80] R.A. Brooker, *Some technical features of the Manchester Mercury Autocode program*, Teddington, National Physical Laboratory, 1958.
[81] R.A. Brooker, B. Richards, E. Berg, R.H. Kerr, *The Manchester Mercury Autocode program*, Manchester, University of Manchester, Computing Machine Laboratory, 1959.
[82] J. Meinguet, *Quelques compléments à notre entrevue du 21 juin 2002*, unpublished hand notes, 2002.
[83] J. Meinguet, Letter to Sandra Mols, 11/3/2002.
[84] J.H. Wilkinson, "The calculation of the latent roots and vectors of matrices on the Pilot model of the ACE," *Proc. Cam. Phil. Soc.*, 50, 1954, pp. 536-566.
[85] J.H. Wilkinson, "Error analysis of floating point arithmetic," *Numerical Mathematics*, 2, 1960, pp. 319-340.
[86] On Wilkinson: B.N. Parlett, "The contributions of J.H. Wilkinson to numerical analysis," in S.G. Nash, ed., *A history of scientific computing*, New York, ACM, 1990, pp. 17-30.
[87] Compare for instance the technical treatment to computational error in the CECE publications (refs. [70-72]) with that in contemporary publications taking in the UK (refs. [83]-[84]).
[88] D.W.J. Cruickshank, "Reminiscences of X-Ray Structure Analysis," *Advances in Molecular Structure Research*, 6, 2000, pp.11-15.
[89] For comments related to the broader practices developed on the Ferranti Mark I: S. Mols, *Making crystallographic computations with the Manchester Mark I, 1952-1957*, Manchester, University of Manchester, unpublished MSc dissertation, 2001, on pp. 49-72.