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DEPARTMENT: ANECDOTES

Building a Computer at the University of Padua, 1958-1961

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In 1954, the first two, general-purpose, electronic computers were imported to Italy. A CRC 102A, manufactured by the American Computer Research Company was installed at the *Politecnico* in Milan, and a British Ferranti Mk. 1 was acquired by the National Institute for Applications of Computing (INAC) in Rome. In the same year, two projects for the local design and construction of electronic computers were launched. The University of Pisa started building the "Pisa Electronic Calculator" (*Calcolatrice Elettronica Pisana*, CEP), and a commercial venture took place at the Electronics Division of Olivetti S.p.A., the manufacturer of typewriters and desktop calculators, which led to the creation of the ELEA 9003 [1], [2].

In the early 1960s, there was, however, another, general-purpose, electronic computer built at the University of Padua. Only two vague and inaccurate citations exist:

> [. . .] in Padua the physicist [sic] Francesco Piva at the end of the fifties undertook the construction of a machine at the instigation of the statisticians [3, p. 78].

> [. . .] Dadda said that the physicists [sic] of Padua, in particular Silvio Bezzi and Carlo Panattoni, wanted to use the computer of the Politecnico computing service, but could not pay the fee [. . .] and decided to build their own machine [4].[1]

Two papers describe the computer [5], [6, p. 3] and the machine is mentioned in two surveys of computers in Italian universities and research institutes made by *Associazione Italiana per l'Informatica e il Calcolo Automatico* (AICA) in 1965 and 1967. In the first, it appears with the specification "own construction," and in the second with the name "Booth" [7], [8]. Some relics of this machine were listed in the collection of the Educational Friends of the World Treasures (FWT) Museum of the History of Computer Science in Padua as "*Electronic computer with vacuum tubes. Built in Padua, second in Italy, on the model of the APE (X)* [sic] *by A. D. Booth 1958/62*" [9]. The artifacts were exhibited in 2021 at Padua's Museo Didattico di Storia dell'Informatica [10]. Wikimedia sponsored the exhibition and offered some of the authors the opportunity to curate the display and write an Italian *Wikipedia* page about the machine [11].

"UNIVERSITY CENTRE FOR STATISTICAL CONSULTANCY AND COMPUTING" AT THE UNIVERSITY OF PADUA

In the early 1950s, six faculties were active at the University of Padua. In the Faculty of Law, an Institute of Statistics and a School of Statistics had operated since 1927. In 1949–1950, Albino Uggè, then full professor of statistics at the University of Venice, was called to Padua. Five years later, the chair of statistics was moved to the Faculty of Political Sciences and Uggè became full professor and director of the Institute and School of Statistics, an office that he held almost until his death in 1971.

Uggè became aware of the potential of electronic computers probably through the influence of Bruno de Finetti, a statistician who had worked with IBM tabulators in the early 1930s and had been campaigning for the use of electronic computing technology in Italy in [12], [13],

[1]Bezzi and Panattoni did not participate in the MS project.

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[14], and [15]. He also collaborated with INAC for the choice of the Ferranti Mk. 1* after visiting several British and American institutions where computers had been built or were under construction [16]. Aware of the importance that statistics was assuming in the worlds of administration, finance, production, and public administration, in the mid-1950s Uggè proposed the creation of a "University Centre for Statistical Consultancy and Computing" (*Centro universitario di consulenza statistica e calcolo*, or *CUCSC*) to provide education, service, and advice not only to other university institutes but also to external institutions. One incentive was the forthcoming establishment of the European Economic Community (EEC) that aimed to grant free circulation of goods, citizens, and capital between member countries. EEC implied a further need for control activities both in public bodies and the worlds of commerce, industry, and banking; hence new technical and organizational tools, and experienced personnel to use them, would be needed.

Uggè thought also that while it would be necessary to have computing machines, like desktop calculators and punch card systems, electronic computers would be even more useful. He worked hard to raise funds for this aim, describing his vision for the CUCSC program in a proposal prepared in May 1958. Uggè referred explicitly to the construction of a "[. . .] small computing engine for educational purposes [. . .]" to address the forthcoming need for computer skills for scientific research and economy:

> If the Center had an electronic calculator, it could use it for the following:
>
> - Execution of numerical calculations of interest to the center itself, as well as other scientific institutes, public agencies, and private companies.
> - Experimental use as a pilot plant on behalf of private institutions planning to install their own autonomous systems.
> - Performance of routine administrative work and scientific calculations on behalf of third parties [17].

The urgency of this project was such that Uggè had already begun to provide educational activities, built a library of about seventy specialized texts, and set up an electronic laboratory with some equipment.

Uggè gained the support of local authorities, including the Padua Chamber of Commerce. Its director, Ettore da Molin, played a leading role in raising the funds required to build the "educational computer." The income granted by sponsors amounted to approximately two million lire in February 1958 (approximately US$3,200 at the time), a small sum when compared with similar initiatives in Italy and abroad. The decision to build the calculator from scratch, instead of purchasing a commercial model, was the consequence of such budget constraints. For the design and the construction of the computer, a competent team was required, but recruiting this kind of professional was not easy in Italy in the 1950s. Two young electronic technicians were hired: Giorgio Contin and Francesco Piva. Both were passionate and skilled builders of electronic instruments. Contin started at a very young age to repair English radios and then moved on with Piva building instruments for physics laboratories, like radiation counting circuits and replicas of other expensive lab instruments. At the time, Contin was a university electrical engineering student. Piva had worked at the University of Padua with the physician Mario Austoni [18] in the field of nuclear medicine and was in charge of equipment at the Institute of Nuclear Chemistry directed by Ugo Croatto. There he also designed circuits for counting radiation particles [19].

THE URGENCY OF THIS PROJECT WAS SUCH THAT UGGÈ HAD ALREADY BEGUN TO PROVIDE EDUCATIONAL ACTIVITIES, BUILT A LIBRARY OF ABOUT SEVENTY SPECIALIZED TEXTS, AND SET UP AN ELECTRONIC LABORATORY WITH SOME EQUIPMENT.

Piva and Contin were joined, part time, by Giuliano Patergnani, a 25-year-old assistant professor in nuclear physics at the School of Advanced Physics. All three had some experience with electronic pulse circuits and Patergnani was aware of the project to build a computer in Pisa, as he had attended one of the first meetings held there [20].

INSPIRATION AND ARCHITECTURE: THE MS AS APE(I)C

Despite extensive search in the archives of the University of Padua, only scant documentation on the construction of the computer has been found. No minutes, internal reports, technical specifications, circuit diagrams, or any other document related to the project appear to exist. This gap is probably due to the loss of the Institute of Statistics' archives during relocation. The most relevant surviving source, which allowed us to partially reconstruct the machine's history, is a collection of invoices and payments for electronic components from 1957 to 1960. Other documents include photographs, notes, and circuit diagrams saved by Contin's son Francesco, one of the authors of this paper. Since the project and the computer never had an official name, we coined the colloquial acronym MS. This may stand for *Macchina degli Statistici* (Machine of the Statisticians), echoing Dadda [3], but also *Macchina Seriale* (Serial Machine).

The goal was to build a computer for educational purposes that could also meet the scientific needs of CUCSC, at a low cost of construction and operation. It was decided that the machine would be a general-purpose computer with stored program architecture, inspired by the APE(X)C (All-Purpose Electronic (X-ray) Calculator), one of the machines designed and built by Andrew D. and Katherine Booth at the Birkbeck College of London (U.K.):

> An order code was also adopted that would allow the use of the programs and subroutines already developed for the APE(X)C [5].

The Booths were two of the pioneers of British computing. After two visits at the Institute for Advanced Study (IAS) in Princeton, where they met John von Neumann and Herman H. Goldstine, Andrew decided to promote von Neumann's "stored program" architecture. Back in England, he and Norman Kitz built a prototype, the Simple Electronic Computer, which was followed by the APE(X)C [21], [22], [23, p. 62], [24]. Together with Kathleen, Booth published a popular text on electronic digital computers and Kathleen wrote one of the first books on programming [25], [26]. Thanks to their publications, it was possible to adopt the same instruction set and thus to take advantage of routines already published in Kathleen's book, so that the computer could be used immediately after construction.

Budget and technical constraints, as well as the need to draw on the Booths' experience, forced the Paduans' orientation toward 1) the use of vacuum tubes instead of the more expensive and less reliable transistors of the time; 2) the choice of a bit-serial architecture that allowed a significant reduction in the number of logic components compared to faster parallel architecture; and 3) the use of magnetic drum memory instead of core memory, which was still an expensive novelty. These architectural choices followed the scheme of Birkbeck College machines. However, the circuits described in the Booths' book were not blueprints to be copied for building a computer. Therefore, Contin and Piva had to transfer the Booths' knowledge and experience through their group's interpretive and inventive efforts.

We have no evidence of direct contact between the MS team and Booth, except some postal expenses

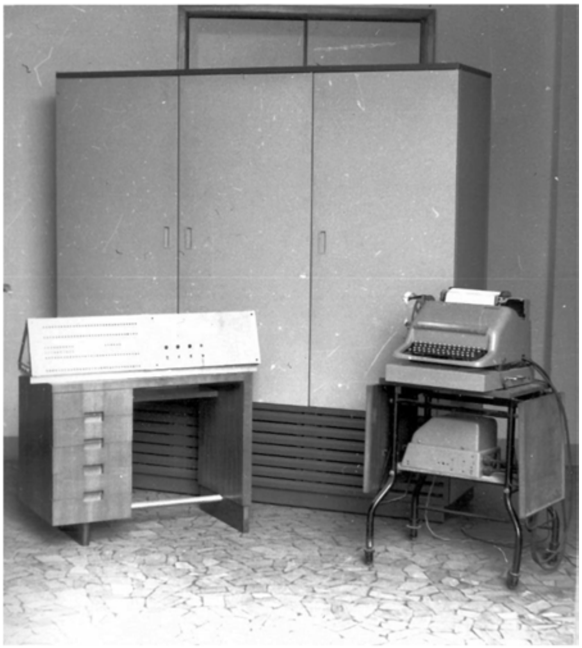

FIGURE 1. MS complete with control panel, left, and I/O peripherals, right. (Courtesy of Francesco Contin).

for letters sent in 1957–1959 from CUCSC to the University of London, of which we do not know the content. There are other hints of links between Piva and Andrew Booth: both were listed among the participants at the UNESCO International Conference on Information Processing held in Paris in 1959 [27], which Piva attended as a delegate and official representative of the University of Padua. For his part, Booth visited Padua in the summer of 1957 when construction of MS was beginning, and in July 1962, when MS was already finished. Recalling the first trip, he wrote that "I gave a talk at the University there and was interested to see a 'copy' of the APE(X)C under construction" [28]. Booth mentioned the city of Bologna instead of Padua, but it is certainly a mistake, excusable by the time elapsed between the visit and the writing of his memoir. In fact, no attempt to build an electronic computer was undertaken at the University of Bologna in the 1950s or 1960s [29].

In 1957, the Institute of Statistics began buying electronic components to build the computer, and orders became decidedly more intense and defined in 1959, with the request of parts for a magnetic drum directly from Wharf Engineering Ltd., a small company founded by Booth and his father to market magnetic drums and, later, computers. The purchase of an oscilloscope in March 1959 indicates that an electronic laboratory was already active. These acquisitions are

FIGURE 2. Interior of MS: left cabinet, halfway up, the magnetic drum; central cabinet, the logic; right cabinet, the power supply. Below are the three cooling fans. (Courtesy of Francesco Contin).

indisputably connected with the construction of the "educational machine" proposed by Uggè, which took place directly at the installation site, on the fourth floor of the building called *"il Bo,"* historical site of the university since 1493. Purchases continued throughout 1959 but decreased after mid-1960, suggesting that the construction was approaching its end.

The MS (see Figure 2) used a magnetic drum memory with a capacity of 1024 32-bits words, rotating at about 3000 r/min, which also provided the synchronization signal for the system clock. The arithmetic was fixed point. The whole computer involved about 250 vacuum tubes mounted on seventy boards, installed in sets of twenty to a rack, according to a modular architecture. Everything was assembled in a cabinet with three sections—for the power supply, the drum memory, and the logic circuits respectively—that could be opened from both the front and the rear. Underneath each section was a cooling fan. The machine had a control panel on which the content of the various registers was readable. These could be manually modified by means of switches, in particular the contents of the two arithmetic registers, that of the control unit containing the instruction, and the address in execution. The technical details reported in the paper by Contin et al. [5] give the following operation times: 600 microseconds for addition and subtraction, 20 milliseconds for multiplication, and 300 milliseconds for division. The input/output peripherals consisted of a punched-tape reader and a teletype, both manufactured by Olivetti.

If the construction schemes of the APE(X)C and MS were still available, it would be possible to understand how much the MS adheres to Booth's projects and answer the question of whether the MS was just a clone, or a local interpretation based on the same software specifications, as suggested by article's reference to Kathleen Booth's text on programming. Some of the PCB cards kept at the Museum correspond to the circuits described in A. D. Booth's books [26], but not all of them; the differences suggest an interpretive effort by the Paduan team. We can call MS the 'APE(I)C' (All-Purpose Electronic (*Italian*) Computer), following the nomenclature used in the literature for other Boothian computers, e. g. APE(X)C, APE(H)C, APE(R)C, and APE(N)C.

The archival sources suggest an overall cost of about 7,000,000 lire in the period 1958–1960, (US$11,200 at the time) albeit with some doubt on the completeness of the expenses. Adding in the salaries of the two technicians, the total could have reached about 10 million lire (US$16,000). The incredibly low cost is comparable with that of the M2, the APE(X)C commercially produced by Wharf Engineering, whose expected selling price was £8,000 (US$21,600) [30] and other small serial machines built in those years. The Norwegian NUSSE, also derived from the APE(X)C, cost US$27,000 [31], the East German D1 just over US$7,000, and the smaller D2 US$2,140 [32].[2]

In 1961, MS's construction was finished, but there is no trace of an official inauguration, nor of its scientific or educational use in the following years. Again, the reason for this lack could be the loss of the archival records. Moreover, no one who played a role in the project is still alive. For the same reason, no copy of programs nor printout of calculations were found. Although it was customary in scientific publications of the time to credit the use of specific electronic computers for calculation, despite extensive research no explicit references have been found referring to this machine. Thus, we can only draw from the recollections of researchers. Felice Vian, later professor and dean of the Faculty of Statistical Sciences, and Ugo Trivellato, who became professor and dean of the Faculty of Statistical Sciences, both remember that after 1961, the MS was in operation. Silio Rigatti Luchini, a later professor and director of the Department of

[2]East Germany projects took advantage of the availability of low-cost electronic components from the Wehrmacht's military surplus.

Statistical Sciences, told us that Odoardo Cucconi, professor of statistics, used the MS to make calculations, but Cucconi does not refer to the use of MS in papers he published in those years. Thus, we can only hypothesize a brief use for educational or experimental purposes, which only partially fulfilled Uggè's vision: eventually, the Center never attracted scientific institutes, companies, or other third parties, as he hoped.

THE CONSTRUCTION OF MS WAS ALSO DRIVEN BY GREAT ENTHUSIASM AND THE VISION THAT A SMALLER, CHEAPER MACHINE COULD PLAY A ROLE IN A RESEARCH ORGANIZATION DESPITE THE COMPETITION FOR LARGE MAINFRAME COMPUTERS.

MS suffered undoubtedly from the same "teething problems" that plagued the first generation of electronic computers. The MS team must have struggled to tackle problems on a scale greater than that of an educational exercise and to use the calculator for the CUCSC's consulting tasks. The expansion of drum memory to 4096 words was envisaged, but we do not know if this was ever done. Uggè's insistent requests between March 1959 and February 1962 for additional funds to upgrade the CUCSC and obtain an expensive (12 million lire) "rapid access memory" for the MS were not approved. Possibly technical issues and limited functionality contributed to the failure to secure funds and eventually doomed the project. But the context was also changing rapidly: on one side more powerful and reliable next-generation industrial computers were available, on the other, in the same years the MS was built, the appetite for computing resources at the University of Padua rose to the point that a university-wide initiative was started in order to secure State funds.

In 1960, the University of Padua founded the Electronic Scientific Computing Center (*Centro Elettronico di Calcolo Scientifico*, CECS). Its board of directors represented all interested faculties, established the practice of interdisciplinary collaboration, and developed a centralized computing center (CECS). Two years later, a grant from the Ministry of Education equipped CECS with an Olivetti ELEA 6001, installed at the Institute of Physics. Meanwhile, at the Institute of Statistics, MS was overtaken by smaller and cheaper machines. According to Fortunato Pesarin, who later became a professor of statistics and faculty dean, an Olivetti P101 replaced MS after 1965.[3] Nicola Margola, then a technician at the Faculty of Statistical Sciences, remembers that the MS was decommissioned in 1970 for its "considerable operating cost" and he himself was put in charge of the demolition.

In 1961, there were eighteen computers installed in Italian universities and research institutes [33]. Six years later the number had risen to 55 [8]. Most were small or medium commercial computers for scientific use, such as the IBM 1620 and the Olivetti ELEA 6001. The only two machines built by Italian university teams remained CEP in Pisa and MS in Padua. In Italy, as well as elsewhere, the era of "homebrew computers" did not last after 1960.

After 1962, the small team that built the MS disbanded. Piva was among the founding members of the first Italian professional association for ICT (AICA) and in the next year was a member of AICA's Directors Committee together with Uggè. Later he devoted himself to cultural activities, including the foundation of the Educational Museum of the History of Computer Science. Those voluntary commitments led to his appointment as *Padovano eccellente*, or "Excellent Paduan," in 2010. Contin was hired by various electronic companies and eventually founded his own. Patergnani pursued his career in nuclear physics with a NATO scholarship at the Enrico Fermi Nuclear Institute, University of Chicago, and a fellowship at the Office of Naval Research, USA. Uggè remained at the University of Padua almost until his death in 1971, and in his last years, he continued teaching and expanded statistical studies that resulted in the founding of the new, independent, Faculty of Statistics, Demographic and Actuarial Sciences in 1968. In the decades that followed, the memory of MS faded.

CONCLUSION

Building the MS at the University of Padua resembled similar initiatives in other universities and research institutes in Europe in the 1950s to develop their own digital electronic computers (see Table 1). Some of them began as early as the late 1940s, often starting with electromechanical relays. Thanks to visits to and contacts in the USA, Europeans soon switched to vacuum tubes and stored program architecture. Like MS, those computers were small, low-cost, serial machines, designed and built by small teams of technicians and engineers, eager to have a computer as a powerful calculation tool as soon as possible, in the absence of inexpensive supply from the few commercial producers in the postwar decade.

[3] Olivetti P101 was a small desktop programmable calculator, sold at a price of US$3,500.

TABLE 1. Small serial computers developed in Continental Europe universities (1951–1960).

Name	Year	Institution—Country	Nr. Tubes (t) Solid state diodes (d) Relays (r)	Internal memory technology	Word length (bits)	Internal memory size (words)	Clock frequency (KHz)	Approx. cost (1950s USD)	Notes and References
M1	1951	Laboratory of Electrosystems at the Inst. of Energy Moscow—URSS	730 t	Magnetic drum	25	512			[34]
G1	1952	ANR, University of Gottingen—BRD	476 t	Magnetic drum	32	26 (36)	7.2		[35], [36], [37]
PTERA	1953	Dutch PTT—NL	650–700 t – 120 r	Magnetic drum	31	1024	50		[35], [38]
NUSSE	1953	Norwegian Computing Center for pure and applied research (NCC)—NO	320–450 t 200 d 10 r	Magnetic drum	32	512	40	27.000[4]	Based on APE(X) C [35], [39], [40]
G2	1954	ANR, University of Gottingen—BRD	1100–1200 t	Magnetic drum	50 (64)	2048	92		[35], [36], [37], [41]
EMAL	1955	Institute of Mathematics (GAM), Warsaw—PL		Mercury delay line	40	512	750		Based on EDSAC [42], [43]
ERMETH	1955	ETH Zurich—CH	1200–1800 t 6400 (500) d 500 (200) r	Magnetic drum	64 (16 decimal BCD)	10,000	32		BCD 2-4-2-1 - serial / parallel [35], [44], [45]
D1	1956	Institute for Applied Mathematics TH Dresden—DDR	760 t	Magnetic drum	72	2048		7.140[5]	[32], [46]
G1a	1958	ANR, University of Gottingen—BRD	520 t 35 r	Magnetic drum	60	1840	180		[36], [37]
XYZ	1958	GAM Ist. Mathematics Warsaw—PL	400 t 2000 d	Mercury delay line	36	8192	645		Based on IBM 701 [42], [43]
D2	1959	Institute for Applied Mathematics TH Dresden—DDR	1400 t	Magnetic drum	56	4096		2.380[2]	[32], [46]
BINEG	1959	GAM Ist. Math. Warsaw—PL	350 t	Magnetic drum	36	512			[42], [43]
EMAL 2	1959	GAM Ist. Math. Warsaw—PL		Magnetic drum	34		27		[42], [43]
DERA	1959	TH Darmstadt—BRD	1400 t 8000 (1000) d 90 (100) r	Magnetic cores	20	3000	200		[47, p. 148], [35]
MS	1960	University of Padua—IT	250 t	Magnetic drum	32	1024	52	16,000	Based on APE(X) C [25], [26]
ESKO	1960	Committee for Mathematical Machines Helsinki—FI	450 t 2000 d	Magnetic drum					Based on G1a - Nonstored, programs on punched tape [48]

[4] *Expected selling price of Wharf M2 (1959) [30].*
[5] *Official exchange rate in 1955 (1 US$ = 4.2 East German marks, Ostmark), the real value of the Ostmark was lower.*

The construction of MS was also driven by great enthusiasm and the vision that a smaller, cheaper machine could play a role in a research organization despite the competition for large mainframe computers. Nevertheless, the ingenuity of the builders could not make up for their insufficient funds: Uggè never obtained the bare minimum of money to make MS a useful computer for local industrial clients or faculties who had problems to be solved through programming.

Several factors contributed to MS's short life, and to its inability to create a center of computing expertise at the University of Padua. On one hand, there was a timing problem: the MS was built following a proven but outdated blueprint. By the time it was operational it was already under attack from two sides: from above, with large to medium but increasingly affordable mainframes, and from below, with smaller but more powerful desk machines. American and European corporations began to offer inexpensive "minicomputers" suitable for scientific computing, which could be bought or leased by smaller institutions [25]. Do-it-yourself computer construction, with its unpredictable cost, building time, and uncertain result, was no longer economically or technically practical. On the other hand, there was an underestimation of the necessary budget and effort to go beyond the feasibility study. Upgrading the MS would have required a continuous R&D effort beyond the resources available at most universities: the small staff of young technicians demonstrated their ability to build a working computer, but probably struggled to program it to solve problems matching Uggè's ambitions. This possibly damaged confidence inside Padua University that CUSCS could eventually deliver a service that by that time had become compelling. This in turn strengthened the competing project to provide CECS with a commercially made computer capable of serving several faculties and institutes, attracting the funds that would otherwise have allowed Uggè's center to thrive.

Uggè's vision was correct and anticipated real needs, but despite his ability to find funds and competent technical staff, the impressive technological change rate would have required efforts and investments on a different scale to make such a vast project viable. By the time the "small computing engine for educational purposes" was available, it was no longer fit to address the more ambitious parts of his program, since in the meantime industry had begun to meet the demand for mightier and cheaper computers.

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