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Learning From Prototypes

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COMPUTER HARDWARE DEVELOPMENT often involves a succession of hardware prototypes. These prototypes are often discarded once their functionality is tested, performance measured, and their faults detected and analyzed. Occasionally, functional prototypes are used for a short while for demonstration purposes during products' preannouncements or unveiling to attract the attention of investors and technology commentators. And this is where the life cycle of prototyping typically ends.

Fortunately, some computer prototypes survive and end up in museums where they are preserved for research as they may still hide the seeds of the success or failure of both the final products and the firms that embarked on constructing them, of technological breakthroughs and paradigm shifts that were yet to come.

York University Computer Museum in Toronto has several prototypes of the MCM/70 microcomputer, which was possibly the earliest computer mass manufactured for personal use. The MCM/70 was designed by a Toronto-based electronics company Micro Computer Machines (MCM) in the early 1970s. I have written about the MCM/70 before.[1] Yet, some key questions concerning the computer's design and introduction to the market remained unanswered until additional prototypes of the computer were acquired by the museum and analyzed.

The computer was publicly demonstrated for the first time during the APL V conference held in Toronto on May 15–18, 1973. Before the arrival of the prototypes at the museum, little was known about this historic presentation. Occasional remarks about the demo buried in oral histories gathered by the museum describe with confidence neither the demonstrated hardware, the scope of the demonstration, nor the reaction of the audience to the breakthrough concept of the portable computer for personal use. Another question that could not be fully answered before the resurfacing of the prototypes was how uncertainty in the company's decision making impacted its shaping and marketing of personal computing. In this article, I describe how the analysis of the MCM/70 prototypes allowed to answer these questions more fully.

EARLY MCM/70 PROTOTYPES

MCM built several prototypes of the MCM/70 before the computer's manufacturing began in mid-1974. All of them have their roots in the Key-Cassette concept developed by the company's co-founder and first president Mers Kutt. A

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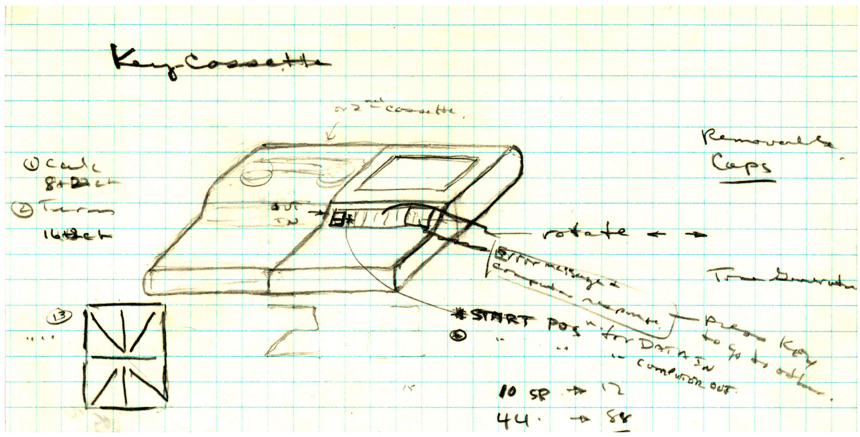

Figure 1. Drawing of the Key-Cassette by M. Kutt (1972). Source: York University Computer Museum.

drawing of it can be found in design notes that Kutt kept from late 1971 until mid-1974 (see Figure 1). The one-page sketch depicted a portable computing device with built-in keyboard, one-line display, cassette storage, and acoustic coupler with built-in modem for communication over phone lines. In addition, the Key-Cassette was to be programmed in the APL language. The Key-Cassette concept showed several key aspects of personal computing philosophy that MCM would be developing in the coming years—an individual-focused complete computing environment that was easy to learn and interact with.

The first attempt at implementing the core Key-Cassette features was a single-board computer put together by MCM's chief hardware engineer Jose Laraya in mid-1972. His computer utilized an Intel SIM8-01 simulation board which the semiconductor company offered to electronics engineers for experimentation with its novel microprocessor and Eprom devices. Although the Sim8-01 architecture was inadequate to achieve MCM's design objectives, this first prototype confirmed that building a versatile microprocessor-based computer was feasible.[2]

Not much is known about the next, rack-mounted engineering prototype constructed by Laraya and his team soon after the SIM8-01-based prototype was declared a dead end. It was sufficiently advanced to be demonstrated to shareholders as a proof of concept on November 11, 1972.

At the end of 1972, the main design issue faced by the company was an insufficiency of memory: the Intel 8008 microprocessor at the heart of the computer could directly address only 16KB of memory while the APL interpreter alone called for much more than that. Furthermore, the MCM engineers had to find a way to "compact" prototype's rack-mounted hardware to fit it into a small enclosure planned for the portable personal computer.

PC DEMONSTRATED

From the early stages of the MCM/70 design process, MCM used the computer's prototypes as demonstrators. In April 1972, in his corporate notes, Kutt expressed with some urgency the need to develop a demonstrator by early June 1972. Under the heading "Shortcut to Demo," he considered packing a power supply and a printed circuit board (PCB) with some MCM/70 circuitry on it into a standard desktop calculator case to have something to show to the potential investors. In the end, MCM came up only with a cardboard mockup which, as it turned out, sufficed to secure venture capital from a law firm in downtown Toronto.

MCM built the first functional MCM/70 demonstrator in early 1973, in time for the computer's public presentation in May during the APL V conference in Toronto. The unveiling of the MCM computer at the conference was a landmark event in the history of personal computing because it showed for the first time that a practical, portable, general-purpose computer designed for personal use and programmed in a high-level language could be economically manufactured.[3] Unfortunately, not much is known about that

Figure 2. Wide-case prototype of the MCM/70. MCM promotional photograph (1973). Source: York University Computer Museum.

demonstration. Only a brief statement about the showing of "the first stand-alone APL microcomputer which elicited a great deal of interest" can be found in L.B. Moore's conference report published in *APL Quote-Quad*.[4] Furthermore, none of the former MCM employees interviewed by me could describe the demonstrated hardware or software with confidence. That changed in 2017 when York University Computer Museum obtained one of the MCM/70's prototypes and a portfolio of early MCM/70 design documents. When analyzed, these objects helped not only to identify the demonstrated prototype but also to determine, in general terms, the presentation's content.

Among the donated documents, there are two drawings of PCB layouts. The first of these drawings is dated May 9, 1973, and titled "MCM 70 PROTOTYPE." The second drawing, dated June 26, 1973, has reference to neither a prototype name nor a revision version. Both drawings define single-board computers, i.e., computers whose main circuitry reside on a single board. It is highly likely that the computer demonstrated by MCM at the APL V conference was the so-called "wide-case prototype" that the company extensively used for promotional purposes in 1973 (depicted in Figure 2), and that the computer's hardware was defined by the June 26th documentation. Here is why—some early documents sent by MCM to its shareholders stated that several MCM/70s were constructed and ready for field trials in early May (hence, before the APL V conference), and that by August, MCM had built ten wide-case machines "for marketing test purposes." One of these documents also includes an image which depicts exactly the same computer as the wide-case prototype shown in Figure 2.[5]

Because of MCM's limited manufacturing capabilities and the fact that the design and manufacturing of the wide-case prototype's case took considerable time, the production of the ten prototypes would have had to begin before May. It is therefore reasonable to conclude that the MCM computers available in May were the first of the ten destined for field trials in August. Hence, what MCM demonstrated during the APL V conference was one of the wide-case prototypes available in early May.

To establish the hardware makeup of the demonstrated MCM computer, I compared the June 26th PCB drawing with the published specifications of the wide-case prototype and with its image (see Figure 2). From the published dimensions of the wide-case prototype and those found on the drawing, it is evident that the PCB depicted in the drawing would fit perfectly into the prototype's case. Furthermore, the types,

locations, and dimensions of the keyboard, numeric keypad, plasma display, and switches (as shown in Figure 2) match the PCB's layout exactly. Therefore, the wide-case prototype was most likely the single-board computer defined by the June 26th documentation. It was built around the Intel 8008 CPU and was equipped with 2KB of RAM and 10KB of ROM which contained, among other software, an interpreter of a dialect of APL—the MCM/APL.

Having the hardware identity of the demonstrated computer established, we can turn our attention to the question of the demonstration's content. In a 2003 interview, Gord Ramer, who implemented the MCM/APL for the MCM/70 computer recollected that "The demo [computer] had almost the complete APL implementation. There were still bugs to be avoided [...] We did not have a special demo version of the software, so the demo was tightly controlled, i.e., the person on the keyboard new what to avoid."[6] APL programming language offers a range of built-in functions and MCM most certainly demonstrated the capabilities of its computer by executing programs involving some of them. But which ones? Early MCM/70 promotional documentation frequently included computer code comparisons to demonstrate the efficiency of coding in APL as opposed to programming in languages such as Fortran and Basic. Computing the average of a set of numbers (APL code $(+/X)\div\rho X \leftarrow \square$) and sorting a set of numbers (APL code $X[\grade{up}X \leftarrow \square]$) where given as examples. But these programs would be considered rather elementary by an APL programmer who, instead, would rather see examples involving APL functions whose evaluation required considerably more time—functions such as matrix inverse which was frequently used for benchmarking. Unfortunately, the low speed of the Intel 8008 processor inside the MCM/70 demonstrator meant that, most likely, MCM demonstrated programs with short execution times and only those that could be directly entered via keyboard. Indeed, the demonstration of long multiple-line APL programs would require a transfer of such programs from external storage into the computer's memory. In a preannouncement document released in May 1973, MCM listed an external cassette unit as an available option. In principle, such a unit could have been interfaced with the prototype via the computer's communication bus called Omniport. However, it is doubtful that such cassette storage was available for the wide-case prototype at the time of its presentation in Toronto. The computer could only be equipped with up to 2 KB of RAM and that was not enough to support an external cassette unit and to provide enough memory for the storage and execution of user's applications.[7] In the end, the announced cassette unit did not materialize as a commercial product. Instead, MCM offered three production models of its MCM/70 computer: a model without cassette storage and with 2 KB of RAM (as in the wide-case prototype) and two models with built-in cassette drives—a single cassette model with 4 KB of RAM and a two-cassette model with 8 KB of RAM (see Figure 4).

Scarce primary sources detailing the presentation make it difficult to ascertain the APL community's response to the demo and to MCM's concept of a personal APL computer. According to Moore's above-quoted statement, the MCM/70's presentation was met with interest. In a 2001 interview, Mers Kutt made a similar comment noting that the computer astounded a group of IBM employees attending the conference. In fact, two of the first dozen MCM/70 units manufactured by MCM went to IBM's General Systems Division in Atlanta, Georgia, for the purpose of "research and analysis." In 1975, IBM announced its own APL desktop computer—the IBM 5100.[8] However, other MCM employees assisting with the presentation recollected a less enthusiastic response from the audience who did not give the MCM/70 computer too much serious thought. Joey Tuttle, a former IBM employee and a member of the IBM 5100 development team, recalled a similar presentation of the IBM 5100 at IBM Rochester. During the presentation, "one of the attendees shouted out, "run +/40000 ρ 1"" which would create an array of length 40 000 filled with 1s and to return the sum of all the elements stored in the array—a simple way to test memory. When the presenter entered the expression and the computer seemed frozen for an extended period of time, "the anticipation and the increasingly nervous body language of the presenter, turned to laughter."[9] In the end, the demonstrated IBM 5100 took over 3 min to finish the evaluation of the expression in question, which

was very slow in comparison with the state-of-the-art IBM mainframes running APL. It is plausible that similar requests were made during the MCM/70's demonstration and that the slow speed of the computer elicited similar reactions to those recalled by Tuttle. Indeed, a request to evaluate an expression such as $0.7 \div \iota 255$ to generate consecutive 255 integers and to divide each of the numbers by 0.7 could easily have resulted in a snicker as it would have taken the machine approximately 50s to evaluate it while the execution of the same code on an IBM System 360 mainframe would have produced the output in a fraction of that time. "Such audiences can judge harshly," concluded Tuttle.

EXECUTIVE—THE MISSING LINK

In the summer of 1973, several MCM/70 demonstrators were on their European and North American promotional tours. Most were the wide-case prototypes. But one was an altogether different piece of hardware, assembled in record short time for a demonstration at the APL Congress that was to take place in August at the Technical University of Denmark in Lyngby, north of Copenhagen, Denmark. In July 1973, MCM decided to pack the current MCM/70 hardware, including a keyboard, a one-line plasma display (Burroughs SelfScan), and a single cassette drive, into an attaché case and to operate all of it on batteries exclusively. The company expected considerable marketing gains from the planned ground-breaking presentation of a never-seen-before luggable, battery operated, general-purpose computer which they named the Executive.

The gamble played off. On August 23, the day after the Executive's demonstration, the Danish daily *Politiken* published a front-page article about a sensational computer from Canada. The article included two photographs depicting MCM employee Ted Edwards operating the Executive on the doorstep of the auditorium where the conference took place (see Figure 3). "In all modesty, a real sensation occurred yesterday when the International APL Congress was about to begin at the Technical University of Denmark." wrote *Politiken*. "When the buses with conference participants from 24 countries arrived from hotels in

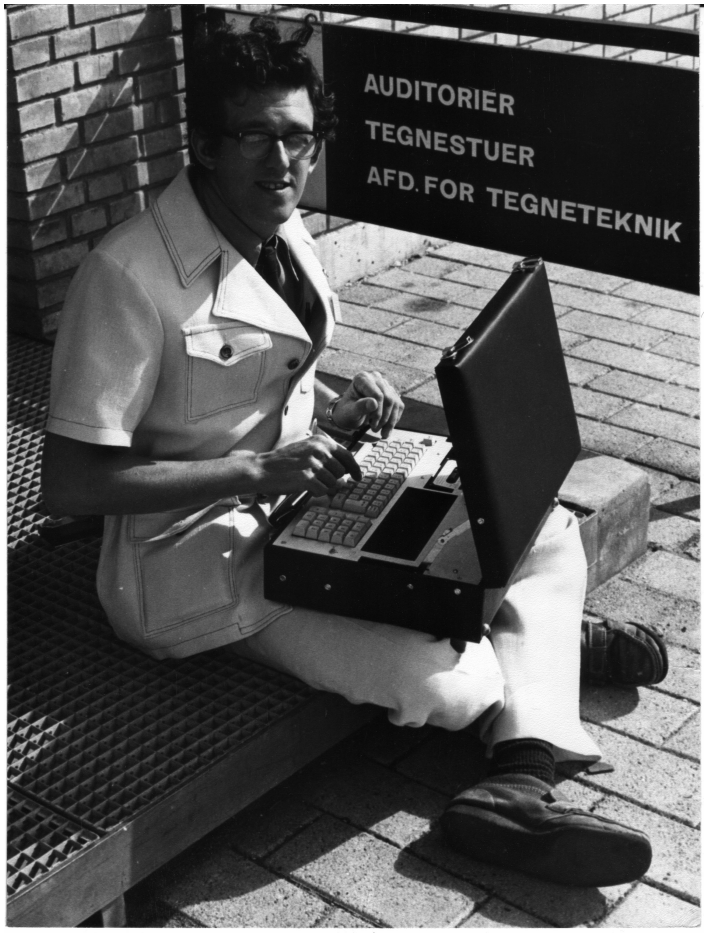

Figure 3. This photograph of Ted Edwards demonstrating the Executive during the APL Congress in Copenhagen appeared in *Politiken* on August 23, 1973. Source: York University Computer Museum.

Figure 4. Two-cassette MCM/70 (model 708). Source: York University Computer Museum.

Copenhagen, he [Edwards] was sitting on the steps of an auditorium building solving complex problems on his data processing machine placed on his lap. Several experts who went by thought that the computer was a joke. Many stated that such a machine was impossible. But others who followed Ted Edwards' programming computations [...] admitted that the machine performed exactly as considerably larger IBM computers running APL and connected to an electrical outlet. There just was not any power cord attached to Ted Edwards' briefcase."[10]

A look inside the Executive's briefcase enclosure gives the impression that the computer's hardware was packed in a rush using, what would be best described as a "chain saw and duct tape" approach.[11] The computer's keyboard had been crudely sawn-off from the wide-case prototype's main board. Other components were attached using means ranging from nuts and bolts to sticky tape. The large ROM board consisting of 88 Intel 1702A Eproms that barely fit inside the case was placed at the bottom and, it seems, was kept in place only by means of the numerous wires pressing against it. The built-in cassette drive allowed for loading and storing APL programs and data. However crudely built, the analysis of the Executive revealed much about the evolution of the MCM/70 concept. The single-board approach employed in the wide-case prototype was replaced by a modular architecture in which computer hardware was logically divided into interconnected individual modules such as CPU, ROM, RAM, and interface modules that occupied separate circuit boards and communicated over a common bus. The Executive's CPU and cassette interface boards were early versions of the boards that would eventually populate the production model of the computer. On the other hand, the RAM board (4 KB) was, possibly, the one developed earlier for the rack mounted prototype and would be redesigned for the production model. Finally, the large ROM board inside the Executive was the same as the one used in the early production models. Because in early 1974, ROMs containing MCM/70's systems software were not yet delivered by the supplier (Electronic Arrays), the first MCM computers were equipped with the same ROM board found in the Executive and, because of its large size, it was mounted externally under the bottom of the computer's case (thus earning it a nick-name "pregnant bottom"). This shows that from the hardware architecture point of view, the Executive was almost identical to the production model and, hence, that by July 1973, the company had already abandoned the single-board approach represented by the wide-case prototype.

For a brief time, MCM contemplated manufacturing the Executive and made announcements to that effect in the press. In October 1973, the computer was shown during the National Computer Show and Conference in Toronto but, in the end, the company quietly abandoned the Executive concept. The surviving MCM corporate documents do not provide any justification for the decision. However, some arguments against the Executive can be reconstructed by analyzing its design and another prototype put together by Edwards some years later. To begin with, the Executive was an attempt at building a fully luggable, battery-operated, personal data processing system. It was to offer complete data processing and communication functionality at the user's fingertips. However, most if not all of the Executive's features were planned for the MCM/70 desktop which, in addition, was not much larger or heavier than the Executive. Like the Executive, it could be operated on batteries and carried around in an elegant leather case that could be purchased for $150 from MCM.

Most likely, there were also arguments of a technical nature against the Executive. Some of these arguments can be deduced from the Executive-like computer designed and built by Edwards around 1975–1976 (see Figure 5; I will refer to this computer as the Executive-E.).[12] From a hardware point of view, the Executive-E is an MCM/70 clone. All the PCB boards used in it are the same as those found in the production model of the MCM/70 or its MCM/700 refinement. However, from a packaging perspective, it is the Executive repackaged into an all-aluminum case. The addition of the second cassette drive may suggest that one of the issues with the Executive was its limited memory and, as a consequence, limited functionality. While the Executive used its single cassette drive for external storage, the amount of RAM that could be made available to a user remained low.

Figure 5. Ted Edwards' Executive-E. Source: York University Computer Museum.

MCM solved the insufficient RAM problem by developing a cassette-based virtual memory system (called AVS) that made over 100 KB of memory available to applications. But AVS required a dedicated cassette drive and there was simply no space left in the Executive's case for the second drive. There was no space left for anything at all, not even an internal fan, which brings us to the second issue—heat dissipation. The Executive's case had no provisions to dissipate heat during the computer's operations. In the MCM/70 production model, which also lacked an internal fan, the heat dissipation problem was solved by packaging all the boards in special aluminum casings sandwiched together to form the back end of the computer and to act as a giant heat sink. In the Executive-E, Edwards used the entire aluminum case of the computer as a hit sink.

It is likely that the Executive-E was an attempt by Edwards at salvaging the Executive concept. Because of its sturdy packaging it could have been marketed as a luggable data collection and processing system for use in harsh rugged environments. However, by the time its design was finished, Edwards was no longer with MCM. It would be left to another company to build and successfully introduce a portable battery-operated computer for rugged environments. GRiD Systems, Inc., introduced its first laptop–the GRiD Compas 1001–in 1981. In the following years, several GRiD laptops would find their way into space supporting NASA's early Shuttle missions.[13]

MARKETING PERSONAL COMPUTING

With the MCM/70 personal computer concept, MCM hoped to create a lucrative niche on the electronics market between the inexpensive, easy-to-use desktop electronic calculators that were inadequate for many data processing tasks, and large, expensive, and complex to operate general-purpose computers. To succeed, the company needed to support its personal computing venture with a well-defined and appealing product philosophy and attractive marketing to promote it. MCM promotional documents from the mid–1973 paint an interesting picture of how the company was stitching together a personal computing paradigm from the computer's basic features as well as its hardware and software options. An August 24, 1973 portfolio of MCM/70 preannouncement documents distributed to MCM shareholders already contained an outline of the paradigm.

> *The revolutionary concept of the MCM/70 is that it brings to the world of computing what the $100 hand held calculator brought to the world of calculating. [It is] of a size, price, and ease-of-use as to bring personal computer ownership to business, education, and scientific users previously un-served by the computer industry.*[14]

But that's not all. The portfolio also listed the MCM/70's basic features together with available options. The list was a very long one: two types of printers (one external and one built into the computer's chassis), cassette drives, serial communications interface, CRT (Cathode Ray Tube) display, RAM expansion of up to 64 KB, and even plug-in ROM modules with preprogrammed applications software. These features and options were designed to capture the core features of the personal computing environment that MCM wanted to offer with its desktop. However, throughout 1973 and 1974, the list of the MCM/70's available options was a moving target, continuously revised with some options added, others dropped to reappear again. Were these changes reflective of uncertainty in company's decision-

making or of an evolving point of view on personal computing that necessitated the shifting of priorities for the development of at least some of these options? Or were they part of a marketing ploy to overwhelm potential customers and MCM shareholders with claims of its offering's sophistication and completeness, an early example of vaporware? The analysis of the surviving MCM hardware and corporate documents shows that all of these concerns were the case.

In late 1973, MCM dropped the preprogrammed ROMs option all together, gave up on memory extension to 64KB, replaced the built-in printer option (which had never materialized) with an external impact printer. But not all of the company's claims were a marketing gambit. The Executive's hardware already featured a partially implemented communications bus (Omniport) that allowed the computer, in principle, to interface with printers.[15] However, what the company did not have at that time was the printer itself, and it was not until mid-1975 when, finally, it offered its MCP-132 printer (the Diablo HyType I printer). At that time, MCM also upgraded the MCM/70 with an EAI communications interface that allowed the computer to communicate with a range of other peripherals. MCM's stated objective "to offer a complete micro computer system" was finally realized.[16]

The MCM/70's built-in display (Burroughs SelfScan) was one of the core features of the all-in-one hardware concept. While such a display enhanced portability, the single-line 32-character-long solution adopted for the computer offered a convenient display environment for only rudimentary APL calculations. MCM maintained that MCM/70's display was sufficient for many tasks because of APL's coding efficiency. For all other applications, there was to be a CRT display, already listed in August 1973 as an available option. Of course, the company could have equipped the MCM/70 with a multiple-line display, as was done for some calculators of the era, if it were not for the fact that the computer required a dedicated segment of RAM for storing characters to be displayed (display memory). More display lines would take away precious RAM from the user's work space. The RAM shortage was so severe that display memory was also used for temporary storage during computations. A first-time user would have been quite surprised and astounded when after entering a command, such as the above mentioned $0.7 \div \iota 255$, the computer would begin a 50-second-long display of strange and dazzling patterns (i.e., visual representations of temporal data stored in display memory) before eventually clearing everything and showing the result of the computation. Therefore, having a single line display built-in and an external CRT terminal as an option seemed like a reasonable solution. But the CRT option disappeared from MCM's 1974 promotional literature and was not discussed (as a work in progress) in any surviving minutes from MCM managers' meetings. It would not be until 1976 that MCM finally introduced such a display for its new computer—the MCM/800. This might suggest that the announcement of a CRT display as an "available" option made three years earlier was, to put it mildly, a careless instance of the company "snowing" customers and shareholders with options that were only meant to enhance the MCM/70's image. Or is it? To answer this question, I analyzed the ROM boards inside the MCM/70, Executive-E, and MCM/800 computers. The inspection of these boards showed that the same three ROM sockets (out of 16) were left unpopulated in the MCM/70's and the Executive-E while similar boards inside the MCM/800s had all 16 ROM chips installed. It turns out that these three empty sockets were reserved for correcting and future expansion of the MCM/70's systems software, including the addition of CRT support. One may therefore conclude that financial or other corporate difficulties that MCM experienced in 1974 forced the company to drop several options, including an inexpensive printer and a CRT display, in order to concentrate on the MCM/70's prompt introduction to the market. However, as evident from the MCM/70's ROM board, some necessary hardware provisions for such options were made at the start.

LOOK OF A GADGET

The MCM/70 concept was shaped by ideas coming from several sources, one of which was the calculator industry. From the late 1960s, desktop programmable calculators were presented as minicomputers and even as minis for personal

use, as was the case with the Olivetti Programma 101 introduced in 1965. Furthermore, the manufacturers of hand-held calculators marketed their devices as consumer electronics gizmos. The MCM/70 was to be both; a stylish "gizmo" look was regarded just as important a feature of the MCM/70 as its conception for personal use. Through the industrial design of the MCM/70 the company wanted to draw attention to a new computing paradigm and to create its own unique identity.

In his 1965 article "The Great Gizmo," Reyner Banham characterized a gizmo as

> *[. . .] a small self-contained unit of high performance in relation to its size and cost, whose function is to transform some undifferentiated set of circumstances to a condition nearer human desires. The minimum of skills is required in its installation and use, and it is independent of any physical or social infrastructure beyond that by which it may be ordered from a catalogue and delivered to its prospective user.*[17]

As early as the MCM/70's prototyping stage, the company's description of the computer provided an almost undeviating instance of Banham's characterization of a gizmo. The Key-Cassette concept was a gizmo (although only on paper), and so was the Executive. The design of the wide-case prototype accomplished not only the requirement of hosting all the necessary hardware in a single box but also of finding the right balance between stylish eye-catching design, functionality, and practicality. Two years of design experiments culminated in the 1974-release of the MCM/70's production model which inherited the all-in-one concept from the Key-Cassette and the Executive, and a defining stylish design from the wide-case prototype. In the late 1970s, the nascent home computer industry would follow in the footsteps of MCM choosing appealing, dashing designs over the industrial look of minicomputers.

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3. Three months earlier, a French company Réalisations Études Électroniques (R2E) announced its microprocessor-based Micral (see, Bui, R. Un miniordinateur pour moins de 8500FF, *zero.un. informatique hebdo*, no. 228, Feb. 12, 1973, pp. 1 and 5.). However, the Micral was not intended to be a personal computer: "MICRAL's principal use is in process control. It does not aim to be an universal minicomputer," Micral User's Manual, R2E, Jan. 1974, p. 66.
4. L.B. Moore, A report of APL V Conference, *APL Quote-Quad*, Jun. 1973, pp. 20–21.
5. The documents in question are dated May 4 and Aug. 24, 1973. York University Computer Museum, MCM Collection.
6. Author interview with Gord Ramer, Jan. 15, 2003.
7. A large portion of the computer's 2 KB of RAM was used for display, APL execution stack, and a variety of tables required by the computer's operating system. Interfacing a cassette drive with a computer would require an allocation of additional RAM to store information about the interfaced device and the tape's content leaving little space for anything else.
8. I have encountered no evidence for the design of the IBM 5100 being, in any way, influenced by the MCM/70.
9. J. Tuttle, private communication, Jan. 2020.
10. *Politiken*, Aug. 23, 1973, pp. 1 and 20.
11. The Executive was donated to York University Computer Museum in 2017.
12. The date codes found on its ICs, suggest that the computer was put together around 1976. Because Edwards left MCM at the end of 1975, he continued the design after leaving MCM.
13. Accessed on: Mar. 2020. [Online]. Available: https://airandspace.si.edu/node/35305
14. MCM/70 pre-announcement shareholder documents, Aug. 24, 1973. York University Computer Museum, MCM collection.
15 This was confirmed using the MCM/70 emulator developed at York University Computer Museum and which uses almost identical systems software to that found in the Executive's ROMs.
16. *MCM Newsletter*, no. 1, 1976, pp. 2 and 3. The MCP-132 printer plotter was sold by MCM for $4500 which was almost the same price as the MCM/70 in its basic configuration ($4970).
17. R. Banham, The Great Gizmo, *Ind. Des.*, vol. 12, pp. 48–59, 1965.