Whirlwind I: computer architectures as testing grounds for the spaces of modernity

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The interdisciplinary research *Whirlwind I: computer architectures as testing grounds for the spaces of modernity* explores how digital computers and computing technologies have influenced the formation, representation and reception of architecture since the mid-20th century. This article focuses on the link between *architecture*[1] and computing, particularly as materialised in the architectural spaces generated literally by both disciplines: the technological device of the *building* and the technological device of the *computer,* which, in the cases of the First Generation, as we will see, correspond with each other.

The birth of the digital age of computing[2] and the progress of modern architecture coincided in time and evolved in parallel. The evolution of the two specialties during these years can be described, studied and analysed according to common parameters and criteria.

A study of the spaces of the first digital computers reveals a series of specific characteristics that may have influenced or been influenced by the architectures that were developing in the purely architectural discipline at that same time.

This article explores and focuses on the *architecture* shaped by *mainframes*[3] (or central units), the first digital computers belonging to the First Generation of Computing[4], which historians date back to the mid-20th century (1950-1960), after the end of the Second World War.

Pre-generation computers

An orderly classification of these early examples of technological devices can be found in the research carried out bythe American electrical engineer Gordon Bell, the co-founder, with Gwen Bell, of The Computer Museum (TCM) in Boston (USA). In 1980, Bell made a poster for the museum showing the first computer technology devices and their technologies, which had been involved in the birth of the digital computer, and organising them chronologically into four main groups [Fig. 01]: he listed the first electronic computers (*computer* technology devices), corresponding to the Pre-Computer Generations or Pre-Generations of computers, and later the first digital computers. He set the date for this birth between 1944 and 1945, when two events coincided: the launch of the *Harvard Mark I* (August 1944) and the publication of the "First draft of a report on the EDVAC" (June 1945) by J. Presper Eckert and John von Neumann[5].

In this classification, Bell organises the generations prior to the digital computer (or pre-generations) into four main groups: (4) the 'manual generation' (1600-1800), which included technological devices such as the *Shicklard* calculator (1623) and punch cards (1728); (3) the 'mechanical generation' (1800-1890), which included Thomas' arithmometer (1872), the comptometer (1887) and the *analytical machine* by Charles Babbage and his team (1833)[6]; (2) the 'electromechanical generation' (1890-1930) which incorporated examples such as the adding machine (1892) and the *mechanical arithmometer* by the Spaniard Leonardo Torres Quevedo (1920), located in the Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos of the Universidad Politécnica de Madrid[7]; and, finally, (1) the 'electronic generation' (1930-1945), which Gordon Bell divided into two sub-groups: one for technological devices based on an electromechanical technology, which included examples such as the computers developed by Konrad Zuse (V1 or Z1 -1936-, Z2 -1939- and Z3 -1941), the *Bell Labs Model I Relay Calculator* or *Complex Number Calculator* (1937-1940) and the *Harvard Mark I* (MK I) (1937-1945)[8]; and the other for technological devices based entirely on an electronic technology: the *Atanasoff-Berry Computer* or ABC (1938-1942), the ENIAC (1943-1948) and EDVAC (1945-1951), developed in the United States, and the *Colossus* (1943) and *Pilot ACE* computers, together with their reports (1945-1948-1950), developed in the United Kingdom.

Bell's diagram focused almost exclusively on American production and construction of *mainframes.* Thus, other cases belonging to the First Generation of Computing (digital computers) produced elsewhere could be listed, such as the BINAC (1948), the *Whirlwind I* (1945-1956), the SSEC (1946-1952), the *IAS Computer* (1946-1951), the SEAC (1950), the SWAC (1950) and the UNIVAC I (1951), all likewise developed in the USA; *Manchester Baby* (1948), *Manchester Mark I* (1949), *Ferranti Mark I* (1949-1951), EDSAC (1949) and LEO I (1951), all developed in the United Kingdom; BARK (1950), developed in Sweden; CSIRAC (1949-1964), developed in Australia[9].

The examples of electronic computers belonging to the 'electronic pre-generation' (1) shown on Bell's poster (highlighted in the diagram with a black box – see top right of [Fig. 01]), are the precursors of the first digital computers belonging to the First Generation of Computing (1950-1960).

This last group, with all the examples mentioned above, constitutes the origin of the first computer architectures ever built. In these spaces of the first digital computers we can see a number of specific spatial qualities that we also find in the field of architecture, with a clear interchange between both disciplines during this period. Although these spaces are not usually counted in the modern story of architecture, they reveal an interesting testing ground, an alternative and complementary laboratory to the one being developed in purely disciplinary spaces.

In all these cases, the technology device of *computer* corresponds entirely to the technology device of *building*, as there is equivalence between both architectures, constituting a single inhabited space.

As Gerard O'Regan points out, these early digital computers or *mainframes* were huge architectures that occupied large spaces, even entire multi-storey[10] buildings, as we will see further on. They were complete and complex computer architectures that were inhabitable by both human and non-human agents[11]. As Giorgio Agamben describes, they were devices inhabited by *living beings* (human agents: programmers, engineers; non-human agents: bugs, moths, mice; all of them considered 'individuals') or 'substances' (objects, things), whose coexistence resulted in multiple processes of subjectivation, giving rise to polyhedral and diverse subjects[12]. According to Agamben, there is not a single moment in the life of living beings or substances that is not modelled, contaminated or controlled by some device[13].

First Generation Computing (1950-1960): The *Whirlwind I* project (WWI) as a case study

The *Whirlwind I* or WWI project [Fig. 02], directed by Jay W. Forrester and his team, and developed by the Lincoln Laboratory (initially called Servomechanisms Laboratory and later the MIT Digital Computer Laboratory) at MIT in Cambridge (USA), between 1945 and 1956[14], was one of the three most important projects developed in the United States in the first half of the 1950s[15]. It was a *mainframe*-type computer, one of the fully digital devices of the First Generation of Computing (1950-1960)[16]. At the beginning, the project sought to produce a single-purpose analogue device (part of the generation of electromechanical devices in Bell's classification, group (2)): a computer to calculate responses to pilot actions in US Navy flight simulators and to control such simulators in real time[17]. In 1945, after an injection of funding, the project changed course radically to begin designing, producing and building a real-time general-purpose digital device. Forrester gave the *Whirlwind I* project a transformational character, thanks to the influence of Von Neumann and Presper Eckert, who were developing the ENIAC. After several meetings, Forrester encouraged the team to be interdisciplinary[18].

Whirlwind I was the first computer or digital device with random access magnetic core memory, and could process 16 digits at a speed of 20,000 times per second, a technology later implemented in all Apollo mission computers.

At the beginning of the project, in the autumn of 1946, Jay W. Forrester began to think about the design and construction of a container building to house this new type of device. He had to find an architect to supervise its construction before the spring of 1947[19]. During the design stage, it was envisaged that the project would be four storeys high to house the future headquarters of the Servomechanisms Laboratory, with average dimensions on the ground floor when compared with other laboratories of the same time at MIT. Initially, the project was intended to be a new 'building' technological device.

With a low budget available for execution, the options of raising a new building (within the MIT Supersonic Laboratory complex) were no longer worthwhile for two reasons: the investment required and the execution times involved. At that time, the option of refurbishing an existing container began to gain strength. Before the end of August 1947, the Barta Building (N42) was considered as a possible location for the project and was finally chosen. The Barta Building (N42) thus became one of the first computer architectures to be transformed, through refurbishment, into the *Whirlwind I* 'computer/ building' technology device.

This MIT campus building still stands today at 211 Massachusetts Avenue. It was built in 1904 by the architect C. Herbert McClare, originally with an L-shaped floor plan to house an industrial laundry for the *E&R Laundry* company[20]. It has an elongated north-south floor plan with an exterior façade running lengthwise along Windsor Street, and a transversal exterior façade, the main one, facing Massachusetts Avenue. With three floors above ground, its exterior appearance is characterised by its red brick facing in its envelope and its distinctive gargoyles, mouldings, towers and ornamentation that frame the niches in the façade and finish off the corners and unique points of the building, such as its main entrance[21] [Fig. 03]. Its main facades look much as they did 100 years ago, despite transformations in the floor plan, implementation of super infrastructures, changes in use, the recycling of the container and the works and refurbishments to which it has been subjected. The windows we see today on a walk along *Google Street View* (made up of vertical openings for groups of two or three windows) are an aluminium replica of the original ones, as are all the other materials and ornamentation, done to preserve its historical character in recent renovations (in 1998 and 2018).

As in the initial project, a container was sought that could hold the four storeys, for a volume that had been calculated to be filled by the device. In 1948, in the Barta Building (N42)[22], the *Whirlwind I* project presented its four floors, distributed as follows: a basement floor that housed all the facilities for the device's power plants (equivalent to the computer's power supply, whose high energy demand was, on average, between 100-150 kW, the equivalent of $2500 of electricity consumption per month in 1964)[23] and some associated laboratories; a ground floor at street level whose main entrance was on Massachusetts Avenue, where the storage device for the alternative computer, the cafeteria, the shop, the office and the warehouse were located; the first floor housed the computer room and the associated control room (equivalent to the CPU or central data processing unit, the control console and the CRT screen)[24], as well as offices and the administration area. The rooftop area held all of the hyper-populated facilities used for air-conditioning. The original L-shaped floor (when the building was used as a laundry) was gradually filled in on the three levels above ground (first floor, second floor and roof). In total, the surface area of the container was roughly 3,300 m^2 ,not counting the rooftop area.

As a 'computer/building' device or physical architectural object, *Whirlwind I* was a large project whose computer room or CPU took up more than 300 m^2. It was not designed and built to reduce floor space. Its size was intended to ensure perfect operation: Forrester knew that reliability was crucial, so he wanted to ensure that every component, cable, wire and vacuum tube was easily accessible, repaired and replaced. To this end, a layout was designed to distribute the flows of 'living beings' in the computer room in the form of a central backbone, as a distributor hall or main corridor, from which various side distribution corridors branched, like perpendicular backbones that gave access to the circuit and memory modules. He organised the floor of the computer room (CPU) as would an architect of the Modern Movement, with some spaces serving (corridors and distributor halls) and some spaces serviced (large cabinets or racks that kept all the components and elements of the system in sight, making their arrangement visible). In 1951, the CPU floor was located on the first floor. It held five rows of cabinets or racks specialised in one type of component, with different functions, parallel to each other and separated by server corridors. These cabinets were built of modular metal frames that incorporated the different components of the device [Fig. 05]. Its layout was perfectly zoned and distributed by specific functions (rows C, A, E, F and P)[27].

Running in plain sight along the ceilings in these corridors was the powerful air-conditioning and cooling system[28] that took up the whole upper part of the living spaces [Fig. 02 and Fig. 08], which operated 24 hours a day, in an attempt to remove the build-up of heat in these interior spaces. The installations were left uncovered for inspection purposes, as an essential part of these computer architectures. The design of the installations played a very important role in these architectures. These systems were essential for correct operation of the 'computer/ building' technology devices, thus ensuring their reliability, a fundamental quality for this type of space[29].

Whirlwind I was a walk-through 'computer/ building' device; you could walk around inside it and see all the components that made it up, as Forrester described it[30]. These new 'computer/building' technological devices were enormous inhabitable architectural spaces that were inhabited not only by thousands of vacuum tubes[31] but also by the many different bodies of 'living beings' that both configured and constituted an essential part of these devices. Individuals inhabited the technological device, spent long periods of time in it, working, programming, operating inside it. They were able to move through and across it, resulting in flows of people, of energy, of information. Human and non-human agents were 'in' the digital device, 'inside' the computer, inaugurating a new use of these two prepositions in the relationship between two disciplines: architecture and computing. The bodies of individuals, substances or *living beings* mixed and mingled in a new way with the devices that they walked around in, thereby constituting different new subjectivities and subjects. These examples of digital computers constituted new architectural configurations, new typologies, new types, new examples of spatial relations, relations between body and space, new articulations between parts, new proportions, new materialities, etc. They were huge inhabited 'prototypes'[32] that defined these new architectures of computing.

The dimensions of this 'computer/building' technology device did not end at the Barta building's outer shell. The 3,300 m^2 of apparent floor space in fact amounted to more than 29,000 km^2. This computer architecture spread out across the territory of Massachusetts Bay, spreading its rhizome-like physical network of interconnected nodes, whose main centre was located at 211 Massachusetts Avenue. *Whirlwind I* was finally launched at the beginning of the new decade: in June 1950 the project was successfully launched, and in 1951, during the Cold War, it held together called the *Cape Cod System*, a network of American radars that was a smaller version of the SAGE (Semi-Automatic Ground Environment) programme[33]. The *Whirlwind I* 'computer/building' technology device, with the Barta Building (N42) on the MIT campus as the sentinel node, connected to 15 other long-range radars more than 160 km away (such as the node at Cape Cod[34] or Martha's Vineyard island) [Fig. 06].

The architecture of computing through the *Whirlwind I* (WWI) Project

The *Whirlwind I* project has been chosen as an important case study, as a model of the first computer architectures, for all these architectural considerations and various others:

For being a pioneer project:

Its development started at the dawn of the First Computer Generation (around 1950), and is one of its main examples. Charles and Ray Eames considered it the most influential example of the first digital computers[35]. *Whirlwind I* was the fastest[36] and largest[37] technological device in its day as well as being the first general-purpose computer to work in real time[38]. In fact, it is considered the forerunner of commercial mini-computers, or even the first example thereof[39]. It was conceived and built as a prototype for future devices[40], networked with other nodes to incorporate an interscalar condition into its architecture (working with a building scale and a territorial scale) [Fig. 06]. Thanks to the hallowed status that spaces for such devices acquire over time, *Whirlwind I* is an architecture that history is determined to preserve, to reconstruct and reconvert into museums, foundations and institutions, although many of them have become mere shadows and talismans of their former selves, due to the dismantling, mutilation and decontextualisation of their elements and parts[41]. This new architecture of immediacy, of real time, had a decisive influence on the development of many *computer/building* technological devices, such as the massive concrete buildings that made up each four-storey node of the SAGE programme; the SSEC (IBM's Selective Sequence Electronic Calculator), a device located in the lobby of IBM's Manhattan headquarters, at street level (1946-1952); the IBM Development Lab in Poughkeepsie (1955) and the Westinghouse Tele-Computer Center in Pittsburgh (1964), both examples of the work of the modern architect and director of IBM's design department, Eliot Noyes[42].

Because its architecture is the hardware:

In early computer architectures what prevails is the *hardware*. The external shells become the computer casing, the basement, the power supply; the rooftop becomes the fan and the offices, cafeteria and store room, the device peripherals. It is an architecture that re-appropriates the existing architectural heritage, for the sake of rehabilitation. It is a reliable and functional hardware that proposes large-scale spaces. Moreover, to achieve this condition it becomes a transparent architecture, one that makes all its infrastructures and facilities visible and accessible from anywhere inside the space[43], *unblackboxing* the space. It is a hyper-dimensional, luminous and resounding[44] architecture, the first to include an interface (created by Forrester's closest collaborator in the development of *Whirlwind I*, Robert R. Everett) as a construction detail[45] [Fig. 07], this element being the first example of what Nicholas Negroponte 20 years later called the machine architecture interface[46]. It is a hardware architecture resulting from the transfer, reuse and recycling among innovations and materials used in the military industry and civil architecture[47]. It even uses the same materials: steel, aluminium, copper, brick, concrete, glass, plastic, etc., are the materials from which both devices are constructed. So obvious is the correspondence between the 'building' device and the 'computer' device that when they suggested dismantling it because it had become obsolete, on 1 April 1959 William M. Wolf, one of its programmers, asked to buy it and MIT told him that he should buy the building in its entirety for $250,000 (thereby establishing an indivisible union of the two devices)[48].

Because its inhabitants are the software:

In these first architectures the software is secondary. Human agents were an indispensable component for the operation of the computer/building technological device, just another[49] cog in the wheel; they were part of the hardware that made up its architecture as well as the software that made it work with a given program. They introduced, read and interpreted the inputs and outputs of the computer. Verbs like plugging, perforating, switching and toggling were physical forms of contact, relationship and interaction that constituted those first hardware- and software-oriented human-computer interfaces. Photographs of these first architectures show that the presence of 'living beings' or 'substances' was a constant in all of them[50] because their existence was necessary for their functioning [Fig. 08]. The human was always 'inside', 'within' the technological device, inhabiting that space of the computer. The various human dimensions are the basis of the origins of computers. Their configuration serves as a design and structure model for computer architectures and for modern architecture, as well as a dimensional model for their elements, as a kind of *Modulor,* which uses the dimensions of the bodies that will inhabit them, humanizing those spaces and bringing them closer to our everyday life[51].

Because it is flexible and reprogrammable:

These first computer architectures worked with prefabrication and modulation[52], using standardised elements and materials from the catalogue, like many modern architectures, thereby facilitating their flexibility to adapt to new configurations [Fig. 09]. It houses a new, unexplored programme that allows for the reprogramming, reuse and recycling of architecture that supports it over time, with hardly any modification to its envelope and structure (it goes from a laundry to a computer, to a workshop, to an industrial building, to a classroom, to a departmental building and to a biomedical research centre in 116 years)[53], despite the rigid programmatic zoning that dominates its layout but facilitates exchange between elements. The typology and configuration of the existing building itself is what gives the device such flexibility, together with the use of prefabricated and modulated components.

Because it is inclusive:

This architecture is collaborative, inclusive towards the greatest possible number of agents, and is recognised as such. It is made by large interdisciplinary teams[54], unlike modern architecture featured in histories, which fosters individualism[55]. Furthermore, it is democratic, inclusive of other bodies and 'living beings' or 'substances', and plural, in comparison with other architectural spaces of modernity or working environments of the time [Fig. 10]. The *Whirlwind I* 'computer/building' device is the first to incorporate an African-American programmer/operator in its design and development[56] and even the presence of women in relevant productive work is considered normal. It is a type of unexplored space that seems to have no connotations associated with race, gender or any other condition[57], which serves as a laboratory to test and incorporate other bodies and other possible relationships into these architectural spaces[58].

For all these reasons, the history of the discipline would do well to pay attention to these other architectures – of the computer – and bring them into the contemporary architectural discourse: because of their influence, their dimensions, their weight, their materiality, their spatial configurations, their physical laws, as a way to understand the formation, representation, communication and reception of 20th-century architecture.

'Computer/building' technology devices such as *Whirlwind I* or the SSEC constitute some of the earliest First-Generation computer architectures that deserve to be considered disciplinary spaces. The case study chosen, in fact, is that of the first moment in which a computer is a building and a building is a computer. This first digital device is an inhabitable place, a space inhabited, lived in, traversed and configured by different types of 'living beings' and 'substances' that are 'inside' it. *Whirlwind I*, as materialised in the Barta building, is not just any building on the MIT campus; it is itself an architectural technological device, a computer, which has a scale and dimensions that are both edifying and territorial. Its external facades and the networks it deploys are, in this case, the computer's casing. Its uses distributed in rooms, its corridors, its roof, its basement, its installations, are all the *hardware*. And some of the 'living beings' that inhabit it constitute the *software* that puts it into operation. This is how this earliest example of computer architecture can be described as an architectural technological device.

1. The use of the word *architecture* in computing has been widespread since the 1950s. David G. Halsted, "The Origins of the Architectural Metaphor in Computing: Design and Technology at IBM, 1957-1964," *IEEE Annals of the History of Computing*, vol. 40, no. 1 (Jan.-Mar. 2018): 61-62, doi:10.1109/MAHC.2018.012171268.

2. Many authors set it in August 1944, with the construction and commissioning of the *Harvard Mark I* computer. Brian Randell, Maurice V. Wilkes, and Paul E. Ceruzzi, "Digital Computers, History Of," in *Encyclopedia of Computer Science*, ed. Anthony Ralston and Edwin D. Reilly (Chichester: John Wiley and Sons Ltd., 2003), 548.

3. Medium- and large-scale computers containing a *main frame*, as opposed to microcomputers, minicomputers, personal computers or workstations. Chester L. Meek, "Mainframe," in *Encyclopedia of Computer Science*, ed. Anthony Ralston and Edwin D. Reilly (Chichester: John Wiley and Sons Ltd., 2003), 1,068.

4. Paul E. Ceruzzi, curator emeritus of the *Smithsonian National Air and Space Museum* in Washington, D.C., establishes a historical classification of the evolution of computing based on successive *generations* (first, second, etc.; some historians go as far as a seventh) associated with certain common characteristics among the technological *computer* devices that make them up. Randell, Wilkes, and Ceruzzi, Op. Cit., 555.

5. That report laid the foundation for the future stored program computers, the *Eckert-von Neumann computers*, and defined the *architecture* of today's computers. John Von Neumann, "First Draft of a Report on the EDVAC," in *Contract No. W-670-Om-4926, U.S. Army Ordnance Department* (Philadelphia: University of Pennsylvania, Moore School of Electrical Engineering, 1945).

6. *The Analytical Engine* or *Differential Machine*, by Charles Babbage and his team (including Lady Ada Augusta Byron or Ada Lovelace, one of the first programmers in history) was developed entirely in a theoretical way, on paper, since it could not be built in its time. It is considered to have been the first computer in history (the first electromechanical device) as its design combined the essential parts of a contemporary computer. Charles Eames and Ray Eames, *A Computer Perspective* (Harvard: Harvard University Press, 1973), 12.

7. Brian Randell was one of the first international authors to acknowledge the *Mechanical Arithmometer* as a precursor device to contemporary computing. Brian Randell, "From Analytical Engine to Electronic Digital Computer: The Contributions of Ludgate, Torres, and Bush," *IEEE Annals of the History of Computing* 4, no. 4 (1982): 366. doi:10.1109/MAHC.1982.10042.

8. Also known as the *Automatic Sequence Controlled Calculator* (ASCC), whose startup in August 1944 marked the birth of the digital computer. Randell, Wilkes, and Ceruzzi, Op. Cit., 548.

9. Gerard O'Regan, *A Brief History of Computing* (London: Springer, 2012), 35, 47-48.

10. Ibidem, 24-25, 35.

11. One of the most famous anecdotes in the history of computing about which much has been written is about a moth (*bug* in English and German) in the *Harvard Mark II Aiken Relay Calculator* (an electromechanical computer), a non-human agent that inhabited the *computer/building* technology device and died trapped in a relay, triggering a programming error in the device. The moth's inhabiting this computing space gave rise to a new meaning of the term *bug*: error or malfunction of a device. Grace M. Hopper, "The First Bug." *IEEE Annals of the History of Computing* 3, no. 3 (1981): 285-286. doi:10.1109/MAHC.1981.10032.

12. Giorgio Agamben, *¿Qué es un dispositivo? seguido de El Amigo y de La Iglesia y el reino* (Barcelona: Anagrama, 2015), 15.

13. Ibidem, 25.

14. The project started up during the Second World War (1943). MIT and Lincoln Laboratory stopped using it in 1959, when it was moved to Concord, Massachusetts by *Wolf R&D* (Wolf *Research & Development Corp.)*, and it was used there until 1974. Alice C. Waugh, "Plenty of Computing History in N42". *MIT Tech Talk*, January 14, 1998, https://news.mit.edu/1998/n42-0114.

15. Michael R. Williams and Michael Roy, *A History of Computing Technology* (Los Alamitos: IEEE Computer Society Press, 1997), 370.

16. Randell, Wilkes, and Ceruzzi, Op. Cit., 555.

17. Williams, and Roy, Op. Cit., 370-371.

18. David Lane and John Sterman, "Jay F. Forrester," in *Memorial Tributes: Volume 22* (Washington D.C.: The National Academies Press, 2019), 115-122.

19. Kent C. Redmond, Project Whirlwind: *The History of a Pioneer Computer* (Bedford: Bedford Digital Press, 1980), 62, 176.

20. Waugh, Op. Cit.

21. Stephen Perry of *Perry and Radford Architects* in Cambridge carried out the refurbishment of the Barta container in 1998 for IS. He was amazed at the original aesthetics of the enclosure, very elaborate and complex for a purely industrial architecture of the early 20th century.

22. Kent C. Redmond and Thomas M. Smith. *From Whirlwind to MITRE: The R&D Story of the SAGE Air Defense Computer* (Cambridge: The MIT Press, 2000), 452.

23. William M. Wolf, *No "e"* (United States: Xlibris, 2005), 66.

24. John A. Ackley, "Whirlwind," in *Encyclopedia of Computer Science*, ed. Anthony Ralston and Edwin D. Reilly (Chichester: John Wiley and Sons Ltd., 2003), 1848.

25. Guy C. Fedorkow, "The Whirlwind Computer at CHM," posted on CHM Blog, November 30, 2018, accessed April 20, 2020, https://computerhistory.org/blog/the-whirlwind-computer-at-chm/.

26. Jay W. Forrester was nicknamed the computer *architect*. Jay W. Forrester, and Robert R. Everett, "The Whirlwind Computer Project," *IEEE Transactions on Aerospace and Electronic Systems* 26, no. 5 (1990): 904. doi:10.1109/7.102724.

27. Fedorkow, Op. Cit.

28. O'Regan, Op. Cit., 26.

29. *Whirlwind I* shut down for a whole month, between 15 December 1949 and 15 January 1950, due to a failure in the electrical installations (the power supply in the basement). Redmond, Op. Cit., 32.

30. He compared the spaces of *Whirlwind* to the walk-in closets in the homes of the well-heeled, where one can walk into and inside enormous wardrobes that show all their owners' clothes hanging in full view. Forrester, Op. Cit., 904.

31. One of the technologies on which most First Generation (1950-1960) computer technology devices were based.

32. Fedorkow, Op. Cit.

33. The SAGE programme was the largest network of connected radars in the United States, a precursor to ARPANET and what is now the Internet. John A. Ackley, "Whirlwind," in *Encyclopedia of Computer Science* (Chichester: John Wiley and Sons Ltd., 2003), 1848.

34. Charles Eames and Ray Eames, A Computer Perspective. *Background to the Computer Age* (Harvard: Harvard University Press, 1990), 151.

35. Eames, Op. Cit., 12.

36. It was 10,000 times faster than the *Harvard Mark I* or *IBM Automatic Sequence Controlled Calculator* (ASCC), developed only six years earlier. Forrester, Op. Cit., 903.

37. It was bigger than *ENIAC*. Randell, Wilkes, and Ceruzzi, Op. Cit., 551.

38. This feature is the basis of all current commercial computers. For example, its magnetic core memory was used for the next 20 years, until the 1970s. Joe November, "LINC: Biology's Revolutionary Little Computer," *Endeavour* 28, no. 3 (September 2004): 127.

39. Despite its imposing dimensions, *Whirlwind I* was, in contemporary terms, a 16-bit mini-computer. Raúl Rojas and Ulf Hashagen, The First Computers: *History and Architectures* (London: Cambridge, Massachusetts; London MIT Press, 2000), 209.

40. Christian Wurster, Computers: *An Illustrated History* (Cologne: Köln Taschen, 2002), 23.

41. The *Whirlwind I* project is preserved in parts in various museums in the United States (The Computer Museum in Boston, now the Computer History Museum (CHM) in California, the MIT Museum and the Smithsonian Institution preserve many of the components of this architecture, some of which are on display in the CHM's permanent exhibition, Revolution: *The First 2000 Years of Computing*).

42. John Harwood, "The White Room: Eliot Noyes and the Logic of the Information Age Interior," *Grey Room* 12, (2003): 17-24. doi:10.1162/152638103322446451.

43. The vacuum valves, the memory, the ventilation and air conditioning ducts, the wires and the wiring are all visible on the interior facades. Forrester, Op. Cit., 904.

44. The computing space was full of indicators and artificial lights and constantly beeped and clicked to *communicate*, as an interface, with the *living beings* that inhabited it. David C. Brock, "Oral History of Joe Thompson," *IEEE Annals of the History of Computing* 40, no. 2 (-04-01, 2018): 6-16. doi:10.1109/MAHC.2018.022921440.

45. It transforms the computer into a technological device with which 'living beings' can interact. Randell, Wilkes, and Ceruzzi, Op. Cit., 14.

46. Nicholas Negroponte, *The Architecture Machine* (Massachusetts: The MIT Press, 1970), 101.

47. This architecture recycles the techniques, materials and methods that had been developed for the army, fostering a crossover of discoveries produced in the military, computer architecture and civil society, in part through its prosaic architecture. Beatriz Colomina, *La Domesticidad en Guerra* (Barcelona: Barcelona Actar, 2006), 12.

48. Wolf, *No "e"*, 63-64.

49. It was designed as a closed system in which the human components were fully integrated into the device's mechanized cycle of detection, decision and reaction. Wurster, Op. Cit., 23-25.

50. The carnal appears in almost all his photographs, not as an element or object to give scale and to be able to compare the dimensions of both elements with each other, but as yet another component of the technology deployed for its proper functioning.

51. Le Corbusier's *Modulor* reached 2.26 m with its arm extended and the cabinets and racks of *Whirlwind I* was designed by Forrester not to exceed 2.44 m and only use a small domestic staircase to reach all its components. The racks were designed to be similar to the cabinets in any home, using many references associated with the domestic environment due to their dimensions or visual appearance. Forrester, Op. Cit., 904.

52. It was completed thanks to its modular and prefabricated condition, which made the system reliable and coherent. Any circuit, component or individual element of a panel that failed could be quickly located and replaced before it caused an error, like a brick in a wall. Indeed, Redmond and Smith compare the use of vacuum tubes to the use of clay bricks to build these computer architectures. Redmond, Op. Cit., 123.

53. Some of its hardware mutated during its lifetime: from a laundry (from the early 20th century to the mid-1940s), computer architecture (1945 to 1959), graphic design workshop (1960 to 1996), university lecture hall with media library (1996 to 2000), to MIT's Information Systems Department (2000 to 2018) and to the Institute for Biomedical Research (2018 to 2020). Some of its hardware was sent off to West Concorde to develop part of the project *The World Game*, by R. Buckminster Fuller. Wolf, Op. Cit., 81.

54. An interdisciplinary team of more than 30 people worked at *Whirlwind I,* and this was one of its strengths, owing to the influence of Von Neumann. Forrester, Op. Cit., 910.

55. This emerges thanks to the heroic action of the architect (usually male, white, Caucasian, Western, austere, clean, serious, etc.). Colomina, Op. Cit., 12.

56. In 1951 Joe Thompson was the first African-American human agent to work and develop a computer space. African-American citizens were not allowed to vote until 1965. David C. Brock, "Meeting Whirlwind's Joe Thompson," 2019, https://medium.com/chmcore/meeting-whirlwinds-joe-thompson-cc8a326597e9.

57. These architectural spaces are not neutral, unaffected by their living beings. Beatriz Colomina and Jennifer Bloomer, *Sexuality & Space* (New York: Princeton Architectural Press, 1992).

58. "The computer didn't care that I was a woman or that I was black. Most women had it much harder." Gwendolyn Lee, 1960, Canadian programmer Clive Thompson, "The Secret History of Women in Coding. Computer Programming Once had Much Better Gender Balance than it does Today. What Went Wrong?" The New York Times Magazine, February 13, 2019, https://www.nytimes.com/2019/02/13/magazine/women-coding-computer-programming.html.

Architecture
Computing
Device
1st Generation
Whirlwind I