The Origins of Digital Computing in Europe

Retracing the paths of influential, but often isolated, computer pioneers.

The mainstream of the early history of computing is generally ascribed to British and American efforts during the 1940s–50s. A number of European pioneers were disconnected from this mainstream by time, most singularly Charles Babbage, or by a combination of geography, politics, and language. The latter include Konrad Zuse, now recognized for building the first binary, digital computer anywhere, and a number of other Europeans who built the first computers in their respective countries [4].

S.A. Lebedev, whose centenary was last November, was one of the most accomplished, but least known, of these "isolated" pioneers. Between 1947–51 he designed and built the MESM, the first operational all-electronic, digital, stored-program, general-purpose computer on continental Europe, and did so under extraordinarily difficult circumstances. He was responsible for more than 15 subsequent models that were used to work on many high-priority problems in the Soviet Union, including the machine that came closest to closing the "computing gap" with the West during the Cold War. For over two decades, he actively combined a position as chief designer and CEO-equivalent in a superpower country, a long-term achievement unique among early computer scientists.

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Ukraine and the MESM

The MESM (Small Electronic Calculating Machine) was designed and constructed by Lebedev and a small group of coworkers at the Institute of Electrical Engineering in Kiev. On November 6, 1950, it solved its first simple problem (Maurice Wilkes dates May 6, 1949 for the British EDSAC), and accepted for full operation by a high-level commission of the Academy of Sciences in late 1951.

The MESM was based on an original design that used a fixed-point representation and a three-address command format. At acceptance, its average speed was 50 operations per second, with a primary component base of approximately 6,000 vacuum tubes; it was improved and used continuously until 1956. As was the case with the ENIAC and other early machines, in addition to its in-house users, teams of scientists working on problems of national importance would visit to use large quantities of computing time—appreciative users included many world-class mathematical scientists of the era. In 1956, the MESM was moved to the Kiev Polytechnic Institute where it was used for three years to train young programmers. It was later scrapped for parts, and only a few pieces, easily fitting into a shoebox, remain today. For more extensive details on the technology and history of the MESM and other Lebedev machines, see [2, 6].

Perhaps the most incredible aspect of the MESM is that it was successfully built at all. No all-electronic computer was ever built under more difficult conditions. By the time construction of the

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MESM began, Ukraine had been hit particularly hard by Stalin's forced collectivization during the 1930s, when millions died from starvation and terror. Recovery had not gone far when Hitler's armies arrived in 1941. The Nazi military pounding, a savage occupation, the reconquest by the Red Army, and Stalin's brutal reassertion of political control from 1945 until his death in 1953 left Ukraine in terrible shape.

Lebedev arrived in Kiev in 1946 and decided to build a digital computer based on vacuum tubes. He assembled a small, young, group of 20–30 people (about 25% women) [6]. For many, their backgrounds would read something like: undergraduate education as a radio engineer finished or interrupted in 1941; spent the next four years surviving the war.

By early 1949, they were ready to start building their computer, using the abandoned former Feofaniia monastery outside of Kiev as their laboratory. The monastery was severely damaged during the war, and could not be reached via a paved road. More generally, the support infrastructure—heat, electrical power, phones, and construction materials—fell far short of what their British and American counterparts had. Then there were the problems with the quality (reliability and tolerances), quantity, and the actual delivery of Soviet-made vacuum tubes and other components. Lebedev also had to make a successful case "from below" to the various government, Academy, and Communist Party authorities for the support of a new technological initiative.

Of all the early computer builders, only Konrad Zuse's travails might be comparable to Lebedev's. Zuse built electromechanical computers in Hitler's Berlin [1, 4, 5], notably the Z1, the world's first operational binary computer. Berlin was thriving just before and in the early years of the war, when Zuse first worked on his machines. His primary problem was that he could not make the case for financial and other support to the Nazi government, which apparently thought the war would end quickly and favorably and did not want to expend resources on Zuse's longer-term ideas. He started building computers where he could, including his parents' living room, but conditions were still much better than they would be later at Feofaniia. However, things got really tough for Zuse when the Allies started winning, and bombing destroyed his Z3 program-controlled relay computer in 1944. To avoid the bombs and approaching Allied (especially Soviet) armies, Zuse took his nearly completed general-purpose relay computer, the Z4, on a refugee's trek from Berlin, to Gottingen, to a small town in Allgau/Bavaria, and finally to the academic haven of the ETH in Zurich, Switzerland, where he got it working and into use by 1950.

Russia and the BESMs

In late 1948, the Institute of Precision Mechanics and Computer Technology (ITMVT) was created in Moscow. In 1953, Lebedev moved to Moscow as the ITMVT Director, a position he held with distinction until he died in 1974.

At ITMVT, Lebedev led the development of approximately 15 computer models [3, 6], several of which went into production and formed the core of his country's high-performance computing for many high-priority users into the 1990s. Although he never again had to work under the conditions at Feofaniia, designing, building, and serially producing a computer in the USSR was never easy.

The most important of the general-purpose computers bearing Lebedev's signature include the BESM, the BESM-2, the M-20 and the transistorized versions M-220/222, and the BESM-6, a machine with a remarkable history that still deserves to be told in full [2, 7]. He was also responsible for several machines made specifically for military applications.

The BESM (High-Speed Large Electronic Calculating Machine) was a floating-point computer that was extensively tested in 1952, and formally accepted by a state commission in April 1953. Its initial speed was only about 1,000 operations per second, largely because of Lebedev's inability to obtain a sufficient supply of CRTs, which were going in greater numbers to his competitor Bazilevskii and his Strela computer. In 1954, Lebedev forced a formal direct comparison of the BESM vs. Strela, which he readily won. This result secured the necessary CRT supply, and BESM performance jumped to 7,000–8,000 operations per second.

In 1955, Lebedev presented the BESM to an international computer science conference in Darmstadt, West Germany, where it was apparently recognized (including by U.S. intelligence) as one of the most powerful indigenously built computers on the European continent. By 1956, it had an experimental ferrite core memory. The BESM was often used 24 hours a day, with an uptime of approximately 72%, 20% in preventive maintenance, and 8% on unexpected problems, including the time required to repeat lost calculations.

By the mid-1950s, the USSR had a need for a substantial number of computers. In addition to Bazilevskii's Strela, it was decided to have a BESM production model. Two competing models arose, the BESM-2 and the M-20, both of which were in serial production by 1959. Ultimately the Strela and BESM-2 faded away, but a large number of M-20s and its transistorized successors the M-220/222 were produced into the late 1960s.

After what effectively amounted to experimentation with a few operational models (BESM-3, BESM-4, Vesna), Lebedev and his team developed the BESM-6 during 1964–67. It went into serial production in 1967; about 350 were built during more than two decades, and quite a few were still in use in 1991, the year the USSR abolished itself. The speed of the BESM-6 approached that of the then-contemporary U.S.-made CDC 6400, winning Lebedev and ITMVT a 1969 State Prize (formerly Stalin Prize), at least partly because of the comparison with the U.S.

In the USSR, some leading academicians effectively built institutions around themselves. The institute director was an active scientist, led a group of other scientists and students, and determined the main line of work, procured funding, space and other resources, and functioned as a chief executive. In the USSR, this existed on a larger scale than elsewhere, sometimes including extensive facilities, hundreds or thousands of people, and dealing with the outside world in ways that resemble a U.S. national laboratory. Some of the best known of these institutions were built around I.V. Kurchatov (nuclear), S.P. Korolov (rocketry), M.V. Keldysh (applied mathematics), and A.N. Tupolev (aviation). Lebedev at ITMVT was such an "institution" and in this way had great influence as a designer, teacher, and developer of technology that went out into the real world, including to most of the institutes just noted.

In some ways, Lebedev and the BESM-6 mark the end of an era. As was the case in the U.S., Great Britain, Germany, and other countries, the early development and application of much of the digital computing in the USSR was driven by defense and other government needs. As long as the Americans were similarly driven, ITMVT and other Soviet R&D and production facilities were able to adequately meet national needs.

The East-West computing "gap" opened rapidly when a greatly expanded range of commercial and other applications took over as the primary drivers of the U.S. computer industry, accelerating development and the infusion of better technology into both the civilian and national defense sectors. As the conditions of these sectors in the USSR and Eastern Europe became of increasingly critical concern, the political and governmental leaderships of these countries (Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania—most of which had started building their own computers in the 1950s) concluded that their own institutions could not deliver the kind of computing they needed. The bottom-line decision was to try to substitute IBM's solutions for what was lacking indigenously. From the standpoint of Lebedev and this column, this meant that large parts of the Soviet and East European computing communities were mobilized, in some cases against resistance, for this effort, known as the Unified System (Edinaia Sistema, ES), based on the functional duplication of IBM's S/360 architecture [3].

Lebedev was a leader of the computer scientists opposed to this decision, strongly favoring the development and use of an architecture of their own for an upward-compatible family. They lost this battle for the mainframes, and ultimately for minicomputers as well. He died as the ES program was ramping up into full swing, perhaps taking some satisfaction in its initial difficulties. ITMVT scientists continued to have license to pursue their own designs for supercomputers after Lebedev died; the best known of these were the El'brus machines under V.S. Burtsev [8].

Places in History?

Some observations on the significance in history of the isolated pioneers are in order. Arguably the two most important criteria for consideration should be original technological contributions and influence on others.

Babbage's originality stands in magnificent isolation. The extra century and color he gave to the roots of computing guaranteed everyone interested in its history would embrace him. It also helped considerably for him to be English, and to have a young female professional consort who liked to write about his ideas. His substantive influence is another matter, and it is not clear whether the other pioneers—isolated or not—knew of him in their early working stages (Zuse explicitly denied it) or might have been only minimally influenced since his designs and component technologies were not seriously studied until the 1970s [4, 7], and were necessarily so different from theirs.

Zuse's highest profile claims to technical firsts are for the binary electromechanical computers built in Berlin by the early 1940s. His work was so confined with so little impact that Allied intelligence did not seem to notice it during the war, nor become interested afterward. Zuse and his central European supporters had to campaign later to get recognition for his originality. He continued to work as a computer scientist, and started a not-too-successful computer company, but his later efforts were not very influential. Although a few other creative German scientists like von Braun went on to post-war achievements and influence elsewhere, Zuse did not. At least he did not suffer the fate of many German scientists and engineers who were rounded up by the Soviets, although one could speculate on what might have happened if he had been and assigned to Lebedev. Lebedev was an outstanding mentor and unbiased manager of bright, hard working, young scientists. A lot would have depended on Zuse's ego and attitude toward working with and under relatively inexperienced Russians and Ukrainians.

Lebedev has no claim to high-profile worldwide "firsts," although there was some parallelism in his early designs that should merit further attention. Furthermore, his legacy for creativity suffers from Western suspicions that, as was likely the case with other Soviet technological achievements ranging from the atomic bomb to the "Buran" space shuttle, his achievements benefited from the fruits of Soviet intelligence collection. Soviet intelligence did collect against computer technology in the U.S. and Western Europe and Lebedev would have been an obvious recipient, but we do not know what he received.

Architectural and implementation details aside, the composite concept of a binary, all-electronic, digital, stored-program, general-purpose computer using a sequential fetch-execute cycle with I/O to the outside is hardly so self-evident that any isolated person wanting to automate arithmetic calculations would independently think of it. From the standpoint of historical assessment, Lebedev had the disadvantage of starting after the Anglo-Americans, whose work was being described in places like an article on the ENIAC in the May–June 1946 issue of the *American Army Ordnance* magazine, something likely to have been collected by Soviet intelligence. There were also reports on the stored-program ideas and machines (EDVAC, EDSAC). We may never know if any of this influenced Lebedev's initial grasp of the composite concept. Given how hard he worked to make a case for the MESM, it is clear that, in contrast to other technologies like the atomic bomb or guided missiles, the computing effort was not pushed "from above" in response to pressing competition from abroad. It is possible that Lebedev thought of the concept on his own, saw the information on Anglo-American efforts, and used it to make his case with the authorities. When it came to defense-related technology, an argument to the effect that "the Americans are doing it" often helped get attention and support.

None of Lebedev's designs was based on close copying of foreign machines and, given some fundamental differences (such as working with Soviet-made components), what he might have gotten from abroad would have been of limited use. Anyone who appreciates what it took to build the MESM around 1950 in Lebedev's circumstances must respect the effort as a world-class achievement of computer engineering. His subsequent machines demonstrate this was not a fluke. He was an exceptionally capable computer scientist who deserves recognition for a string of technical achievements—perhaps the longest and most sustained of any pioneer—although they were geographically confined. He labored for a distinctive, long-term national capability, and fought against the wholesale adoption of technology from abroad.

Finally, it might be noted that all three men tried to build computers to serve recognized national needs, having no choice but to pursue their aims through their governments, with mixed results and all ultimately ending in rejection. Babbage received initial funding for his difference engine, but he did not deliver a working machine, and his ambitions for the analytical engine went beyond what the British Admiralty would support. Zuse built some small machines such as a special-purpose relay computer for a factory making remote-controlled bombs, but the German government would not support his more advanced ambitions. Although it was an uphill battle all the way, Lebedev was remarkably successful with his government—surprisingly so since in general it was the least supportive of lower level people showing initiatives—for more than a quarter century, but ultimately was to be rejected in a way that probably greatly disappointed him. In the cases of the first two men, the rejection was largely of personal ambitions; in Lebedev's case his government essentially said it did not believe he and his fellow Soviet computer scientists could deliver what was most needed anymore. **C**

References and Notes

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