Computer Development in the Socialist Countries: Members of the Council for Mutual Economic Assistance (CMEA)

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Abstract. Achievements of the East European Socialist countries in computing -although considerable- remained little known in the West until recently. Retarded by devastations of war, economic weakness and very different levels of national science, computing ranged 'from little to nothing' in the 1950-s. However, full-scale collective cooperation with the USSR based on principles of equal rights and mutual assistance was aimed at *increasing of common creative power*. Centralised planning and ability to concentrate efficiently national resources on priority issues, state support for science and progressive educational system *accessible for everybody* played decisive role. The progress was impressive. Some (GDR) reached world's level in science and engineering such as some (in Hungary) – advanced computer education, programming and efficient usage and some (in Bulgaria, Cuba) starting "from zero point" turned into reputable manufacturers. In 1970-1990, 300,000 people as the united team of eight countries jointly designed and produced advanced family of compatible computers ES. Given general review also displays some important technical and organisational details.

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Keywords: Computer development, East European countries, computer family ES, free education, cooperation

1 Introduction

Little was written abroad computer development in the East European[1] socialist countries – partners of the USSR, during relatively long period, although some of their achievements were of considerable interest.

The lack of foreign attention was primarily caused by natural desire to display first the own pioneer discoveries and most important inventions. The results of the East-European (outside the USSR) computer research appeared notably later than in the "great powers", what could be another reason of "the silence". Besides, long time in the beginning eastern countries did not consider themselves as generators of pioneering projects or principal technical achievements. Additionally the cold war confrontation and propaganda hampered obtaining and publishing appropriate

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[1] The name 'East Europe' to be often meet in this report means only the Socialist countries, such as GDR, Hungary, Czechoslovakia, etc., not including the USSR.

authentic information. No wonder that only few - usually fragmental - materials sporadically became accessible for the Western reader.

As for more popular foreign publications or mass media, they were mainly influenced by the large computer manufacturers, interested first of all in their own publicity.

Otherwise, what could be the explanation of the fact that many educated young people in Western Europe were pretty sure that computer history was concentrated around IBM, the Apple Macintosh, or "Microsoft". It was often a surprise (e.g. for the West German students) that the world's first computer was devised in Germany by Konrad Zuse, or, say, that the Netherlands also created interesting projects?

Even situation in the USSR - one of the world's two biggest computer producers, equally remained almost "terra incognita" until the last decade. This time anti-Soviet cold-war propaganda coincided with atmosphere of exaggerated secrecy in the "Eastern block" itself. No wander that the first comprehensive publication on this subject appeared in the West only at the threshold of the 21st century.

Detailed demonstration of the computer history of all socialist countries can not be given in a single concise report. The present paper is not an attempt "to show everything". It is just a review written to help the reader to get a better understanding of the general course of computing history.

Although the East-European computing is not rich in scientific "sensations", it is interesting to observe the whole process of development in various aspects. Their economic potential was mainly incomparably lower than that of the "powerful West" or the USSR and their science and technologies were sometimes at a "beginner's" level. According to the initial conditions East European countries could be divided into following, approximate, groups.

The USSR possessed powerful economy, science, and performed progressive computer production.

The German Democratic Republic (GDR), Hungary, Poland, and Czechoslovakia had general scientific power and experience but little or no computing. Their economies were weakened by the war.

Bulgaria, Romania, Cuba, Mongolia, and Vietnam had neither proper science nor technologies applicable even for producing the simplest electronic devices.

Most of historical reviews and essays on computers and computations typically focus themselves on *scientific* and *technical aspects*. As their authors are mainly computer specialists or even the inventors themselves, they can provide the most precise, authentic and complete information and comprehensive explanations.

However, the role of general *social factors* in computer development also should not be neglected. Computer research and engineering is most complex subject, involving broad spectrum of scientific and other issues, including even humanities, when it deals with programming. Although influence of the social factors on scientific discoveries or technical inventions is very disputable and abstract issue, in the problems of (computer) proper application or of research and production organisation it can already be traced, while their impact -not necessarily direct one- on the general course of progress is often decisive. That can be clearly displayed by the example of East European (CMEA) countries, with their "alternative" social structures.

All of them managed to concentrate efforts and achieve impressive results within historically short time. Instead of training people to use imported computers (more typical for developing countries) they established their own research and production and developed efficient implementation. Besides economic benefits, that considerably stimulated development of national science.

No need to say that scientific and economic assistance of the USSR was very important factor. However, one cannot speak about any "pressure", especially in scientific or humanitarian area. Relations between the CMEA partners were based on the principles of equal rights, mutual respect and assistance with general motto, "common strength for the common success".

None was interested in turning others into raw material suppliers, assembling work-shop with cheap work-power or a trivial consumer market.

Of course, forming cooperation on practice was not easy. Different dynamics such as bureaucratic inertia and political problems caused complications. However, results speak for themselves. The first steps were made in the 1960-s. In 1972 all CMEA members adopted agreement on common development and production of the compatible computer series ES. Joint international coordinating commission was appointed. United team of more then 300,000 scientists and specialists from all countries were running their own ES program in 1972-1991. They successfully produced hard- and software and solved, "their own problems with their own resources".

At the same time the more powerful Western Europe, was weakening by inner competition. Many firms could not resist the pressure from the stronger IBM "partners" and, by the end of the 1970-s, had to close their own computer production.

Science and education of the CMEA countries became the fields to demonstrate advantages of the state support and centralised control/planning system. They enabled quick concentration of national resources and efforts on the programs of state priority, or important for perspective, even if they could not always immediately "pay back" in terms of investments.

Equally important were the absence of resource-wasting competition and government (or national) property in industry, that enabled high-tech equipment production on much lower investments. Private manufacturers would charge maximal prices for government orders in such case.

Accessibility of the highest level education and culture for everybody was one of basic programs, or constitutional principles, everywhere (in the East Europe). Propaganda and public opinion on education and culture were extremely high. They were considered as the criteria of social progress; success of an individual in education or scientific work was publicly estimated as his or her personal contribution to the common prosperity. Owing to cooperation, each country could regularly send its young people to the universities of the other partners. Thousands of foreign students permanently studied at universities of the USSR[2] or the GDR. Owing to that, an enormous mass of highly qualified specialists ("intellectual reserve") grew within one generation, not only in advanced Czechoslovakia and GDR but also in Bulgaria, Cuba, etc. That became their "Key to the door of computer society".

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[2] As an example, in 1974 alone the USSR accepted more then 20,000 students from other socialist countries.

Important was also the fact that success of the national science had positive, stimulating, influence on the moral atmosphere in the whole society, what in its turn increased integral creative potential of the country.

2 German Democratic Republic (GDR)

Previously most of the East Germany belonged rather to agricultural, not industrial area. It was devastated by the war. However, German technological traditions, high-quality manufacturing, advanced engineering and rich scientific and educational heritage survived and formed the basis for rebuilding further progressive development of the country. Besides, one should not forget that in pre-war time, Germany already won the first place on the list of computer pioneers. It was the young engineer Konrad Zuse, who devised the first programmable computing machines Z-1 and Z-2 (with programs stored in memory) by the end of the 1930s, and, between 1942 and 1945, he created a system of commands named ‘Plankalkul’, recognised by specialists as the first high-level programming language. German researches on electronics, especially on semiconductors, were also in progress as early as in the 1920s and the 1930s.

Post war restoration of the Academy of Sciences (former Academy of Sciences Prussia), with its more than a 250 year-long tradition, as the GDR Academy of Sciences and its further development was one more important factor. Its work in the GDR was very efficient. By 1991 it consisted of fifty-eight research institutes with the total number of about 22,000 collaborators. After “integration” into West Germany (which had no academy after the war), the academy of GDR was dissolved. However, owing to the efforts of its members, it was partly revived as a scientific society.

Creation of new state, revival of destructed economy, and development of an electronic industry, practically from the zero point, needed time. The first practical steps to creation of the GDR electronic computers (outside theoretical and laboratory experiments) were taken in 1963, according to the new state program passed by the 6th Congress of the ruling Socialist United Party of Germany (SUPG) (15-21.01.1963). It read,

> *“Herewith the Congress announces the beginning of new reformation process, focused primarily on the state economy, problems of the young generation and culture”.*

The “Development of the electronic data processing systems” was mentioned as a special direction of national efforts.

The result of that, the electronic (transistor) computer called ‘Robotron R-300’ (speed 5000 ops, RAM capacity 40 Kbit) was produced in Karl-Marx-Stadt (Chemnitz) in 1965. The R-300 was jointly created by such organisations such as the institute of electronics in Dresden, Karl Zeiss factories in Jena, enterprises ORWO, the office machinery factory in Sommerda, the Dresden institute of data processing. In 1965, twenty-two participants formed a cooperative enterprise “Robotron-300” (since 1969 -“VEB[3] Kombinat Robotron”). It was headed by “VEB Rafena” of Radeberg.

[3] VEB – Volkseigener Betrieb- (lit.) “enterprise owned by people” – a socialist form of collective ownership.

Within 1968 - 1971, about 350 "Robotron-300" machines were manufactured. "Robotron" was very powerful enterprise and it was established with the purpose of bringing GDR's lagging behind the Western competitors to minimum.

By the end of the 1960s, the GDR was the most active to promote project ES/ESER[4] because (besides other reasons) by that time it already started its own development of the IBM compatible computers on basis of the R-40.

The next computer, the R-21, appeared in 1970, but soon it was replaced by the first large German machine of the ES/ESER series. VEB "Robotron" was in charge of scientific researches in all computing related branches and also of numerous joint projects with the USSR for the ES/ESER computers. Serial production of ES computers began in 1973 and, by the end of the 1970-s, their total number exceeded 50% of all German computers. Within the years between 1972 and 1975, the number of control computers for production processes grew more than ten fold.

"Robotron" produced processor units, peripheral devices, and data transmission devices, managed the sale of office machinery factory "Zentronik" production and was also in charge of the data processing systems, their sales, implementation, and maintenance.

In the 1970s, new enterprise "Gruna" was founded in Dresden, it was responsible for production of central processing units for the R-21. "Robotron" was constantly growing and it was always efficiently re-organised in correspondence with new needs.

Development of microelectronics and the following reduction of computers' sizes changed character of its manufacturing. The government passed a proposal (resolution on microelectronics of the SUPG central committee, from 1977) to decentralize management of the computing machinery applications. For that purpose, an enterprise on microelectronics was founded in Erfurt in 1978. In 1978, its eight-bit central processor unit U808 was taken by "Robotron" as a basic component for microcomputer ZE-1 and special system K1510, which was followed by the K1520 with central processor U880 (Zilog-80 was its prototype). The U880 processor was also implemented in office computer A-5100 and later, in the 1980-s, in a very popular PC "Robotron-1715", which was in commercial production until the end of the GDR itself.

In 1986, computers also appeared in retail trade (microcomputer set Z1013). Microcomputer systems K1510 and K1520 were especially popular in banks and railway terminals. By 1989, "Robotron", with its twenty-two enterprises-participants and almost 77,000 personnel, was the biggest computer manufacturer in the GDR.

The 10th Congress of SUPG defined the program on increasing efficiency of computer operation organization. According to it, the computers should be used during several working shifts a day. Operational efficiency of computers was also increased by extension of their application range. The first computers were used for registration, later in research, and still later in technical preparations for production. Level of the personnel qualification was also stably rising. According to the official data of 1974, economical efficiency of computers exceeded 1 Mio German Mark a year. In 1975 an average operation period of the computer at an enterprise equalled 15.6 hours a day and in some branches even 18 hours per day.

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[4] ES (Russ.) Edinaya Seriya – Unified Series, ESER (Germ.) – Einheitlihes System Elektronisher Rechentechnik

Within ES/ESER program GDR specialised its participation on development and production of central processors of medium power and memory devices on magnetic tape. The first computer ES-1040 was produced very actively and was exported to seven countries. In 1976, central processor ES-2640 was given a special award for its high quality. Owing to cooperation with the USSR, Karl Zeiss factories in Jena quickly established production of the magnetic tape storage devices. Before 1976, GDR sold 13,000 such units. The ES-2640 storage devices also received awards for their high quality.

The GDR took active care of solving organisational problems within CMEA and actively promoted strengthening of partnership between the ES/ESER program participants. It always insisted on introduction of common unified system of quality and reliability evaluation and intensifying software exchange between the partners.

Large computers R-55 and R-57, produced by the GDR belonged to economically important machines; large numbers of them were exported to the USSR in the 1980-s. Equally, much attention was paid to the software production. In 1987, a part of "Robotron" in Dresden became the leading centre of the software development for the whole GDR.

3 Czechoslovakia

In the beginning most of the work on electronic computing machinery was closely connected with the name of Antonin Svoboda, a pioneer of control and analog computers. Owing to rich experience that he received while working in Paris, in the USA, and also at the Cambridge radiological laboratory, Svoboda was able to make a big contribution to a new science. Thus, the institute of computation machinery was established on his initiative at the CzSSR Academy of Sciences. A number of (later) prominent scientists began their career in that organisation. Also the "heritage" of Prague factories for precession machinery played important role in the creation of national computer manufacturing basis. Thus, one of them – the firm "Aritma" – produced punch-card machines. In 1951 a national enterprise for office equipment was established. It was responsible for service and distribution of all Czechoslovakian computer hardware.

The first –relay- computer SAPO (*SAmochinny POchytach*) with good parameters for its time was created within the period 1949–1957, at the laboratory of mathematical machines, which later grew into the Scientific Research Institute of Mathematical Machines (VUMS). After that, VUMS developed computers MSP-2, EPOS, and ZPA-600 and numerous peripheral devices. The "National Eliot 803A", 803B", and 503" computers were purchased in England for research purposes as well as some models of the Soviet Minsk and the Polish Odra machines.

In the period from 1949 to 1974, the total production of "Aritma" consisted of approximately 18,000 punch-card micro-calculators "Aritma" (Aritma-100, Aritma-1010 and Aritma-101), about 220 computers, also 1000 analog computers MEDA, and other 160 special single-program analog machines.

Quite naturally, East European countries revitalised their traditional international connections. Thus the hybrid systems HRS - Robotron 4241, HRS 7200 and HRS 7000 were jointly produced with enterprises of the GDR. Czechoslovakian national enterprise Tesla began production of the second generation computers on the licence of French company Bull. Parallel with “Aritma” computers were produced by the “Zbrojevka” factories in Brno (typewriters and mechanical calculators), factories for instrumentation and automatic systems in Koshize, and Tesla in Prague. Nevertheless, by the end of the 1960-s the proper level of stable production, that could meet national needs, was not yet reached.

The situation changed for better only in 1969, when the production was re-organized. Thirteen leading manufacturers began to be integrated into a joint system. Besides Tesla, “Zbrojevka” factories and others, also the sales organisations, such as “Kancelarske stroje” in Czech Republic and “Datasystem” in Slovakia, provided some important services. All that integrated structure was headed by the Prague enterprise of automation BT-Zavt aimed at international cooperation.

Zavt took part in the joint production of the ES production and later in the series SM (ES-1021, ES-1025, SM-1, SM-2, SM-3-20, SM-4-20) (family of smaller computers). It also manufactured microcomputers and microcomputer systems, analog- and hybrid- computers, such as MEDA-41TC, MEDA-42TA, MEDA-43HA, ADT-3000 and HRA-4241.

Some participants produced peripheral devices for the ES and the SM, others data processing systems and devices and also office machinery (e.g. typewriters Consul). Zavt was responsible for design and production of popular automatic control systems, instrumentation and scientific equipment for laboratories.

Scientific researches were performed by VUMS, by the Institute of mathematical means (VUAP), and by the institute of computing machinery applications UAVT in Prague, by the institute of computing (VUVT) in Zhilinka and by a research centre in Bratislava.

Participation in the ES program was based on the following doctrine: Czechoslovakia concentrated on production of such ES computers and equipment that could first of all satisfy its own needs. It exported its peripheral devices that won good reputation, to the other partner countries and obtained money was mainly invested into further development of its own computer industry.

The ES-1021 computers (or R20A) of the Prague VUMS were designed for solving scientific, engineering, and economic problems of industrial enterprises of medium capacity. However, they could also perform functions of satellite computers for large machines. They were produced by factory ZPA in Zakoviza, famous for the minicomputer MSR-2 and medium machines ZPA-600 and ZPA-601. Aritma of Vokovize produced perforators and punch-card reading devices.

In 1974 Czechoslovakia took new series of urgent measures. According to new (fifth) five-year economic development plan, 340 computers would be manufactured. Three hundred of them would be ES computers. The (sixth) five-year plan suggested further increasing of production to 800 - 1000 pieces.

CSSR became one of the leading manufacturers of the peripheral devices, in particular magnetic tape reading units, for the world market. All export operations were performed by the national enterprise KOVO and delivery, assembly, and testing were made by *Kanceljarski Stroje* (KSNP).

4 Hungary

Already in the pre-war time, Hungary became a motherland of scientists famous in computer world. However, most of their work was done abroad. Thus Laszlo Kozma (1902-1983) was working upon a relay computer at the Bell Telephone Laboratories in Antwerp, Belgium, in the 1930-s. He devised it by basically using telephone components.

Janosch (John) von Neumann (1903-1957) was born in Budapest, where he received education and also his doctoral degree in mathematics. Between 1926 and 1930, von Neumann held position of *privatdozent* in Berlin. In 1930 he married Mariette Kovesi in Budapest and soon, upon the invitation of professor Osvald Weblen (USA), moved with her to the Princeton University, where he spent the rest of his life. World famous are his theoretical principles of computer architecture.

The post-war computer researches started in the universities of Budapest and Zeged. In 1957, the Hungarian Academy of Sciences received from the USSR Academy of Sciences a complete set of project documents on digital electronic computer M-3, created by Moscow academician I.S. Bruk and his team. Assembled in Budapest M-3 became the first Hungarian electronic computer. Nevertheless, during the following years, computers were mainly imported. Purchasing of licences was also practised in later years. In 1968 the French company CII (which "inherited" famous BULL) handed Hungarian specialists the rights for computer CII-10010. In France itself that model was developed into a series of civil and military computers.

In the beginning of the 1960-s, Hungary had only ten computers and by 1967 it had eighteen. Participation in the Council for Mutual Economic Assistance (CMEA) noticeably intensified that process. In 1970 there were 80 machines; in 1972 Hungary had 120 machines; in 1975 the number reached 400 and by 1980 more then 700 machines. The "new period" began in 1969, with the ES project. After a short time, Hungary launched production of the ES computers and later minicomputers of another series - SM. In parallel with it, Hungary maintained relations with Western computer manufacturers such as Siemens, CDC, and UNIVAC. Various forms of development were well combined and successfully supported each other. The alphanumeric display Videoton VT-340 / ES-7184 and the minicomputer VT-10108 are famous examples of that support. The agreement with the French CII of 1971 focused on production of the ES compatible minicomputer of the third generation.

Production of the ES computers started in 1972. First those were ES-1010, then ES-1010-M, ES-1011 and ES-1012. Their export began in 1973-1974. Besides the computers themselves numerous printers, intellectual terminals and punch-card input devices were also manufactured. Computers ES-1015 and SM-53 appeared on market already by 1979.

According to the governmental information, about a hundred leading Hungarian enterprises possessed their own computers by 1979 and 1500 more regularly rented working time at the computer centres of collective usage. Governmental reports emphasised high efficiency of the computer implementation in national economy and science.

Development of control and information systems, as well as the coordination of computing machinery production and implementation measures, became the processes of national importance and dimensions. Timely getting special, highly professional organisations in charge of those processes brought a credit to their initiators. In 1976, an independent self-financing scientific-research institute for applied computation systems (SZAMKI) was established with a staff of 500 collaborators.

SZAMKI was a competent organisation that maintained scientific relations and performed both local and foreign projects. SZAMKI performed projects on the ES operation systems, established new computer centres, designed computer networks for informational and translation systems, ran a large project in the field of qualification upgrading, published computer books and journals and was very active in cooperation with other CMEA countries. In general, this institute played very important role in Hungarian computer development.

Hungary always had very good contacts with the GDR, which were supported by the bilateral agreement on “Development and joint production of the machinery for remote data processing, data banks creation, design and production of processor units, microcomputer modules and line printers” adopted in 1972. Relations with the USSR and CSSR were also successful.

According to the new development program for electronic industry of 1981, seven enterprises became suppliers of its production. The Hungarian Academy of Sciences controlled the research work.

Development of the programming products became another strong point of Hungarian computing. In 1969 the national educational centre on computing was established. There, young scientists established a school of programming in cooperation with the University of Budapest. With the support of the UNO, it quickly grew into a very popular “International Centre of Computer Education” (Hungarian - SZAMOK). It was officially opened in 1973. In the same year the school received more than 8000 applications. Although SZAMOK had only one computer IBM-360/145 and one PDP-11/70 - a machine with multiple accesses in time shearing mode, it managed to achieve notable results, both in general computer education and in system programming, corresponding the level of the best world standards of that time. Its education was accessible not only for Hungarian, but also for foreign students. In addition to Hungarian, all courses were available in German, Russian and English languages. During the period from 1969 to 1978, SZAMOK gave education to more then 52,000 specialists. That activity created perfect conditions for establishing new computer centres and programming firms.

Most important was that, those efforts turned Hungarian computing into independent science. One more independent organisation also made sufficient contribution. It was the scientific “Janosch von Neumann Society”, founded in 1975 that dealt with programming, algorithms, system organisation, etc. Its basic task consisted in “support of the centralised state program on computing development”. The society published two periodic journals “Computation machinery” (Szamitatstehnika) and “Informatics and Electronics” (Informacio es Elektronika), which won special support.

Popular TV courses of the BASIC programming language turned to be one more successful program. More than 3000 of its 6000 applicants successfully passed graduation exams. The government also supported numerous computer clubs.

In the 1990-s some Western specialists, programmers, and simply those interested in “computer matters” in the East, wrote (in internet) that they could only dream about such public atmosphere so good for children education and general development. Rapidly spreading "computerisation" still supported successful programming branch, sufficient part of whose products had comparable or even equal quality level with software found in Soviet or Western markets. Hungarian applied programs on general, special, and also unusual subjects were regularly demonstrated at the international fairs in Leipzig and Hanover.

5 Poland

Same as Germany and Hungary, Poland had a solid scientific potential and traditions both in mathematics and calculation devices. However, its economy was greatly undermined or rather almost completely destroyed by the war. Despite sufficient support from the USSR (that also suffered from heavy losses) any serious production of electronic devices seemed to be unthinkable that time. Nevertheless, development of Polish computing began as early as in 1948 at the Institute of Mathematics in Warsaw, where the group of mathematical devices **(***Grupa Aparatow Matematycznyh* - GAM**)** headed by Henryk Granevskiy designed analog computers for solving differential equations. Their computer (*Analizator Rownan Rozniczkowyh* - ARR) with 400 electron valves was completed in 1954. Appearance of the first Polish computer sufficiently facilitated work of mathematicians.

Generally speaking, the "Polish way to computer" followed more or less the same pattern as in the other Eastern European countries. In the beginning very poor quality of electron valves became serious obstacle. First the problem was solved by traditional imports. As a result of that, the XYZ digital computer appeared in 1958. Although its architecture repeated that of the IBM-701, design of its basic elements was taken from the Soviet BESM-1. An improved model of XYZ, named ZAM-2, was already a large machine with performance of 1000 ops (both floating- and fixed-point operations). Some of its units were even exported. Its Special System of Automatic Coding (***S****ystema* ***A****utomatichnogo* ***KO****dowania* - SAKO) was the specific feature of the both computers. Efficient programming system, often called "Polish Fortran", was created in 1960.

Nevertheless, main period of computer development began with joining CMEA and the ES program. Poland produced computers ES-1030 and, after a number of improvements, manufactured famous ES-1031 and ES-1032. It also took part in development of software for ES computers. Between 1971 and 1975, Poland began commercial production of fourteen various devices, five of them were implemented in various ES computers. Those were magnetic tape storage units (ES-5001), user node (ES-8514), programmable MPD (ES-8371), modem (ES-8013), and a collective system for data preparation on magnetic tape (ES-8013). In addition to ES computers, Poland also produced its own series of computers MERA.

6 Bulgaria

In the beginning of the 1950-s, Bulgaria did not nave any electronic industry and could not even produce simple components for radio. It was typical agricultural country. Nevertheless, the government launched national campaign for total education and took all necessary measures to facilitate it. Education of all levels became free and accessible to everyone. There were only few universities, so hundreds of Bulgarian students regularly studied at many universities and institutes of the USSR, the GDR, and the CSSR. Together with the students from, Poland, GDR, Hungary, Cuba and Viet-Nam numerous young Bulgarians were very common in almost every big technical Soviet university. Already in the 1960-s special attention was given to preparing electronic and computer specialists. The first Bulgarian computer centre was opened in 1961 and the first computer VITOSHA, was made in 1963. Electronic industry was gaining power. The first Bulgarian transistors were produced on Japanese and other licences. By the beginning of ES program, Bulgaria already possessed necessary scientific potential to be an equal (and very active) partner. Relations with the USSR traditionally were very close on all levels. Bulgaria participated in the joint production of the ES-1020, then the ES-1022, and then the ES-1035. National enterprise ISOT integrated fourteen other large manufacturing enterprises and a number of research centres. Within one generation, Bulgaria managed to grow to be an important partner in computer production. It became a recognised manufacturer of magnetic memory carriers (tapes and discs), sufficient amount of them was exported to the USSR. In the 1980-s, especially with the appearance of minicomputers and PCs. Memory devices and magnetic discs of Bulgarian ISOT became very popular among the Soviet computer users. In the 1980-s, Bulgaria also produced its popular PCs called PRAVEC.

7 Romania, Cuba, Mongolia, and Viet-Nam

Production and implementation of computers in these countries developed mainly in the same way. In the beginning their scientific and engineering basis was prepared by systematic sending of their students to study in more advanced countries (USSR, GDR, etc.), then followed development of their own researches and projects (at first, minor ones).

For an example, Cuba before the Revolution of 1961 possessed only two (imported) computers. In 1969, the Centre of Digital Researches (CID) and some other institutes were found and the first Cuban minicomputer CID-201-A was in operation in 1970. It was designed by Orlando Ramos, pioneer of Cuban computer engineering. Cuba took part in the ES program what helped it to create certain electronic industry. Efficient state programs on mass computer education (including school programs) were introduced including obligatory practicum for school-children who should perform various tasks at computer centres and work with computers. Clever educational policy and state measures on propagation of computer knowledge soon created “new generation” of people basically prepared for learning and working in computer-related fields. Although Cuban engineering did not reach the level of big machines, later it launched production of its own minicomputers and various digital devices of good quality. Especially popular was –and still is- its digital medical equipment that is actively exported.

Notably, nowadays Cuba remains the only country, which –to certain extent- is preserving “scientific spirit of the CMEA” and developing its engineering traditions.

Despite limited scientific and engineering achievements, experience of these countries in *computer implementation* was undoubtedly interesting. Besides technical projects, mathematical researches and software development, efficient organisational measures were undertaken on governmental level, which created favourable conditions for intensive "computerising" of these, formerly pure agricultural, lands.

In the beginning Romania made efforts to develop independent computer industry, but with only moderate success. It produced several models of minicomputers "Felix" on French licences, then joined the ES program but was not active in it.

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– For more information on the topic, please address http://www.computer-museum.ru/
= Additional materials, comments and possible corrections will be gratefully accepted by the author: (nitussov@hotmail.com)

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