A Visit to Computation Centers in the Soviet Union

JOHN W. CARR III, *University of Michigan**; ALAN J. PERLIS, *Carnegie Institute of Technology*; JAMES E. ROBERTSON, *University of Illinois*; AND NORMAN R. SCOTT, *University of Michigan*

The four authors spent a two-weeks period from August 27 through September 10, 1958, visiting Computation Centers in the Soviet Union at Moscow, Kiev, and Leningrad. The visit was the result of an invitation by the Soviet Academy of Sciences reciprocal to an earlier trip in June to the United States by four Soviet computer scientists. Their trip to the United States is described in the News and Notices section of the *Communications*, Vol. 1, December 1958, pages 23–25.

The invitation was addressed to the four Americans by Academicians S. A. Lebedev, Director of the Institute for Precise Mechanics and Computational Techniques, and A. A. Dorodnitsin, Director of the Moscow Computation Center of the Academy of Sciences. The four Americans had all met and served as hosts to the Soviet computer visitors at the Engineering Summer Conference on Digital Computers at the University of Michigan in Ann Arbor, and on a side trip to Urbana, Illinois, where the Soviet scientists visited the Computer Laboratory of the University of Illinois. Mrs. Jane Robertson, wife of Professor Robertson, accompanied the group to the Soviet Union.

The itinerary of the visitors to the Soviet Union may be outlined as follows:

August 27–September 4. Arrived Moscow. Visited the Institute of Precise Mechanics and Computing Techniques, the Computing Center of the Academy of Sciences of the U.S.S.R., and the Computing Center at the Moscow State University.

September 4–6. Visited the Computing Center of the Ukrainian Academy of Sciences at Kiev.

September 8–9. Visited the Leningrad branch of the V. A. Steklov Mathematical Institute of the U.S.S.R. Academy of Sciences.

September 10. Departed Moscow.

Unassigned time was for travel. At each computing installation, each of the four visitors gave one or more lectures in computer-oriented areas such as numerical analysis, circuitry and logical design, and automatic programming. They talked with Russian and Ukrainian computer mathematicians and engineers working on comparable problems and were given very complete guided tours of the following Soviet equipments:

1. Strela, Computation Center, Moscow
2. BESM I, Institute of Precise Mechanics and Computing Techniques, Moscow
3. BESM II (under construction), Computation Center, Academy of Sciences, Moscow
4. URAL (Serial No. 23), Computation Center, Academy of Sciences, Moscow
5. Strela, Computing Center, Moscow State University, Moscow
6. Setun (under construction), Computing Center, Moscow State University, Moscow
7. Kiev (under construction), Computing Center, Ukrainian Academy of Sciences, Kiev
8. URAL (Serial No. 38), Computing Center, University of Leningrad, Leningrad.

Four separate reports of the authors' visit have been collected, tentatively to be published by the U. S. Government Printing Office. Hence a detailed account of all portions of the trip will not here be given. The four American visitors were treated in a very friendly fashion. In addition to the computer installations, they were invited to visit many historical and architectural monuments and saw much of both the downtown and outskirts of the three cities visited. Their two interpreters, Miss Anya Martinova and Viktor Karlovich Zeidenberg, both members of the Staff of the Institute of Precise Mechanics, gave unstintingly of their time and effort to make the trip successful. Numerous social events, including invitations to the Moscow apartment of Academician Dorodnitsin and the country dacha of Academician Lebedev, aided in making hosts and guests better acquainted under optimum conditions.

Travel to the Soviet Union for the visitors was supported by various university and governmental sources, including the National Academy of Sciences of the United States and governmental contractors with the three universities for research projects on which two of the authors were working. Within the Soviet Union all travel, lodging, and food expenses were paid for by the Academy of Sciences; a similar arrangement had been made for the four members of the Soviet group visiting the U. S. A. Mrs. Robertson paid her own expenses to the Soviet Union.

The characteristics of the seven different Soviet computers that were seen have been collected in a table by J. R. Robertson. The table overlaps in a few features a previous table published by one of the authors (*Communications A.C.M. 2*, No. 1 (Jan. 1959), 33), prepared before the visit to the Soviet Union. Some of the sources are listed there, others are included in [General Works on Digital Computers, 5, 6] in the Bibliography of this paper.

The table of characteristics and the following descriptions of the latest machines viewed, the SETUN, Kiev, and BESM-II, are taken directly from J. R. Robertson's trip report.

* Now at the Research Computation Center, Consolidated University of North Carolina.

Introduction

The computing machines visited fall into two categories: those which have been completed and those which are under construction. Attention in this report is given primarily to the computers under construction and to engineering matters of a more specific nature. Major features of the machines are summarized in table 1.

BESM II is not included in the table, since its characteristics were stated to be the same as BESM I except for certain methods of construction and the use of germanium rather than vacuum diodes.

SETUN

The digital computer SETUN is under construction at Moscow University. More attention was given to miniaturization than elsewhere among places visited, with elements mounted on cards which were in plug-in trays perhaps 2″ × 3″ × 6″ deep. The arithmetic unit, control, console, and input-output control are mounted in one unit approximately 7′ high by 11′ long, with a separate unit 6′ long for the memory cores, the drum, and magnetic tapes. The lower 30″ of the units is not used.

SETUN is to be a base 3 machine with 18 digits per word, each digit having one of the values −1, 0, or +1. The machine is to be serial, fixed point and with a single address in each of two commands per word. It was described as asynchronous, with a 200 kc. clock. Addition and subtraction will require 180 μsec, multiplication 360 μsec. No division instruction will be provided. A normalization instruction is included in the order code of 27 instructions to facilitate floating point computation. One index register is provided with one digit of a command indicating one of the three alternatives: add index, subtract index, or do not modify.

The memory hierarchy includes an 81-word ferrite core memory and approximately 2000 words of drum storage. The drum rotates at 7000 rpm, with a maximum access time of 14 msec, corresponding to two revolutions, one for waiting, one for transfer of a b ock of 27 words. The drum is physically small, perhaps 4″ in diameter by 6″ high, and has 60 tracks. Addition of magnetic-tape units is planned at some later date.

Input and output will be on 5-hole punched paper tape; all transfers are to be in blocks of 27 words. The reader will be photoelectric, reading 400 lines/sec and requiring 15 to 20 lines to stop. A printer is also to be available.

Components are to be a "type of magnetic amplifier using ferrite cores," except for 70 vacuum tubes used as "generators" (drivers). The explanation given for base 3 operations was that the hysteresis loop of the cores was not sufficiently square and that compensation was required. Thus, two cores are necessary for each digit and

TABLE 1

	URAL	STRELA	BESM I	SETUN	KIEV
Completion date	1955	1953	1953	Under constr.	Est. 1959
Base used	2	2, 10	2	3	2
Digits per word	36	43 Binary	39	18	41
Fixed or floating point	Fixed	Floating	Floating	Fixed	Fixed
Multiplication time	10 ms	~ 500 μs	270 μs	360 μs	200 μs
Primary storage	Magnetic drum	Electrostatic	Ferrite core	Magnetic drum, cores	Ferrite core
Primary storage capacity	1024	1023	1023	~ 2000	~ 2000
Primary storage access time		Read 20 μs, write 40 μs	6 μs	14 ms max	10 μs
Commands per word	2	1	1	2	1
Addresses per command	1	3	3	1	3
Auxiliary storage	Magnetic cinema film	Magnetic tape	Magnetic tape		3 Drums
Components	800 v.t. 3000 GE diodes	8000 v.t. 50–60,000 diodes	4000 v.t.	Ferrite cores	2000 min v.t.
Input	Punched cinema film	Punched card		Punched paper tape	Punched cinema film
Output	Punched film and Printer	Punched card	Printer	Punched paper tape and printer	Printer
Power consumption, kw	8	149	75	?	?

three states can be utilized. The motivation given for construction of the machine was dissatisfaction with STRELA, said to be too complicated for open-shop university use.

A base 3 digit is stored in two cores in the core memory, on two tracks on the drum, and on two holes in the paper tape.

A single unit, containing one record tube and a five-transistor read amplifier, can be switched to any one of three tracks of the drum.

KIEV

The computer KIEV is under construction in the newly formed Computing Center of the Academy of Sciences of the Ukrainian S.S.R. and is expected to be completed in the summer of 1959. A copy of this machine is to go to the atomic research establishment at Dubna.

The computer is to be asynchronous, with *no* clock. All storage is static in flipflops with information transferred by pulses. Other features include:

1) Fixed-point binary, 41 bits per word, three address.
2) 2000 word magnetic core storage, with 10 μsec access.
3) 3 drums of 4000 words each, 84 tracks per drum, 1500 rpm, return to zero recording, addressable by separate words or by blocks of variable length.
4) Input from punched film tape at 40 words/sec. Punched cards proposed, output printer like that of BESM.
5) Built-in binary to decimal and decimal to binary conversion. Division is included; square root is not built-in.
6) Plug-in packages, with two double triodes per package, with a total tube complement of 2000 miniature vacuum tubes.
7) Number representation is absolute value in memory, ones complement in the arithmetic unit.

BESM II

BESM II, under construction in the Computing Center of the Academy of Sciences in Moscow, will have the same logic and circuits as the (modified) BESM I, except that vacuum diodes are to be replaced by germanium diodes. Plug-in units are mounted on a panel which is itself removable.

The following description of the BESM I and BESM II computers and work in the laboratories on ferrite cores, switching theory, transistors, modular number systems, and permanent storage is taken directly from the report of N. R. Scott.

The BESM I Computer

At the Institute of Exact Mechanics and Computing Techniques the BESM I computer was inspected. This machine has been described by Academician S. A. Lebedev in a paper in the *Journal A.C.M.* (July 1956) but some interesting supplementary information was learned. The electrostatic storage (Williams tubes) has been replaced by a magnetic core memory, allowing the average speed of operation to be increased from 7–8,000 operations/sec. to 8–10,000 operations/sec. A small printer has been built and attached to the machine. This device prints 20 lines/sec., each line having 10 numerical characters. (So far as could be determined, no Soviet machines employ any non-numerical characters.) The 20 word/sec. punched tape reader mentioned in Lebedev's paper is still the means used for inserting programs and numbers. Lebedev agreed that this is a slow rate, but said that in their work they did not need much input data. An interesting item in the BESM I is a group of built-in subroutines on plug-in chasses. The routine for sin x, for instance, is an interpolation procedure based on stored tables of first and second differences for 10 increments in x. The numerical values in this table are inserted by manual patchboard. Except for the diode matrices used in these subroutine circuits, the BESM I does not use semiconductor diodes. This machine was built under the direction of Lebedev after he had successfully completed the MESM computer at Kiev. Lebedev, who is now the director of the Institute of Exact Mechanics and Computing Techniques, said he does not know whether his BESM I computer has been copied elsewhere in the Soviet Union, although it was our impression before visiting the U.S.S.R. that there are three BESM I machines.

The BESM II Computer

In the building which houses the Computing Center of the Academy of Sciences and also the V. A. Steklov Mathematical Institute, the BESM II was seen under construction. The welded steel framework was in place as was much of the wiring interconnecting the plug-in packages and the main frames. Samples of the plug-in packages, which are being assembled in the same building were seen. The construction throughout was rugged and well-shielded, but was entirely hand work. However, Prof. Lebedev said that BESM II is to go into serial production. This machine can therefore be regarded as a prototype.

The BESM core memories have or will have a capacity of 1023 words with an access time of 6 μsec. The storage units are of the word arrangement or "end-fire" type. Publications (in Russian), predominately describing core technology, were supplied during the visit and are listed separately.

Ferrite Core Work

An active group in the Institute for Exact Mechanics and Computing Techniques in Moscow is conducting work on ferrites ranging from manufacture of cores to circuit design. Leaders of this work are Iu. Vizun and V. V. Bardizh. This group is making the core planes for the BESM II computer. They have a small chemical laboratory where cores are manufactured from the basic raw materials. Dies are available for pressing not only cores for the BESM memory, but for several larger sizes and one smaller size as well. The smallest core has the dimensions:

1.2 mm (0.047″) outside diameter
0.8 mm (0.031″) inside diameter
0.6 mm (0.024″) thickness

In contrast to methods in the United States no control of the atmosphere is maintained during the heat treating process. Automatic core testers are used, and completed planes are given complete electrical tests. No attempt is apparently made to rewire planes when defective cores are found; 48 rows are wired even though only 39 are necessary, and two extra cores are placed on each end of each row.

For the BESM II memory, cores with closely matched characteristics are needed, and a group which was seen being tested was giving a yield of at most 5 per cent. Core matrices for the BESM II are being assembled by hand.

Cores for the KIEV computer were manufactured in the Institute in Moscow; however, wiring of planes is being done in Kiev.

No work was in evidence on the fundamental physics of magnetic phenomena. Although members of the laboratory inquired about U. S. research on thin films, they did not appear to be conducting such work, nor were they working on electro-plated magnetic elements.

Publications: The following recent publications (in Russian) of an engineering nature were obtained from members of the Institute for Exact Mechanics and Computing Techniques:

1. V. V. BARDIZH, Characteristics of Magnetic Cores with Rectangular Hysteresis Loops, (1957).
2. IU. I. VIZUN, Some Principles of Designing Magnetic Permanent Storage Devices, (1957).
3. IU. I. VIZUN, Test Equipment for Determination of the Basic Characteristics of Magnetic Cores, (1957).

Switching Theory

In Leningrad, Scott talked briefly with Prof. A. G. Lunts, of the Electrotechnical Institute, who is known in the United States for some of his work on Boolean matrices. Prof. Lunts supplied a copy of each of three of his papers: "Synthesis and Analysis of Relay-Contact Circuits by means of Characteristic Functions," 1950; "Applications of Boolean Matrices to Analysis and Synthesis of Relay-Contact Circuits," 1949; and "A Method of Synthesis of (l, k) Poles," 1957. Prof. Lunts' interest in this problem has now led him into the study of linear graph theory as an abstraction of the topological properties of switching nets.

Another worker in switching theory is Prof. S. V. Yablonski, at Moscow State University. He presented copies of several papers by himself and by his associates. One of these is a paper improving upon a limit of Shannon's giving a bound for large n, for the least number of switches required to realize any function of n variables.

Transistors

In the laboratories visited, very few transistors were seen. Strela, BESM, and URAL (of old design) and KIEV (new design) have no transistors. The SETUN group at Moscow State University, described elsewhere in this report, are using transistors only in the reading amplifiers for the magnetic drum. However, in the course of a short visit in a laboratory of the Electro-Mechanical Institute in Leningrad, a breadboard circuit using 84 transistors was seen. This circuit consisted of two integrators, each having 14 flipflops connected as a counter. Integration is performed by pulse-counting, and the integrators are connected in a closed loop through an adder, a subtractor, or a suitable weighting circuit in order to generate second-degree curves (circles, ellipses, parabolas, hyperbolas). This device is to be employed in generating curves for automatic-machine tools.

Modular Number Systems

In Kiev, Mr. A. Mialkovski, an engineer on the KIEV computer, told of the interesting work of Dr. Antonin Svoboda, of Czechoslovakia, the author of one of the volumes in the M.I.T. Radiation Laboratory Series, who has been investigating a type of arithmetic in which numbers are encoded, by congruence relationships, as residues with respect to a set of bases which are relatively prime, thus permitting addition and multiplication to be executed without carry. Svoboda's most recent paper is "Rational Numerical System of Residual Classes" (*Stroje Na Zpracovani Informaci*, Vol. 5 (1957), pp. 9–37; in English). The paper also contains references to other papers on this topic, in Vol. 3 of the same journal, by M. Valach and by Svoboda and Valach. Svoboda is expected shortly to publish a paper describing an experimental machine employing this system of arithmetic.

Permanent Storage

A form of permanent storage using printed capacitors has been developed by the Laboratory for Electric Modeling, which is part of the Institute for Exact Mechanics and Computing Techniques. The capacitors consist of a sheet of paper with conducting lines of zinc (sprayed or painted on) on opposite sides of the paper. The short conducting segments to the capacitors are severed by a card punch if the corresponding digit to be stored is a 0, or are left intact if the digit is a 1. Thus, on readout, no pulse is obtained from a disconnected capacitor, while an output pulse is obtained from a connected capacitor. A typical sheet has 512 bits of storage, and 512 of such sheets may be stacked and fastened in a block to give 2^{18} bits of permanent storage in a space about $8'' \times 12'' \times 2''$.

A memory device incorporating this system is on exhibition in the Hall of Science at the Agricultural and Industrial Exposition in Moscow, in a room near the Sputnik models.

The following description of automatic programming efforts in the Soviet Union is taken directly from the report of A. J. Perlis, as are the discussions on language translation.

General Remarks

Three automatic programming systems (algebraic translators) were found in use or being prepared, one each in Kiev, Leningrad and Moscow.

If there are others being developed, mention of their specific details was not made to our group.

Of the three systems only the system in Moscow is in active computer use.

The other systems are under development and partially coded, but not operative. But then there are not operating computers in these two cities on which these systems may be tested. (An URAL has recently been delivered to Leningrad University but was not as yet operating.)

The systems are only for scientific calculations. No automatic programming for data processing was in evidence.

The format of these systems is quite conditioned by the nonexistence of direct alphanumeric input on any Russian digital computer. Thus, there is no symbolic machine-like coding system in Russia corresponding to SOAP and SAP.

The translators were, and are, being written in machine language. However, on the STRELA there is a loading program which permits the use of floating addresses for combining parts of programs.

None of the translators allow the automatic combination of programs (themselves written in algebraic language) to form new programs. Indeed, the general problems involved in the construction of assembly systems seem to have been neglected.

In the operating system for the BESM and STRELA there are no simple provisions for the use of subroutines from a standard library. Indeed, the subroutine library concept—while clearly understood—seems not to have developed as in the United States and Britain.

The Cambridge group (EDSAC) and the IBM FORTRAN group, of the programming efforts foreign to Russia, seem to have had the most effect on their programming developments.

In the book on coding by Kitov, there is a chapter describing the algebraic coding scheme of Liapunov (Moscow University). Liapunov emphasizes the distinction, an improper one in the author's opinion, between interpretative systems, subroutine libraries, and algebraic translators. The programming system developed in Moscow for the BESM and STRELA uses the Liapunov formalism for describing logical operators.

Because the complexity of their problems do not warrant it or because they have chosen to accent optimization problems, the Soviet automatic programming systems do not provide the flexibility of notation available in some American systems.

However, they have done quite well in solving some optimization problems arising in the construction of algebraic translators—minimization of temporary storage, minimization of arithmetic operations, and minimization of indexing and logical operations.

Indeed, there seems to be strong emphasis on theoretical programming, i.e., the theory of algorithms. The work of Ianov and Ershov (both of the Moscow Computing Center and Moscow University) is directed toward deriving necessary and sufficient conditions for proving algorithms (or programs) equivalent and in deriving complete sets of transformations for taking one algorithm into an equivalent. Liapunov at Moscow University is reportedly developing a theory of algorithms which permits the definition of a norm over sets of algorithms so that processes leading to minimization over parameters may be defined. Nothing has been published of these efforts. Liapunov, being on vacation, was not available for direct discussion.

Programming research in Russia is definitely considered within the framework of contemporary Russian mathematical research, and vigorous work is being carried out at the Universities of Kiev, Leningrad, and Moscow.

The Kiev Automatic Programming System

An algebraic programming system is being developed at Kiev under the direction of Prof. Kalushnin, an algebraist at the University. This system is far from completion. Little if any has been machine tested. Indeed, only the scanner has been programmed.

Statements, written in Polish prefix notation, are scanned from left to right looking at (in general) triplets of symbols. Whenever a triplet has the form $0\ \alpha\ \beta$ where 0 is a binary operator symbol and α, β are operand symbols, a three address command is compiled, checked against previous compilation for removal of redundancy and a new right (possible more than one) symbol is appended to the right of a storage symbol q (the result of $0\ \alpha\ \beta$).

Redundancies in the coding produced are checked for—utilizing the commutative and associative laws of arithmetic—as instructions are compiled.

The authors of the system have an algorithm which converts a statement in standard algebraic (utilizing parentheses) notation into Polish prefix notation.

Since the arithmetic operators no longer act as delimiters the use of arbitrary symbols as names of variables require concatenation operators to be introduced, else +ABC would be ambiguous meaning A + BC or AB + C. However, such ambiguities are resolved by using symbols of equal length.

The Leningrad Programming System

A group of four people is working with Prof. Kantorovich in Leningrad on an automatic coding system called PRORAB. This group is most concerned with a system which has the most convenient notation for inserting information about algorithms into the computer.

The input to the system is not the so-called line formula, standard in the U. S. A., but rather as a sequence of inscriptions

$$K_1 = (F_1, K_1', K_1'')$$
$$\cdots\cdots$$

which says that K_1 is defined by the objects on the right.

Actually, this is a type of three-address code representation of a formula, whose sequencing is derivable from the inscriptions.

As far as could be gathered, the translation from a formula to the ordered scheme is not done by PRORAB but

by hand. PRORAB is concerned with generating *sequential* code from any presented scheme.

This group has concerned itself with simplification (removal of redundancy) problems in the construction of this code. The aim is to build a calculus based on such relations between inscription forms so that transformations of explicit schemes may be rationally studied, and automatically instigated by PRORAB.

PRORAB, then, consists of programs which transform explicit schemes—currently only arithmetic schemes—into machine code. No "scanner" to transform line formulae into such schemes has been produced. PRORAB is being tested on the STRELA at the Academy's Moscow Computing Center.

Professors Fadeev and Fadeeva of the Leningrad Academy are preparing for publication a handbook on numerical methods for solving algebraic systems. These methods are being programmed in PRORAB for machine testing.

Publications:

1. KANTOROVICH, L. V., On a mathematical symbolism convenient for performing machine calculations, *Doklady, USSR, 113* (1957), 738–741.

2. KANTOROVICH, L. V., On performing numerical and analytic calculations on a machine with executive programs, *Proceedings AN Armenian SSR, 10,* (1957), 3–16.

Automatic Programming in Moscow

Automatic Programming is more advanced in Moscow than in Kiev and Leningrad. This is not surprising since the best equipment, information, and personnel appear to be centered there.

The Computing Center of the Academy has developed an automatic programming system, in conjunction with theoretical work on programming and algorithms by the staff of Moscow University. Thus, Professors Liapunov and Shurabura, of the University, have worked on the theory of programming and a symbolism due to Liapunov is the basic language form of the Moscow programming system. Ianov, of Moscow University, has been working on a theory of equivalence between algorithms.

The principle designers of the programming system itself are A. P. Ershov and L. N. Korolev. Ershov has authored a book describing the construction features of the translator, including flow charts (and their analysis) of each of its important parts. No one has as yet done this with any American programming system. Consequently, this book contains much valuable information not to be found elsewhere in print at this writing.

The form of the language follows the specifications of Liapunov. These are outlined in Kitov's book.

A. J. Perlis wrote and ran a program on STRELA using this system.

This system has a line-formula language quite like FORTRAN or IT. The notation employed is quite natural and somewhat freer than in American systems. Since the computers STRELA and BESM accept only numeric quantities, replacement of all non-numeric symbols must be done *by hand* outside the computer before input of a program. The numeric replacement of a symbol representative of an operator or a punctuation mark is fixed, that, for a symbol which is the name of a variable is an arbitrary floating address (called "conditional number"). Thus, one may use arbitrary alphabets, etc., in the source program. One prepares a copy of the program utilizing only such numerical input punched in a standard form on cards for entry into the machine. The compiled output is punched out on cards and another input is required for the running of the program.

The Compiling Algorithms

Formulae are scanned from left to right. The operator of highest priority, together with its operands, is coded in three-address code and the result is left in temporary storage α_1, and α_1 is substituted in the formula. The above is repeated until all operators have been so treated. A new α_1 is used with each extraction of an operator.

Example:	$\sin(a + c \times d) \Rightarrow y.$	
Scan:	$\sin(a + c \times d) \Rightarrow y$	
Generate		$\times$, c, d, α_1
Re-scan	$\sin(a + \alpha_1) \Rightarrow y$	
Generate		+, a, α_1 α_2
Re-scan	$\sin(\alpha_2) \Rightarrow y$	
Generate		Trf, α_2 , , 0001
		Perf, , , ≪sin≫
		Trf, 0002, , y.

Note the two types of generated packets of three-address code. Locations 0001 and 0002 for the input and output respectively, of all the standard functions.

Economization Algorithms

All generated code is tested for certain obvious redundancies. Clearly 0, a, b, α_k (0 denotes an operator) is redundant if 0, a, b, α_n $(n < k)$ has already been compiled, and neither a or b has been stored in an intervening instruction. In such obvious redundancies α_n is substituted elsewhere for α_k. A similar treatment holds for the function packets.

The redundancies are recognized by taking into account the commutative laws of addition and multiplication but *not* the associative laws of multiplication and addition nor the distributive law of multiplication over addition. Thus, in

(1) $(a + b + c) \times d$
(2) $((a + b) + c) \times d$
(3) $d \times (c + (b + a))$
(4) $(a + (b + c)) \times d$
(5) $a \times d + b \times d + c \times d,$

the first three are recognized as equivalent while (4) would be duplicated.

Working storage is also assigned to minimize the number of distinct α_i addresses in the temporary storage block.

Consider the following example:

$\sin (a + c \times d \times \cos g) + f/g + \ln \cos g \Rightarrow y$

The code produced would be:

Line	*Op.*	*1st address*	*2nd address*	*3rd address*
1	Tr	g		0001
2	Perf			cos
3	Tr	0002		α_3
4	$\times$	c	d	α_4
5	$\times$	α_4	α_3	α_5
6	$+$	a	α_5	α_6
7	Tr	α_6		0001
8	Perf			sin
9	Tr	0002		α_9
10	/	f	g	α_{10}
11	Tr	α_3		0001
12	Perf			ln
13	Tr	0002		α_{13}
14	$+$	α_9	α_{10}	α_{14}
15	$+$	α_{14}	α_{13}	y

In α_i the subscript i is the conditional number of the line at which it is generated (and entered in the 3rd address position).

Let now a directory of temporary storage S be given. Let S_f be the first free location listed in the directory. Let S_i be an arbitrary element in the directory.

The code is scanned backwards (from right to left on each line and upwards from line to line) until an α_i or an S_i is found.

The algorithm is so organized that

(i) α_i is never found in the 3rd address position,

(ii) S_i is only found in the 3rd address position.

Thus:

1. S_i is found. Set S_i as free in the directory. S_i is about to be used for storage so that on reading backwards it must have been free immediately prior to this occurrence.

2. α_i is found in line k. Let β denote the 3rd address of line i. Then:

a) if $\beta = \alpha_i$, substitute S_f for β and the occurrence of α_i in line k. Note S_f to be occupied.

b) if $\beta = S_i$, substitute S_i for the occurrence of α_i in line k.

The application of this algorithm to the example reduces the number of α_i to 3.

Subroutine Library at Moscow University

The computer center at Moscow University, operating essentially under an open shop computing policy, is used by the various scientific departments of the University and the technical institutes in Moscow.

Approximately seven routines are listed by name in the subroutine catalogue. These were (1) Linear equation solver using elimination; (2) Linear equation solver using iteration; (3) Floating-address loading routine; (4) Numerical quadrature using Simpson's rule; (5) Matrix inversion routine; (6) Runge-Kutta differential equation solver; and (7) Polynomial root solver using Regula Falsi.

No description of the subroutine's requirements is provided in the catalogue. Listed with the name of a routine is a collection of the names and locations of programmers who have previously used the routine. Each new user then contacts a previous user to learn details of operation. Actually, each of the seven routines listed above is now a category of routines, with each user making multiple modifications of his predecessor's handiwork.

Staff at Moscow University

There are four areas of specialization in mathematics at Moscow University: pure mathematics, mechanics, computer mathematics, and astronomy. Both the faculty (about 40) and enrollment in computer mathematics are at least as large as any of the other three areas. Academician S. L. Sobolev heads this department, though he is to soon head the computer mathematics group at the new Siberian Academy of Science Center in Novosibirssk. Among those to accompany him is A. P. Ershov. Four computers are to be installed there by midyear of 1960.

It is the computer mathematics group at Moscow that is constructing the SETUN to provide for simpler and more flexible operation of their center than is possible with the large and relatively unreliable (10-minute mean free error time) STRELA.

We were informed that the mathematics group intended to continue research in computer design in the future. Thus, SETUN is a single-address computer and algorithms are being developed which maximize the use of an accumulator during extended calculation of algebraic formulae. Prof. Shura-bura is attempting to determine the optimum size of core memories. The faculty regard the interplay of design, construction, application, and programming as quite necessary and invigorating for a university computing center.

Language Translation

The Soviets have been pioneers in accomplished machine translation of national languages. Their work was first reported in 1956. Progress since then has been steady though undramatic. A separate center for this work under the directorship of S. Lebedev and assisted by I. Mukhin is now in operation. The group numbers about 40 and is staffed mostly by young female linguists. In progress are simultaneous efforts to machine translate Chinese, Japanese, German, and English into Russian. Chinese and English are farthest advanced. At present the dictionaries are:

English → Russian	4000 words
Japanese → Russian	1500 words
Chinese → Russian	1900 words
German → Russian	2000 words

Each Chinese character is constructed from 129 elements.

The current work in English to Russian is concentrating on the problem of polysemantic words. This difficult problem, still not solved, may account for the lack of dramatic progress in their work. However, another reason may account for this even more. Thus, their linguists apparently do not know how to program—and are not being taught seriously what programming is; and their programmers are not linguists. The interchange of requests and solutions between these groups, we were told, creates a good deal of noise, interminable delays, gross repetition, and slow progress. The lack of alphabetic computer input-output has also hindered them but not as severely.

In Moscow no work was reported on the development of an automatic programming system for language translation. Some work on automatic programming of synthetic languages—more flexible than algebraic ones—is being carried out under Andreev at Leningrad. However, he was reported in Moscow when our group was in Leningrad. Ouspensky teaches a course in mathematical linguistics at Moscow University.

The group of Lebedev has spoken of a computer specifically for language translation but not even preliminary designs have been started as of September.

Korolev is developing machine representations of dictionaries. His current approach is to take English words encoded in numeric form and to compress them to a standard length, e.g., by truncating after the jth letter and adding successive truncated "tails" to the "stem," the addition being arithmetic or modulo some base on each digit position, etc. These codes are then treated as numbers which may, as such, be ordered. To find a correspondence between a text word and a dictionary entry the number associated with the text word is applied to the dictionary (coded numbers of same) and the bisection principle is applied. To find 1 from N entries, at most $[\log_2 N] + 1$ comparisons will be needed. The drawback in this method, or course, is that these numerical encodings do not necessarily preserve "nearness," thus, if $j = 4$, the encodings of "stop," "stopping," "stopped," will not necessarily yield nearly like codes. Thus, the dictionary must be quite large or a preceding encoding analysis must be made or iteration on these processes might be required. Processes like the above are being (or have been) coded for the BESM.

* * * * *

The following presentation of work in mathematical logic and numerical analysis that was discussed, mainly in Leningrad, is taken from the report of J. W. Carr, as are the list of new Soviet books, the general conclusions about the trip, the two appendices concerning Soviet reports on work accomplished, and the bibliography of documents brought back from the trip.

Prior to a first session at the Steklov Institute in Leningrad, Perlis discussed with a student of Kantorovich the structure of the Mathematics Faculty at Leningrad University as compared to that of similar American universities. There are four divisions in the Mathematics Faculty there: Pure Mathematics, with from 60 to 80 students; Astronomy, with 20 students; Mechanics, including Hydrodynamics, with 60 to 80 students, and Computational Mathematics, apparently including Mathematical Logic, 20 to 40 students. Professor Kantorovich is in the latter group.

All students take an elementary course in calculus, an elementary course in differential equations using a text by Matveev, and hydrodynamics. Lectures in algebra are from texts by Gelfond, Malcev, and by Kurosh on group theory. The functional analysis course uses texts by Riescz and Nagy, and Neymark's *Normed Rings*. The complex variable texts are Privalov, and *The Geometric Theory of Complex Variables* by Golusin. The lectures on real variables are from a text by Natanson. At this stage the students separate and enter one of the above named specialties. Carr and Perlis conferred with mathematicians at the V. A. Steklov Institute, near the Hotel de L'Europe, where the group was staying.

Among those who attended these sessions were:

Professor G. I. PETRASHEIN, Director of the V. A. Steklov Mathematical Institute, Leningrad Division.

V. P. ILYIN, of the Institute Staff, who was interested in variational methods and in "estimating methods in variational problems."

V. A. ZALGALLER, of the Institute Staff, a specialist in linear programming, interested in applications to production techniques.

Mr. VENKOV, interested in algebras.

D. K. FADEEV, of the Institute Staff.

Mme. FADEEVA, interested in linear algebras and linear computational techniques, of the Institute Staff.

Professor L. V. KANTOROVICH.

The main discussions at this session were on Linear Programming and Linear Systems. However, Professor Petrashein first expressed an interest in exchanging information on "applications of mathematics to geophysics," particular in the use of digital computers. He has been involved in the theory of seismic waves and has computed tables describing their propagation using the Strela and BESM at the Moscow Computing Center in Moscow. He stated that his co-workers generally use machine codes, without the need for subroutines.

Computation in Linear Systems

Madame Fadeeva was interested to learn that her book on linear systems has been translated at the U.C.L.A. Institute for Numerical Analysis. She and her husband, D. K. Fadeev, are now readying for publication a book consisting of nine chapters and 100 paragraphs, to be a Handbook on the solution of linear systems. The book is to be published in late 1958 or early 1959. She had not heard of Bodewig's book on matrix calculations, or of the recent work of J. H. Wilkinson of the National Physical Laboratories in England. Her book was based on experiments with small problems tested by hand computations, but more recent experiments had been made on the solu-

tion of linear systems using the Leningrad PRORAB automatic programming scheme on the Moscow Strela Computer.

Linear Programming at the Leningrad Institute

Of particular interest was the discussion with V. A. Zalgaller and Professor Kantorovich on work in Leningrad on Linear Programming. They stated that they had known about this type of problem in 1939, when it was first studied in a Leningrad University report of Professor Kantorovich. At present, they use a "dual program" method of computation. Both were familiar with the work of Dantzig and Orchard-Hays on the Modified Simplex Method, and one of Professor Kantorovich's students is interested in an extension of this method but has not as yet published his results.

As an example of recent work in this area in the Soviet Union, they cited Kantorovich's and Rubinstein's works published in 1956 in the journals *Doklady AN SSSR* and *Uspekhi Matematiki* [Linear Programming, 6, 7]. Experiments in the railroad industry using linear programming have produced a great economy of metal in building railway carriages. The methods have been used on "complex problems in the oil industry, producing economics." People have been trained to solve problems at certain factories on hand machines. The "problem of timber cutting" has proved to be too big for hand computation. The largest sized linear programming matrix solved has been of the order of 30, they stated, but larger matrices up to 300 (= sum of number of rows and columns) have been simplified and then solved. Digital computers are now being used. (A report of work by another Soviet group on the machine M-2 is given in Appendix I.)

The two mathematicians cited their book, *Rational Cutting Out of Material* (Kantorovich and Zalgaller, 1951) as a discussion of some of these practical solutions which they are now teaching in an in-training course in industry on hand methods in linear programming.

Discussions on Logic

Carr discussed the work in logic at Leningrad with Professor Shanin of the University and the Steklov Institute. Professor Shanin pointed out that the work in the area first pioneered by A. A. Markov in Leningrad (he is now at Moscow State University) is being continued by himself and others. He noted two recent publications of the Steklov Institute, Leningrad Division [Logic, 5, 6], one of which included several papers pertinent to the area of "cybernetics," including one on relay-contact networks by Yablonskii. He was most familiar, among Americans, with the work of Kleene and Curry. (One of his students later commented that the mathematical logic seminars usually concentrated on the work of American mathematicians, with the students assumed able to follow the work of Soviet authors in this area with little direction.)

During a short discussion of present and proposed automatic theorem-proving techniques in the United States (the Newell-Simon program, other proposals for the propositional calculus, and plane geometry) he suggested possible use of the Gentzen calculus, or experiments with proving theorems in a finite geometrical array, where statements with finite quantifiers on such predicates as "above," "below," etc., could be posed for possible proof by a machine. He uses such a system in teaching elementary logic to his students. When Shanin was informed of the simpler Turing machine descriptions developed in the U. S. by Moore and Clarke, he stated that similar work had been done in the Soviet Union.

Numerical Analysis

Professor L. Lozinskii, who had been interested in a report of Carr's on floating-point error analysis, described work he had done on propagated error bounds in numerical solution of ordinary differential equations; he stated that he had developed nonexponential bounds for explicit numerical solutions. This work is to be published in *Izvestia Vyshykh Uchenyk Zavedenii Matematiki*, a new journal of the University of Kazan, which may be subscribed to at cost of 60 rubles per year by writing to:

Gosudarstvennoe Izdatel'stvo
Universiteta V. I. Liapunov-Lenin
Ulitza Lenin 18
Kazan, U.S.S.R.

Visit to the Leningrad Computing Center of the V. A. Steklov Mathematical Institute

To be shown an example of "computers used in an industrial situation," the entire group of four Americans was taken to the Leningrad Computing Center of the V. A. Steklov Mathematical Institute, located away from the main Leningrad building of that Institute, in the same building as the Electro-mechanical Institute, the Energetics Institute, and the Institute of Eastern Countries (Historical and Material Studies).

New Soviety Books

During the course of the trip, several new Soviet books not generally known in the United States were mentioned.

Computers

1. BRUK, I. S., editor, *Bystrodeistvujushchaya Vychislitel-'naya Mashina M-2.* (High-speed Computing Machine M-2).
2. KITOV, A. I., *Bystrodeistvujushchei Vychislit'elnii Mashiny.* (This book is now somewhat known in this country. Portions of it, particularly on the Strela order code and automatic programming, have been translated by J. W. Carr, III.)

Computational Mathematics

1. FADEEV, D. K., AND FADEEVA, L., a handbook on computational methods in linear algebra, to be published in 1958 or early 1959.

2. RYABENSKII, V. S., AND FILIPPOV, A. F., *O Korrelosti Razhoctyx Metodov* (On Stability of Finite Difference Methods).
3. A new book on differential equations by CHUDOV was also mentioned.

Programming

A new book on digital computer programming by A. I. KITOV, A. A. LIAPUNOV, and one other was also mentioned.

Automatic Programming

1. ERSHOV, A. P., *Programmirujushchaya Programma dlya Bystrodeistvujuschei Elektronnoi Schetnoi Mashiny* (Programming Programs for High-Speed Electronic Computing Machines), Izdatel'stvo Akademii Nauk SSSR Moscow, 1959. This is a description of the two algebraic compilers on the BESM and Strela, whose design was supervised by Ershov.

Conclusions

J. W. Carr had previously visited such British University computer installations as Cambridge, Manchester, and Leeds; commercial facilities at Ferranti, Ltd., English Electric Co., and Leo Computers, London; and production facilities at Elliott Brothers and Leo Computers, London and Ferranti, Manchester. He had also visited a Bull factory at Amsterdam in the Netherlands, as well as the Royal Dutch Shell installation there. On his return from the Soviet Union he visited the Danish Regnecentralen in Copenhagen, where the DASK, a computing machine in the Scandinavian tradition of design, is being built. The visits allowed direct comparison of Soviet work with that in Western Europe. However, it should be remembered that the U.S. group did not visit any Soviet computer production facilities.

As to the equipment seen, the British EDSAC II (Cambridge) and Danish DASK were of later design than the BESM I. All three are of comparable speed. The Western technology, with these equipments, appeared to use more advanced components (transistors in input-output on the DASK, magnetic cores for control on the EDSAC II, for example.) The short range of performance of the CRI storage of the Strela indicated that it was comparable in reliability to that on the Shell Ferranti Mark II in Amsterdam.

Input-output via punched cards, except for alphabetic characters, compared favorably to Western efforts as did the proposed SETUN computer paper tape reader. The various magnetic drums appeared of a satisfactory design, but the BESM and Strela magnetic tape units did not compare favorably with (particularly) American units. The visitors did not get to examine the high-speed photoelectric printer on the BESM, but the mechanical printer speed was not high. The core storage units on the BESM appeared to work reliably, as did that machine in general.

The general opinion of the U.S. group, on Soviet computer equipment, was that in the areas of production control of components and equipment, Soviet technology is not as advanced as that of the West.

In automatic programming, it would appear that Soviet work in this area, while ahead of that in Western Europe, is still somewhat behind the United States. The main difficulty in practice would appear to be the lack of generalized alphanumeric input on their computing machines, and a still present doubt (as generally holds in Great Britain) in the general usefulness of these machines for logical purposes (game playing, symbol manipulation, theorem proving, etc.) In the theory behind automatic programming, however, the Soviet work is ahead of any others. The theoretical work based on Markov's original papers could serve as a basis for an expansion of computer usage into these areas at a rapid rate once it was decided to do so. There are obviously more and better logicians and mathematicians connected directly or indirectly with computers at Moscow, Kiev, and Leningrad universities than at any universities in Western Europe or the United States.

Language translation is a major effort on the part of the Soviet scientists and it would appear that only equipment is holding them back. Whenever their "special purpose translator" becomes available, they should have enough theoretical and practical knowledge to perform competent scientific translations. The BESM at present does not appear to have enough storage to do a completely satisfactory job in this area.

In numerical analysis and related functional analysis, again there appear to be more and better mathematicians directly involved with computers than in the United States. There is no university program in computer-oriented numerical analysis and logic anywhere comparable in the size of faculty and student body, or in curriculum, in the United States, with that of Moscow State University, except perhaps at M.I.T. The Soviet student output in this area—of qualified computer-oriented mathematicians, not just computer programmers —may, soon surpass that of the United States.

The continuing interest of the entire Soviet population in Cybernetics (illustrated by giant sales of Wiener's book, *The Human Use of Human Beings*) is penetrating the society. It should motivate many more students to enter this area. Despite a relative slow start, and mainly because of the flexibility of their mathematical leadership, Soviet use of computers may be expected to surpass in quality and quantity that of the United States, that is, unless the top-notch American mathematicians wake up to their responsibilities. Most mathematicians in the Soviet Union, of all backgrounds, unlike most of their counterparts in the U. S. A., are apparently tremendously interested and excited by the possibilities of digital computers.

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5. *Vychislitel'naja Matematika i Vychislitel'naja Tekhnika*, Report II, 1955. This is an earlier version (and volume) of what is now *Vychislitelnaja Matematika*.
6. VERTGEIN, B. A., Approximate Solutions to Non-Linear Equations, *Uspehi Math. Nauk*, Vol. 12, No. 1 (73), Jan.–Feb. 1957, p. 166 (in Russian).

Appendix I

Key Excerpt from the Soviet Literature Pertinent to this Report

Linear Programming

"For about a year investigations have been carried out on the M-2, connected with application of electronic digital machines for economic computations, necessary for planning in the people's welfare. The basis of the method is the computation and execution of experimental calculations of tables of interregional connections. Tables of size 44 × 44 (44 branches of subject and 44 for predicates) are computed for expressing costs, and tables of size 17 × 17 in the natural indices. Several variable tables have been completed, composed for the union republics and economic regions. These will characterize the basis of interregional connections. With the aid of these tables it will be possible to solve the questions of the largest rational cooperation between regions of the land, and to work out the optimal scheme of flow of goods."

Excerpt from SEMKOV, B. F., Small-size Calculating Machines, *Vestnik AN SSSR*, Vol. 28 (Jan. 1958), pp. 60–64.

Appendix II

Excerpts from a Soviet Description of Recently Published Books and Journals

LIAPUNOV, A. A., editor. *Problems of Cybernetics.* (10,000 copies) In 1958 the publishers will begin the issue of collections dedicated to cybernetics. It is proposed that included in the collection will be papers on the following divisions: General questions; Programming computing machines; General questions of automatization of production; The theory of information; The theory of algorithms and automata; The theory of control units; The theory of games and tactics: Methods of analysis of operations. They will illuminate the application of cybernetics in linguistics, biology, and economics. In the first issue a great wealth of presentation of the division on programming (in this number the automatization of programming) and mathematical linguistics will be given.

Popular Lectures on Mathematics. (50,000 copies) ARCHANGELSKII, N. A., AND ZAITSEV, B. I., *Electronic Digital Machines.*

BASILEVESKI, IU. IA., *Questions in the Theory of Mathematical Machines.* "Use of these machines increases not only in mathematics, but also in physics, biology, neurophysiology, medicine, linguistics, machine tools, aviation and other regions."

FADDEEV, D. K., AND FADDEEVA, V. H., *Computational Methods of Linear Algebra.*

BUSLENKO, N. P. AND SHREIDER, IU. A., *The Method of Statistical Trials and Its Realization on Electronic Digital Machines.*

KURTSEV, M. A., *Arithmetic Units and Electronic Digital Machines.*

NIKOLSKII, S. M., *Quadrature Formulae.*

SHURA-BURA, M. R. AND OTHERS, *The Method of Standard Sub-Programs* (8,000 copies). Extending the application of electronic digital machines in science and the people's welfare poses the very important question of shortening the amount of work in programming (in the preparation of problems for solution on the machine). One of the important methods of speeding up and easing the composition of programs is the use of systems of previously composed and carefully tested standard subprograms for meeting some of the composition of parts of the complex computational processes. This method is exposed in the monograph. Concrete programs are written in the code of electronic digital computer M-2 (the book describing the machine M-2 was issued by the Government Publishing House in 1957). In this there appears the results of special applications of methods on the machine working either with floating, or with fixed point, since the machine M-2 may work in both memory regimes. The book may serve as a textual aid for preparation of specialists in programming but also presents an interest for workers in computational centers.

SHURA-BURA, M. R., *Programming Mathematical Problems for High-speed Computing Machines.* For the goal of very complete use of the power of large as well as small automatic machines, it is necessary to solve the problem of maximal automatization of programming. Definite positive results in the direction are already obtained, but it is still necessary to do more. In particular the method of standard programs for automatization of programming is weakly developed. For conditions of putting forth a large series of a single machine this method may play a large role in familiarization with a given machine by different organizations which apply standard programs for automatization of programming.