SETUN's Reverberations

How the SETUN Computer was Perceived by the "Western" Scientific Community

Francis Hunger

> "Of course, I learned about the advantages of [ternary] programming from books which devoted major interest to this problem. I later found out that the famous American scientist Grosch (Grosch's law) was interested in ternary number systems, but no ternary computer was actually realized in the US."
> (N. P. Brusenzov)[1]

> "SETUN actually started my interest in MVL [Multiple Valued Logic] from a digital systems point of view, and we had read the early works of SETUN in the early 1970s."
> (David C. Rine)[2]

In 1958 the Russian engineer Nikolai P. Brusenzov and his collaborators constructed the world's first ternary computer, which remains unique even today. The computer built at the Research Computing Laboratories of Moscow State University (MSU) was named SETUN, after a small river in the vicinity.

The following study examines how scientists in the "West" learned of the existence of the SETUN and investigates the information disseminated about this computer in scientific publications in the USA.

It is apparently the case that the very fact of the SETUN's existence in the Soviet Union encouraged, and in some cases even triggered, Western research into ternary logic applications. Although the designer of the SETUN could not claim to be the first to have thought about ternary logic and computing technology, the impact of the computer's existence should not be underestimated.[3] In a 1977 summary of the development of multiple-valued logic and computing technology, G. Epstein, G. Frieder, and D. C. Rine

---

[1] Malinovski 1995 (transl. F.H.).
[2] David C. Rine, e-mail to the author, March 23, 2005.
[3] Grosch 1952.

reached the following conclusion: "However, the SETUN computer awakened interest in subsystems such as arithmetic units and numerous electronic modules as cited in an abridgement of the bibliography for Thelliez' doctoral thesis." Michael Yoeli wrote in 2005: "From a software viewpoint the idea of ternary computing is indeed attractive, and the SETUN was an important contribution to this idea."[4] Before discussing the assessments and valuations of Yoeli and others, it is necessary to ask how Western scientists learned about the SETUN.

Historical Excursion I: Scientific Exchange

Although separated by the Iron Curtain, Eastern and Western scientists were keen to learn more about technological developments on the opposite side. As early as 1955, Sergei A. Lebedev presented the BESM-1 computer in a brochure printed in four different languages and, in a lecture delivered to a conference held by the Institute of Applied Mathematics at Darmstadt Technical University, revealed the advanced progress of endeavors toward electronic calculation devices in the USSR.
Interesting in connection with the SETUN is a series of visits exchanged by American and Soviet scientists in the period 1958-59 as a result of the initial contact established with Lebedev in 1955 at the above-mentioned conference.[5] Until 1959 no official scientific exchange program had existed between the National Research Council of the US Academy of Sciences and the Academy of Sciences of the USSR. In the available articles from 1959-60 of the US journal *Communications of the ACM*, the American authors describe the initial visits as very intensive and the atmosphere as often hearty. Nevertheless, communication among the scientists was apparently dogged by cultural and scientific misunderstandings, even if the authors apparently confined themselves mainly to technological details.[6] The organizational structure of Soviet scientific institutions was fundamentally alien to American scientists, and it may be assumed that the converse was equally true.[7] Outsiders could scarcely understand the interplay of various aspects of post-war Soviet society – the maneuvering within the ideological framework of Soviet Communism, the placing of research commissions primarily in the hands of academic institutions with no direct involvement of prospective manufacturers, the interdependencies and rivalries among research institutions, the structural problems caused by the five-year-plan rhythm, and the allocation of resources by GOSPLAN, the state planning committee.

[4] Yoeli in an e-mail to the author, March 12, 2005.
[5] Carr 1958 describes how this contact developed.
[6] An example of the mutual foreignness is given by an excerpt from the description of the accompanying program compiled for a visit of Soviet scientists to the US in 1959: "Slowly, but finally with enthusiasm, they [the visiting Soviet scientists] were quite impressed by the cars; if not by the number, then by the construction and design of the vehicles. Prices of the cars were asked constantly and were not readily believed when the conversation involved used car lots. It seems it would be advisable to take some other group that is coming here to a used car lot and actually show them the cars at close range with their prices" (Zaitzeff and Astrahan 1958, 11).
[7] Klimenko 1999.

Soviet visitors very probably found the structure of academic research in the USA equally difficult to comprehend, since the great variety of governmental and private actors was fundamentally different from the Soviet model. Research interests and facilities were not automatically in the hands of central organizations, but dependent on the balance of interests of the most diverse governmental, civil and military committees, private foundations in the capacity of funders, as well as universities whose interests were closely intertwined with those of commercial computer manufacturers. These problems of comprehension continue to color the contemporary reading of the publications of that time.
In regard to these exchange projects, moreover, it is difficult to retrospectively gauge the proportion of secrecy and deliberate misinformation as opposed to voluntarily disclosed basic information. Bažir I. Rameev, for example, later stated that the lack of exhaustive documentation meant that some of the data presented to visiting Americans was incomplete; nevertheless, the same information was presented as facts in the American publications.[8]

In the course of the visits exchanged in 1958-1959, scientists were shown, or received written information about, the following computer installations current at the time:

- MESM, BESM I, BESM II, STRELA I, STRELA III, URAL I, URAL II, SETUN, KIEV, M-20
- *IBM 650, IBM 705, IBM 704, IBM 7090, TX-0, TX-2, MARK I, MARK IV, UNIVAC I, BENDIX G-5, SEAC, NORC*[9]

Therefore, by the early 1960s, if indeed not earlier, either side disposed over basic information about the other side's projects. An official exchange program endorsed by the National Research Council in 1959 led to further exchange projects in the ensuing years.

If the visits exchanged in 1958/1959 had given Eastern and Western scientists basic insight into the research progress made by the opposite side, then the subsequent meetings were more geared toward specialized research interests. Public documentation regarding the early computing technology of the 1940s and '50s was comparatively sparse, and the knowledge of certain developments was strongly focused on the achievements of specific individuals. As electronic computing technology shook off its experimental character, so knowledge became more generally accessible through publications. Face-to-face meetings became less necessary, therefore, once information began to be distributed over the translation and study of the printed sources. In the USA, for example, the RAND Corporation[10] think tank established the field of "Soviet

---

[8] Smirnov 2005.
[9] This listing concerns those computers which were viewed in the course of exchange visits. The visitors also discussed many other computers that were already completed or still in development, or swapped information material.
[10] The industrialist Donald Douglas approached the US Air Force in January 1946 with a plan for joint industry-government coordination – in short, a think tank. Project RAND (coined by Arthur Raymond from *R*esearch *an*d *d*evelopment) was originally founded with Douglas Aviation. On May 14, 1948

Studies" and in the period 1963-74 regularly published material on "Soviet Cybernetics," among other subjects.[11] The journal *Soviet Cybernetics Review* was dedicated to the goal of "disseminating to a wide range of specialists information about Soviet publications, activities, and new developments in computing technology, cybernetics, and scientific policy." This research field was funded by the United States Air Force as RAND-Contract No. F44620-67-C-0045. Among the authors credited in the journal's masthead was Willis H. Ware, whom RAND had dispatched to the USSR as a member of the second group of American computer scientists in 1959. Since the relevant sources were unable to be examined, no attempt can be made to describe the flow of information in the opposite direction, namely from the USA to the USSR.

Nevertheless, on both sides of the Iron Curtain this scientific exchange was politically instrumentalized with a view to exploiting the academic contacts for social-ideological purposes. One of the many related publications can be singled out as an example: the so-called Kaysen Report[12] drawn up under Dr. Carl Kaysen (Princeton Institute for Advanced Studies/MIT) on behalf of the US National Research Council (NRC) in 1977. Based on interviews with a broad range of American research institutions and individuals involved in the exchange program, this "Review of US – USSR Interacademy Exchanges and Relations" aimed to reflect upon developments to date and in this light make recommendations for future NRC funding policies. The study stated as the program's initial objective the desire to become acquainted with the relevant Soviet individuals and institutions, by which means it was hoped to rule out in the future surprises such as that recently induced by the unexpected launch of the first "Sputnik" satellite. This goal was subsequently widened to include the aspect of "relieving tension" between the two antagonistic systems. Interestingly, the Kaysen Report served Günther Kröber, a corresponding member of the GDR Academy of Sciences, as starting material for a lecture in which he discussed the desirable level of contact between the GDR Academy and the US National Academy of Sciences: "No absolute threshold exists for scientific cooperation with capitalist countries. The pace of development must always remain below that of the growth of Communist knowledge potential. Compliance with this dynamic ratio creates essential security warranties for Communist society."[13]

Project RAND separated from Douglas and became an independent, nonprofit organization. Some ten years later, following the Sputnik shock, the think tank established the special field of Soviet Studies. "In a real sense, Soviet studies were invented at RAND" (Jonathan D. Pollack). Material relating to the social, sociological, political and scientific life of the Soviet Union was collected from various sources (unclassified documents, news sources, intelligence services, etc.) and examined by the department, then supplied in public or classified publications to a variety of readers in the USA and the Western world. The goal was to better understand recent Soviet developments and to enable decision-makers to react swiftly.

[11] Edited by Holland B. Wade (http://www.rand.org/pubs/authors/h/holland_wade_b.html).

[12] National Research Council 1977.

[13] Kröber 1979.

Historical Excursion II: The Sputnik Shock and the US Research Landscape

The chronological proximity between the Soviet Union's launch of the Sputnik satellite on October 4, 1957 and the subsequent beginnings of scientific exchange is evident. The shocked reaction of the USA to the Sputnik launch clearly influenced the way in which US scientific publications perceived Soviet computers, among them the SETUN, in the 1950s.

The Soviet Union owed its early success to developments which may be seen as rooted in Stalin's totalitarian implementation of Marxist-Leninist doctrines. In order to satisfy an interpretation of Marx whereby the emergence of Communism presupposed the existence of a proletariat, the Soviet Union was subjected to a program of "catching-up industrialization." The creation of kolkhozes and the establishment of heavy industry within the framework of five-year plans cost many people their lives during the 1920s and '30s, but did indeed lead to long-term economical and technological development discernible as "progress."

Within the bounds of this ideology of progress, science and technology were assigned high priority in solving the "problems of mankind." Moreover, the concentration on producing graduates in the natural sciences resulted (although interrupted by World War II) in a large number of outstanding specialists. The USSR entered into a permanent systemic competition with the capitalist countries in order to demonstrate the supremacy of its own social model, resulting in a pronounced concentration of strength in the area of R&D. Since especially military researchers worked in isolation from the realities of production processes and paid little heed to follow-up costs, brute-force solutions received priority, making it possible to deploy relatively large amounts of human and material resources. In the case of Sputnik, the abundant resources even compensated for the usual delays and setbacks induced by the somewhat inflexible system of five-year plans.[14]

The scientific landscape in the USA was far more segmented than in Europe (or the USSR). Not until 1941, in the aftermath of Pearl Harbor and the USA's entry into World War II, did the idea of supporting the research sector with taxation revenue win general acceptance. Before then the geographically isolated USA had felt "disconnected" from European military campaigns.[15] A first sign of an altered policy was the Manhattan Project, under which the American nuclear bomb was constructed from 1942 onward. In regard to rocket science, however, the US Navy, Army, and Air Force were in disagreement and pursued separate projects. Moreover, the military underestimated factual developments in the Soviet Union and refused to take seriously Soviet statements

---

[14] McDougall, 1985, 64f.

[15].McDougall 1985, 76f.

about the imminent satellite launch in the framework of the “International Geophysical Year” (IGY) in 1957/58.

Writing in 1985, historian Walter A. McDougall recapitulated the post-Sputnik situation as follows: “No event since Pearl Harbor set off such repercussions in public life.”[16] The American public was dumbfounded that the Russians, of all nations, should be the first to successfully send a satellite into space. The launch of the Sputnik mounted on a ballistic missile also implied that the Soviet Union had the ability to fire nuclear warheads directly onto US territory. Before then it had been necessary to fly a bomber over enemy territory and eject the bomb over the target zone. Although parts of the military were aware of the importance of a space program and expected America to complete its own satellite in the near future (Project Vanguard - launch planned for November 1957), the general public – and also scientists, the military and the government – were overwhelmed.“ There was a sudden crisis of confidence in American technology, values, politics and in the military. Science, technology, and engineering were totally reworked and massively funded in the shadow of Sputnik.”[17]

The intention of closing the technological and military gap between the rival powers[18] underlay John F. Kennedy’s announcement of the “man on the moon” program to the US Congress on May 25, 1961: “I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish.” This announcement heralded a general surge in technological research in the USA[19] that eventually led not only to space travel but also to technologies like the multimedia computer, the Internet or the Global Positioning System. It is clear that the impact of the SETUN on Western scientists was not comparable with that of the Sputnik, and to the best of our knowledge the SETUN was used primarily for civil research purposes. In view of the vast impact of the Sputnik, however, it may be assumed that the mere fact of the SETUN’s existence triggered, or at least encouraged, the related research endeavors in the West.

---

[16] McDougall 1985, 142.
[17] Dickson 2003, 4.
[18] Walter McDougall argues that there was never really a gap, and that the perceived margin was the result of successful Soviet propaganda in conjunction with the fortunate timing of the Soviet space program (McDougall 1985).
[19] Paul Dickson describes how the “man on the moon” program changed US society’s attitude towards science in the 1960s (Dickson 2003, 225–31: “Upgrading the three *R*s”).

2. Information Gathering

In order to explore the way in which information on the SETUN was disseminated in the West (USA, Canada, Great Britain, Israel and Japan), texts with direct references to SETUN and/or its constructors were sought. The articles examined were found via the Columbia University Library[20] and the Compendex Catalogue[21] either by cross-references or with one of the following keywords:

- three-valued logic
- ternary/trinary
- base-3
- TERNAC
- SETUN
- Brusenzov, Brusentsov

The analysis covers a period of more than 20 years beginning in 1958 and takes into account documents published in the USA by US-American, Canadian, British, Israeli, Japanese, Argentine, and Indian authors. Of the articles found with the above keywords, 44 were still available in libraries, whereas 57 were unable to be traced for various reasons.[22] Disregarding indirect allusions to the SETUN,[23] references to the SETUN by name and direct references to three different sources containing descriptions of the SETUN were found in 13 of these 44 documents. These references refer basically to three different instances:

1. Two groups of American scientists visited the Soviet computing centers in 1958/1959 and actually saw the SETUN. Their published reports were widely disseminated in the US in the ensuing years (Robertson et al. 1959, Ware et al. 1960).
2. A summary on Soviet computing technology compiled by Rudins in 1970 likewise derived its information from Robertson 1959 and Ware 1960.
3. Several articles by Brusenzov and his co-developers originally published in the USSR or other Eastern Bloc countries were eventually procured and translated into English. Some scientists personally translated from the Russian; other articles appeared in English-language scientific periodicals as translated reprints of articles.

[20] http://www.columbia.edu/cu/lweb/index.html

[21] Compendex is one of the most comprehensive bibliographic databases of engineering research currently available, containing over eight million references and abstracts taken from over 5,000 engineering journals, conferences and technical reports (http://www.engineeringvillage2.org).

[22] For a complete compilation of all examined texts see the appendix. In the case of some documents, the sources stated in original texts could not be traced in databases or libraries. It may be assumed that the sources still exist, but limited time prevented further research in potentially accessible databases. The origins of several other documents could be clarified, but the documents could not be procured for time, pecuniary or administrative reasons.

[23] "Indirect" reference signifies the citation of a third document in which SETUN is referred to by name. From a rough review of these sources, it may be assumed that most of the documents contain at least one indirect reference to a text in which the SETUN is named.

In order to convey an impression of how the SETUN was depicted in academic US publications in the period 1958-1978, all 13 direct references are cited below, together with a description of their context. As well as the specific texts, the authors are named together with their institutional background. Comments are added where necessary.

3. Sources and Commentary

The first report that a ternary computer existed in the USSR appeared in an article entitled "A Visit to Computation Centers in the Soviet Union" by John W. Carr III, R. Norman Scott, Alan J. Perlis, and James E. Robertson, published in *Communications of the ACM* in June 1959. Several more references to the SETUN elsewhere in the text indicate that the compiled material was also used for seminars and public lectures, so that it may be assumed that the information was widely disseminated.[24] Three of the thirteen investigated documents which name the SETUN refer to this article.

Author	Affiliation
Carr III, John W.	Research Computation Center, University of Michigan
Scott, R. Norman	University of Michigan
Perlis, Alan J.	Carnegie Institute of Technology
Robertson, James E.	University of Illinois[25]

Although the visitors to the Soviet computing centers viewed the SETUN and other Russian computers at first hand, the report does not mention Brusenzov by name, and it remains unclear whether they met him in person. Primarily a technical description, the article offers little clue to the reasons for the construction of the SETUN, stating "dissatisfaction with the STRELA," a vacuum-tube-based machine constructed during the same period at Moscow State University, as the main motivation behind SETUN's development. Unfortunately, no attempt is made to explain Brusenzov's decision to use three-valued logic. It should further be mentioned that the SETUN was still under construction at the time of the visit.

As the writers were describing the first official visit paid by American computer scientists to Soviet computer centers, they opened with a fairly detailed description of the overall conditions under which the visit took place.

> "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. […] They talked with Russian and Ukrainian computer mathematicians and engineers working on comparable problems and were given very complete guided tours […].
>
> 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" x 3" x 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

---

[24] The article is often referred as "Carr 1959," pointing to John Carr's role as editor. Since James Robertson actually delivered the description of SETUN, the reference used in this study is "Robertson 1959."

[25] Prof. James E. Robertson (1942-1999), an electrical engineer and specialist in error-checking systems, pioneered basic techniques of efficient binary division (now known as SRT). The computers IBM 650 and ILLIAC were in use at the University of Illinois at that time.

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 block 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 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.

[…]

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."

(Robertson in Carr 1959)

In 1959, merely eight months later, a second group of US scientists viewed computing installations at several sites in the USSR (a return visit had been paid by Soviet scientists in the interim period).[26] The SETUN, which Brusenzov and his crew had brought to completion in December 1958, was shown once again, and Brusenzov was mentioned by name in the resultant publication. Remarkably, nobody who subsequently cited this document credited Brusenzov as the constructor of the SETUN or the originator of the idea of using ternary logic. The article by Ware (ed.), Alexander, Armer, Astrahan, Bers, Goode, Huskey, and Rubinoff appeared under the title "Soviet Computer Technology"

---

[26] Zaitzeff and Astrahan 1958.

in *Communications of the ACM* in March 1959, and subsequently in *IRE Transactions on Electronic Computer* (March 1960), as RAND Corp. report file RM-2541 (March 1960), and in *Bulletin Provisional International Computation Center* (July-October 1960).

Author	Affiliation
Ware, Willis. H.	RAND Corp.
Alexander, Samuel N.	National Bureau of Standards, United States
Armer, Paul	RAND Corp.
Astrahan, Morton M.	IBM
Bers, Lipman	Institute of Mathematics, New York University
Goode, H.H	University of Michigan, Bendix System Division
Huskey, H.D.	University of California
Rubinoff, M.	Philco Corp.

"Thursday, May 21 [1959]

The rest of the group [W. H. Ware (ed.), M. M. Astrahan, S. M. Alexander, P. Armer, L. Bers, H. D. Huskey] visited the Lomonosov Campus of the Moscow State University and its computing center. The work of this computing center was discussed and the STRELA and SETUN installations were visited and described. We met or spoke with the following:
Academician S. L. Sobolev, Head, Computing Chair, MSU […]
N. P. Brusenzov, Chief engineer of the SETUN machine

[…]

SETUN

This base-3 machine being constructed at Moscow State University appeared to be in operation when we saw it (fig. 16). It was explained that the choice of base-3 was made because it can be shown that in some sense a base of 3 provides the most efficient utilization of equipment. [Footnote missing.] Since a base-3 electronic technique is not available, they decided to construct a base-4 machine and to utilize only 3 of the 4 possible states. The unused 4th state in each case is available for some form of checking. This machine is regarded as experimental, and as an educational training program for engineers. In part they felt that SETUN was a protest against the huge, complicated machines being built elsewhere. It was thought easier to operate a simple machine at their center. The machine contains 4,000 magnetic cores, 4,000 germanium diodes, approximately 100 transistors, and 40 vacuum tubes. It operates at a 200-kilocycle clock rate. It uses 1 MC transistors, which are rated at 150 milliwatts dissipation at 25 degrees centigrade, but can tolerate a maximum of 100 degree centigrade.
SETUN has only 81 words of storage and 27 different instructions. It is a single-address, fixed-point machine, with 18 ternary digits per word. The point is fixed between the second and third digits from the left. It is serial and contains two instructions per word. There is no divide instruction.
The ferrite core store can be regarded as having 162 9-digit words because the half-words can be addressed. The drum store contains 2,268 half words. Number representation of SETUN requires 2

binary digits per base-3 digit; therefore a 9-digit, base-3 word, will require 18 tracks on the drum. There are three such groups of 18 tracks on the drum, or a total of 54 heads. In each band of 18 tracks there are 756 words recorded in parallel; there are thus 756 bits around the 13-inch circumference. It is planned to add magnetic tapes to this machine at some later date.

Addition time is 180 microseconds, including all accesses. Fetching of the next instruction is overlapped with the execution of the previous one. Multiplication time is 335 microseconds, and transfer of control is 100 microseconds. SETUN includes a normalizing instruction (shifting operations to facilitate programming of floating-point), one index register, and teletype input and output. The German type RFT teleprinter is partially base-9 and partially base-3. A 9-digit word is printed as two base-9 digits, then one base-3 digit, then two more base-9 digits. The characters used are:

Base-9: ᔭ, Ʒ, Ƨ, Ɩ, 0, 1, 2, 3, 4
Base-3: i,0,1

Five-level punched paper tape is used for the input and output."
(Ware et al. 1960)

The above description is more detailed than that offered in Robertson 1959, and it may be assumed that Ware et al. used the previous account to complete and verify their own publication. Additional information is now offered on the context of SETUN: "This machine is regarded as experimental, and as an educational training program for engineers. In part they felt that SETUN was a protest against the huge, complicated machines being built elsewhere" (Ware et. al. 1960). The previous article's direct comparison with the STRELA has now been replaced by a more general allusion to "complicated machines elsewhere." The statement is not attributed to any one author. Once again, no answer was given to the question why Brusenzov decided to use ternary logic.

The next article able to be traced was published two years later, in 1961, and dealt with the research findings of Hallworth and Heath of the University of Manchester. The authors were working on "Semiconductor Circuits for Ternary Logic," and although the SETUN was not named directly, a clear reference was made to Robertson 1959.

Author	Affiliation
Hallworth, R. P.	IBM British Laboratories, former Member of Faculty of Technology, University of Manchester
Heath, F. G.	Faculty of Technology, University of Manchester

"Interest has increased recently in non-binary switching theory, because certain advantages may be obtained by using a radix higher than 2 in digital computers [Robertson 1959] as well as digital communication systems. […] Generally in both applications binary circuits and logic have been used because of their simplicity. It can be shown, with certain assumptions, that the most efficient radix for computing is 8, which makes 3 the best integral value."
(Hallworth and Heath 1961)

R. D. Merrill was one of the most published writers in this field of research; seven publications on ternary logic were found for the period 1963-73. In regard to the SETUN, Merrill was the first to cite a source other than Robertson 1959 or Ware 1960. He referred to an article entitled "The Order Code and an Interpretative System for the SETUN Computer," which was published in 1962 by E.A. Zhogolev, the main programmer in the SETUN team.[27]

Author	Affiliation
Merrill, R. D.	Electronic Sciences Lab, Lockheed Missiles & Space Co., Palo Alto, Calif., USA

"The SETUN, a Russian stored program computer, incorporates the ternary number system in its arithmetic unit. [Zhogolev 1962] The mechanization was not wholly ternary since the control logic is binary and information is binary encoded for storage in the bulk and random access memories. Evidently the SETUN was so designed to take advantage of the relative ease of representing negative and positive numbers and the simplicity of performing round-off when using the ternary representation."
(Merrill 1965)

Merrill was the first to offer an explanation for Brusenzov's use of ternary logic: "Evidently the SETUN was so designed to take advantage of the relative ease of representing negative and positive numbers and the simplicity of performing round-off when using the ternary representation." His use of the word "evidently" makes it clear that he was expressing his own, and not Zhogolev's, viewpoint.[28] One year later, in 1966, Merrill embedded the SETUN in a wider context.

"Moreover there have been several instances reported recently where ternary logic and switching networks have found practical application. For example SETUN, a Russian stored-program computer, incorporates the ternary number system in its arithmetic unit to take advantage of the relative ease of representing negative and positive numbers and the simplicity of performing round-off in the ternary representation [Zhogolev 1962, Merrill 1965]. Also many proposed content addressable memories utilize tristable switching and memory elements to accomplish masking and associated operations [Lewin 1962]. Ternary switching theory has been proposed as a useful means

[27] "I will check my files, but seem to remember that this information came from [Antonin Svoboda] from Czechoslovakia, in this country then, who was famous at that time for his work with the application of the Chinese Remainder Theorem (modular arithmetic) to digital computing and error correcting codes. His work was given to me by Dr. Howard Aiken, then the director of Harvard University's Laboratory for Computing" (Merill, March 30, 2005). Svoboda built the first Czechoslovakian computer, named the SAPO, in 1957.
[28] Zhogolev's introduction reads: "However developed the order code of a computer may be, it provides the mathematician with a very imperfect tool to describe the computational processes. This tool can be considerably enlarged and improved with the usual methods for making programming more automatic (standard sub-routines, compiling and interpretive systems, program generators, etc.) The need for an improvement in the basic programming structure is most acute for small computers with a simple logical structure and, usually, a small set of very elementary operations. In this article we consider the first steps towards an improvement of the basic programming of the SETUN using an interpretative system which can be a basis for the future improvement of this apparatus" (Zhogolev 1962 [transl. R. Feinstein]).

of designing hazard-free binary gating, and series parallel contact networks [Eichelberger 1965, Yoeli and Rinen 1964]. NASA has actively supported the development of tristable fluid logic devices for hydraulic switching systems [Reader and Quigley 1963/63]. Still another area is the use of ternary logic redundancy in binary networks to improve operating reliability [Varshavsky 1964]."
(Merrill 1966)

Merrill's survey showed how research into ternary logic and computation had broadened from 1958 onward. Writing in 1968, Yoeli and Halpern described a similar development:

Author	Affiliation
Yoeli M.	Faculty of Electrical Engineering, Technion, Haifa, Israel
Halpern, I.	Faculty of Electrical Engineering, Technion, Haifa, Israel

"Only recently, considerable interest in non binary, and especially ternary, switching circuits has arisen owing to the potential advantages of ternary over binary systems. […] The Russian computer SETUN [Brusenzov 1962, Brusenzov 1965] is an interesting experiment of a digital computer, which uses a symmetric ternary number representation. This number representation has many advantages, which are discussed in the sequel. However, whereas the SETUN uses magnetic circuitry in its arithmetic unit, this paper proposes a ternary arithmetic unit which supplies present-day diode-transistor circuitry. Detailed circuit realization, and logic diagrams of ternary gates, of a 3-stable element, and of a full adder are developed. From these modules, a complete ternary arithmetic unit can be simply constructed."
(Yoeli and Halpern 1968)

Yoeli and Halpern were the first to quote directly from articles written by Brusenzov.[29] Describing the SETUN as an "interesting experiment," they presented their own project – the TERNAC – as a technically logical advancement. Their description of the progress made with their own ternary design suggests that they were close to implementation.

In his article "Three-valued digital systems," D. I. Porat refers to Robertson 1959 without naming the SETUN, and instead talks generally of the existence of a "ternary computer." As was the case in many other articles too, the purpose of Porat's indirect reference to the SETUN is to underscore the relevance of his own research.

Author	Affiliation
Porat, D. I.	Stanford University, Calif., USA, formerly of University of Manchester, UK

"Digital equipment design is based on the binary-number system because of the availability, low cost and reliability of binary switching and storage elements. Higher radix systems are

[29] Michael Yoeli writes in an email to the author: "I don't remember how I came across the references you mention…" (Yoeli, March 2, 2005). In regard to his knowledge of Russian, he later stated: "I did take a beginners' course in Scientific Russian, but did not make much progress" (Yoeli, March 18, 2005).

implemented by use of binary coding; however, at least one ternary computer [Robertson 1959] has been in operation which incorporates 3-valued elements."
(Porat 1969)

Author	Affiliation
Rudins, George	Rand Corp

George Rudins delivered a short summary relating to the SETUN in "Soviet computers: a historical survey," an article published in RAND's *Soviet Cybernetics Review* in January 1970. Astonishing is the fact that Rudins, who was also managing editor of the journal in which the article appeared, omitted to state sources for his article.

"The first Soviet computer with alphanumeric I/O capabilities, the Setun', was developed in 1958 as part of a graduate student project at Moscow State university; N. Brusenzov, who worked on the Strela with Basilevskij, was also involved in this project. The Setun' was capable of performing 4000 opns/sec (1-address), and had 81-18-bit words of core store. It was the world's only computer to ever use base-3 logic. According to the Soviets, base-3 logic was supposed to provide the most efficient utilization of hardware. Since base-3 electronic technique is nonexistent, they decided to construct a base-4 machine and to utilize only three of the four possible states. Although the entire project was regarded as an educational training program for engineers, an attempt was made to serially produce it, but it failed miserably – base-3 logic turned out to be highly impractical."
(Rudins 1970)

The information now available makes it clear that Rudins' summary included erroneous and incomplete information: Contrary to what the article implies, Brusenzov did not work with Basilevsky on the STRELA computer. The STRELA was constructed under Basilevsky at the SKB-245 special design office in the SAM plant in Moscow, which was affiliated with the Ministry of Mechanical Engineering and Instrument Building. Later it was moved to the MSU Computing Center. Brusenzov's laboratory was integrated in the Computing Center of Lomonossov Moscow State University, but Brusenzov worked in the electro-engineering department, not in Basilevsky's department.
Rudins further mentions that an "attempt" was made to serially produce the SETUN but "failed miserably." Here again, the information was inaccurate. It is true that no *mass* production of the SETUN came about – for instance, a plan to produce some thousand units annually at the *Zbrojovka Jan Šverma* factory in Brno, Czechoslovakia, was turned down by the Soviet authorities, who were unwilling to see the profits going to the Czechs(Brusenzov in Rjumanzev 2004). However, *series* production of the SETUN began at the Kazan Mathematical Machines plant[30] in November 1961, resulting in the distribution of 50 computers to various locations in the Soviet Union (Malinovski

[30] Kazansk Mathematical Machines Factory (now ICL), 34 Sibirsky Trakt, 420029 Kazan (http://www.icl.kazan.ru/eng/activities/production/background/).

1995).[31] Seen in this context, Rudin's conclusion that "base-3 logic turned out to be highly impractical" was clearly flawed, or even misleading.[32]

Gideon Frieder started to work on the TERNAC in the early 1970s. His goal was to create a ternary computer that would enable ternary logic and arithmetic to be evaluated against binary logic. The TERNAC was designed not as hardware but as a software *emulation*, written in FORTRAN-IV, of a ternary computer.[33] Frieder cited Ware 1960 as the source of his information about the SETUN.

Author	Affiliation
Frieder, Gideon	State University of New York, Buffalo, USA
Luk, C	State University of New York, Buffalo, USA

> "There seems to be quite an abundance of hardware units built for ternary computers, including adders, multipliers etc. [Dept. of EE, 1971]. Furthermore, a ternary computer was built in the University of Moscow in the late 50's [Ware et al. 1959]. These existing devices illustrate exactly the problem to which we referred in the previous passage; they employ base-3 arithmetic without any reference at all to how such arithmetic should be applied. Although ternary systems were known for a while, and in particular balanced ternary was looked into [Knuth, 1969, vol. 2, pp.173-176], there is, to the best of my knowledge, no a priori attempt in those systems to decide if arithmetic should be implemented in balanced or regular ternary."
> (Frieder and Luk 1972)

In 1974 a "Summary of the Development of Multiple-Valued Logic as Related to Computer Science" was presented by Gideon Frieder, G. Epstein and D. C. Rine at the Symposium on Multiple-Valued Logic. The authors cited two original-language sources in regard to the SETUN. For the first time, Again 1960[34] was cited as a source, and reference was also made to Zhogolev 1962, the article first cited in Merrill 1965.[35]

Author	Affiliation
Frieder, Gideon	IBM Israel
Epstein, G.	Indiana University
Rine, D. C.	Department of Statistics and Computer Science, West Virginia University, Morgantown, USA

---

[31] For comparative purposes: DEC produced 50 fully transistorized PDP-1 units in the period 1961-1964 (Ceruzzi 1998, 128).

[32] For further information on the Soviet computer technology industry and the state system of planning and strategy, see Klimenko 1999.

[33] "There was also a MIL (Microcode Implementation Language) version for the Burroughs B1700. Inasmuch as the Burroughs limited the availability of MIL to a very small number of laboratories, and the B1700 was not readily available as an emulating machine, the Fortran-IV version seemed to be essential for wide evaluation purposes" (Frieder, July 12, 2005).

[34] I was able to trace one article by Again of 1960, but it does not directly address SETUN.

[35] See also Appendix A.

> "The earliest document seriously proposing a full scale ternary computer was written in 1952 by Grosch [Grosch 1952]. It advocated the implementation of a balanced ternary (digits –1,0,1; radix 3) arithmetic unit for the Whirlwind II computer which was then in design.
> The first full scale implementation of a ternary computer called SETUN was completed in 1958 at Moscow State University [Again 1960, Zhogolev 1962]. Restricted by poor hardware reliability and inadequate software, there was no extensive attempt to use SETUN for critical comparison of binary and ternary computers in the area of arithmetic."
> (Frieder, Epstein, and Rine 1974)

An interesting shift of emphasis is revealed by the authors' depiction of the historical context in which ternary logic and computing technology developed. By mentioning that Grosch presented his deliberations on ternary logic for the WHIRLWIND computer in 1952, the information that even before 1958 somebody was at least thinking about ternary computing was set off against the undeniable fact that the SETUN was the first ternary computer. Evidently, with the Sputnik shock of 1957 still prominently in the background, the question of who was "first" received high priority.

Frieder, Epstein, and Rine further stated that the SETUN was "restricted by poor hardware reliability and inadequate software." This was not the case – or not if one grants credibility to Brusenzov, who stressed the high reliability of the SETUN (90 percent usage time) compared with other Soviet computers of the period. The grave war damage on Soviet territory meant that computer development in the USSR did not reach the level of that in the USA until at least the mid-1950s. The account given by Frieder, Epstein and Rine is partly explainable by the fact that they were describing developments of 15 years previously. However, the SETUN was never intended for use in comparing binary and ternary arithmetic, and the authors' suggestion to the contrary is indicative of an attempt to justify their own research interests.

Zvonko. G. Vranesic, who authored the next article, was one of the most widely published authors in the field of ternary logic.[36] At the time of writing he was involved in research at the University of Toronto. Although his first traceable article on the subject was published in 1971, he first referred to the SETUN in 1974, three years later. Mentioning SETUN by name, he did not cite the previously known sources but revealed the existence of an article, written in Russian, published in the *Moscow State University Vestnik* (1962).[37]

Author	Affiliation
Vranesic, Z. G.	Department of Electrical Engineering and Computer Science,

[36] See Appendix A.
[37] "I don't remember where I found the reference to Brusenzov's paper, but I got a copy of it through the University of Toronto library. The paper was in Russian, which I can read because I grew up in Croatia (which was then a part of Yugoslavia) and had to take Russian as a required foreign language. The paper was interesting only as one of the first attempts to build a non-binary computer" (Vranesic, e-mail of March 14, 2005).

	University of Toronto, Ontario, CA
Smith, K. C.	Department of Electrical Engineering and Computer Science, University of Toronto, Ontario, CA

> "Some of the early attempts concentrated on the development of basic devices which were essentially non-binary in nature. Such was the case of the Rutz transistor [Kaniel 1973], the parametron [Schauer, Steward, Pohm, and Reid 1960], multi-aperture square loop ferrite devices, etc. [Anderson and Dietmeyer, 1963]. Magnetic cores received special attention [Ivaskiv 1971; Santos, Arango, and Pascual 1965] and even became a key building block in the SETUN computer [Brusenzov, Zhogolev, Verigin, Maslov, and Tishulina 1962]. Eventually these attempts gave way to the approach of utilizing readily available binary components for construction of circuits which exhibit multi-valued behavior."
> (Vranesic and Smith 1974)

It was not possible to establish the source of Rath's knowledge of the SETUN. At the end of his article he cited as general references Hallworth and Heath (1961), Merrill (1966), Porat (1969), and Yoeli and Halpern (1968); these sources all contain references to the SETUN and in some cases briefly describe the computer.

Author	Affiliation
Rath, Shri Sudarsan	Department of Electrical Engineering, Regional Engineering College, Rourkela, Orissa, India

> "Ternary means an element of a switching system which will perform 3-valued transmission and 3-valued switching. The Russian computer SETUN is an interesting experiment in digital computation. It uses 3-valued devices and follows a symmetric ternary system of logic states 1,0,-1."
> (Rath 1975)

In 1977 Epstein, Frieder, and Rine contributed to the book *Computer Science and Multiple-Valued logic, theory and applications*, edited by D. C. Rine, a chapter on the "Development of Multiple-valued Logic as Related to Computer Science."

Author	Affiliation
Frieder, Gideon	IBM Israel
Epstein, G.	Indiana University
Rine, D. C.	Department of Statistics and Computer Science, West Virginia University, Morgantown, USA

> "Ternary systems for computation were discussed in 1840 [Cauchy 1840, Lalanne 1840]. By 1950, there were ternary devices widely enough known to be included in a review book [Epstein and Horn 1974]. However, it was not until 1958 that the first full scale ternary computer was completed at Moscow State University [Again 1960, Brusenzov 1960, Robertson et. al. 1959, Zhogolev 1962] although ternary computers where proposed as early as 1952 [Grosch 1952]. While this encouraged work on subsystems such as arithmetic units in Canada [Vranesic and Hamacher 1971], Japan [?], Switzerland [Haberlin and Müller 1970], and Israel [Yoeli and Halpern 1968], the

low-level programming language devised for this Russian computer was so difficult to use that there was little insight into 3-valued logic by users.

[…]

The earliest document seriously proposing a full scale ternary computer was written in 1952 by Grosch. It advocated the implementation of a balanced ternary (digits –1, 0, +1) arithmetic until for the Whirlwind II computer which was then in design. However, there was no discussion in this document of algebraic or logic operations.
In the late 1950's the first full scale implementation of a ternary computer as undertaken by a Russian team at the Computing Centre of Moscow State University. This computer, completed in 1958 and named SETUN, was briefly described by Carr et al. [Robertson and Carr 1959] in a 1959 survey of Russian computers. It was used for some time but both poor hardware reliability and inadequate software hampered its usage [Zhogolev 1962]. Additional details may be found in [Again 1960, Brusenzov 1960].

The SETUN computer was a fixed-point arithmetic computer with words of 18 ternary units (trits) in length. There were two trits to the left of the fixed-point rather than one. The memory consisted of a core storage unit of 81 words and a magnetic drum unit of 1944 words.
The representation of a trit in flip-flops or the core storage unit was accomplished through the use of two coupled cores, which provided three stable states. The hysteresis loops for these coupled cores did not allow four stable states. The representation of trits on the magnetic drum or input/output tapes was through binary-coded ternary on two stacks, hence wasting a single binary digit (bit) of information per trit. This waste was compounded through the use of a ternary-decimal (a further waste of 17 bits of information per decimal).
The SETUN was an arithmetic machine. The only logic operation it had was digit-by-digit conjunction (logical multiply). It was therefore completely unsuitable for any evaluation of ternary logical operations. Yet there was no extensive attempt to use it for critical comparison of binary and ternary computers with respect to arithmetic operations.

However, the SETUN computer awakened interest in subsystems such as arithmetic units [Haberlin and Müller 1970; Yoeli and Halpern 1968; Vranesic and Hamacher 1971; Mine et. al. 1971] and numerous electronic modules as cited in an abridgement of the bibliography for Thelliez' doctoral thesis [Thelliez 1973]."
(Epstein, Frieder, and Rine in Rine 1977)

Here the SETUN is allocated more space than in the 1974 summary. Interesting is the authors' conclusion that the SETUN had roused interest in further research into ternary computers.

Wide access to integrated circuits from the late 1970s onward meant that the use of transistors as base components for computers was discontinued.

Why “Western” Research Stopped.

Examination of the sources naturally leads to the question of why research interest in ternary computing tailed off after a period of 20 years. The following two questions were e-mailed to several important authors: “Do you remember where you found out about the existence of SETUN?”; “Why did you stop your research into ternary computing or ternary arithmetic?“

Michael Yoeli, who was involved in research into ternary logic at the Technion in Haifa in the 1960s, delivered the following comment upon developments at that time and the influence of SETUN from a contemporary perspective:

> “We were attracted by the general idea of ternary computing. However, the problem is to design the relevant hardware, in such a way that the ternary computer becomes competitive with available binary computers. SETUN was an effort to deal with this problem, but there is no doubt that this effort failed and the idea of the SETUN was indeed eventually abandoned. At the time the SETUN was built in Moscow, computer hardware technology was just in its beginning. However, even more advanced technologies do not offer a reasonable challenge. Our computing unit was just a design on paper, but no effort was made to implement this idea. From a software viewpoint the idea of ternary computing is indeed attractive, and the SETUN was an important contribution to this idea.”[38]

Thus, Yoeli states the success of binary memory units as the main reason why efforts to actually implement the theory of ternary logic in real applications, i.e. ternary microchips, were unattractive and unable to obtain funding.

Roy D. Merrill, who was associated with the Lockheed Missiles and Space Corp Research Lab in the 1960s, takes a different stance:

> “We [Lockheed Missiles and Space Corp] had a contract with the Air Force to explore a number of areas that might enable the computer designer to devise means of making the computer operate faster and with less complexity. […] We researched Residue Arithmetic because addition, subtraction and multiplication arithmetic operations could be carried out without waiting for the carry bit. We researched ternary arithmetic because it could possibly have helped ease the complexity of the logical design. Neither proved to be successful for other than very special applications.”[39]

Zvonko Vranesic, who worked in the Department of Electrical Engineering and Computer Science at the University of Toronto in the early 1970s, writes about the advantages and disadvantages of ternary logic:

---

[38] Yoeli, e-mail of March 12, 2005.
[39] Merrill, e-mail of April 26, 2005.

> "Ternary logic has some useful arithmetic properties, such as allowing the balanced representation of numbers. Its main drawback is that there do not exist any practical implementations of ternary storage circuits. Thus, if one has to use binary storage devices, it is clear that it makes more sense to try 4-valued logic circuits which can interface to the binary memory more efficiently."[40]

And he further explains:

> "The reason why storage devices are binary is that it is easy to use transistors as simple switches that have two states, OPEN and CLOSED, which can be interpreted as 1 and 0. There are no simple elements that can be implemented using the Integrated Circuit technology which would naturally exhibit 3 states."[41]

His explanation correlates with the answer given by D. C. Rine, who during the 1970s researched at the Department of Statistics and Computer Science of West Virginia University in Morgantown, USA. Rine states that his interest in multi-valued logic (of which 3-valued logic is a subset) was linked to the general development of microprocessors. In the 1970s companies including IBM, Motorola, and National Semiconductors started to explore the combination of 2-state logic with 4-state logic in microprocessors to improve speed and memory capacity. Applying to engineering processes the purely scientific findings relating to multi-valued logic often proved difficult:

> "As we studied, and invented, the idea of Technology Readiness (TR) models and Technology Maturity (TM), it was discovered that there is a transition for most technologies through 9 different TM/TR stages from research ideas inception through integration into existing systems. So it took the research inception of n-state logic[42] to make its way from purely research (isolated) ideas to a maturity and readiness such that the existing computer systems technology could accept or interface with 4-state VLSI maturing technology. The very important point to observe is that an important point in time much be reached when technologies evolving from reach to more mature/ready technologies can usefully interface with current existing computer systems wide technologies. If evolving/maturing new technologies do not reach that point in an appropriate time then they will generally never be used in current/existing systems. Many interesting and novel research ideas never go beyond the phases from inception to stand along maturity, and are therefore never used in existing systems."[43]

The example of microchip development in the 1970s shows that the merging of 2-state and 4-state logic was successful. But this success also diverted researchers – Rine, for one – from further pursuing research into any n-state logic where n would be an uneven power of 2.

---

[40] Vranesic, e-mail of March 14, 2005.
[41] Vranesic, e-mail of March 17, 2005.
[42] Multi-valued logic.
[43] Rine, e-mail of March 23, 2005.

> "I turned my attention to directing PhD research dissertations using interval logics, formal methods proof systems and formal natural logic communication systems which seemed to hold more promise for my own research. And I could not see a way or a path for reaching the higher TM/TR levels with 3-state VLSI[44] logic. More recent dissertations/papers appeared in those areas."[45]

In answer to the question why research eventually stopped, Gideon Frieder, who was in charge of the development of the TERNAC emulator at the SUNY Buffalo during the 1970s, writes:

> "Essentially, we were victims to our own success. In developing the algorithms for the emulation of a balanced ternary machine on a binary host, we found that one can implement both the [ternary] arithmetic and the logic on binary hardware. So if somebody is interested in using a ternary computer, it is easy to implement it as software or microcode. The realities of Moore's law showed us that ternary hardware is not cost effective in the state of affairs in the 80s."[46]

Rine and Frieder's answers must be viewed within the general context of the 1960s. In 1956, when talks began about developing the SETUN at Moscow State University's recently established Computing Research Center, the machine that would become the SETUN was envisaged as a binary computer. However, Soviet computing technology was still in its infancy, and therefore relatively experimental.[47] With little previous experience to fall back on, many machines were built "from scratch." In the case of SETUN, a special seminar was attended by mathematicians and electrical engineers, who spent several months devising a general plan for building a calculating machine of this kind. Brusenzov, a trained radio engineer, was working in isolation from other ongoing projects (e.g. STRELA, BESM), and thus in a favorable situation to formulate a fundamentally different solution.

By the 1960s, when serious research into ternary computing began in the West, the situation was entirely different. Broad experience in the construction of binary computers and elements was available, and there existed a growing industry that was about to swap transistors for ferrite cores and vacuum tubes.[48] It was accordingly much more difficult to launch a project related to ternary computing and actually advance it far enough for a computer based on ternary logic to be built and used.

---

44 Very Large-Scale Integration: the accommodation of thousands of transistors in a small space (e.g. the microchip).
45 Rine, e-mail of March 23, 2005.
46 Frieder, e-mail of June 15, 2005.
47 This experimental phase of computing came somewhat later than in the USA because Soviet universities and factories had to be rebuilt after World War II and the death toll also affected the sciences. Brusenzov was conscripted in 1943, served as a military radio operator, and was first able to complete his schooling in 1948. He was one of a group of 25 recruits who went to war in 1943; only five of the group survived.
48 Cerruzzi 1998, 64.

In summary, the accounts indicate that research into ternary computing, ternary arithmetic, and ternary devices was motivated by:

1. general interest in ternary computing in the early, experimental years of computing;
2. the possibility of exploiting the specific qualities of a balanced ternary numbering system (-1 | 0 | 1), especially for residue arithmetic;
3. hopes of radically simplifying hardware design.

The reasons for the failure to develop a functioning ternary computer in the USA or Canada are closely linked with aspects of technology readiness and product maturity:

1. problems with designing the relevant hardware;
2. problems with translating the construction design into functioning ternary devices;
3. the competition from existing binary hard- and software;
4. the fact that research was being conducted within a highly complex and dynamical field of applications for civilian and military clients.

It becomes clear that new technologies do not emerge in an ideological, social or economic vacuum. The historical, political and specific context must be taken into account. This account traces the Russian SETUN computer's "career" through early Western computer science, and shows that the existence of the SETUN partly triggered research interest in the West or at least encouraged existing research activities. Western scientists were able to use the SETUN to justify their own research projects and as an argument to gain funding.