The first public demonstration of machine translation: the Georgetown-IBM system, 7th January 1954

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Abstract

The public demonstration of a Russian-English machine translation system in New York in January 1954 – a collaboration of IBM and Georgetown University – caused a great deal of public interest and much controversy. Although a small-scale experiment of just 250 words and six 'grammar' rules it raised expectations of automatic systems capable of high quality translation in the near future. This paper describes the background motivations, the linguistic methods, and the computational techniques of the system.

1. Introduction

On the 8th January 1954, the front pages of the *New York Times* and other major American newspapers (*New York Herald Tribune, Christian Science Monitor, Washington Herald Tribune, Los Angeles Times*) carried reports of the first public demonstration of a computer for translating languages. Reports were syndicated in many provincial newspapers, and articles about it appeared in the following months in popular magazines (*Newsweek, Science, Science News Letter, Discovery, Chemical Week, Chemical Engineering News, Electrical Engineering, Mechanical World, Computers and Automation*, etc.) It was probably the most widespread and influential publicity that machine translation (MT) has ever received,[2] and it was undoubtedly the first non-numerical application of the newly invented 'electronic brains' that most people had heard of. Translation itself was a largely unknown 'art' and the prospect of a machine capable of 'deciphering' foreign languages was exciting. The demonstration raised expectations of fast and easy international communication in a world that had already become divided by confrontations and misunderstandings between the United States and the Soviet Union.

2. The background

The first suggestions for using computers to translate natural languages were made in 1947 by Warren Weaver in conversation with Andrew Booth. In 1948 Booth collaborated with Richard Richens on the first experiments in 'mechanical translation' using punched cards in 1948. In 1949 there were newspaper reports that Harry Huskey was contemplating translation on the SWAC computer in Los Angeles. And then, in July the same year, Warren Weaver wrote the famous memorandum which stimulated the beginnings of MT research (Weaver 1949. In the following years research on machine translation began at the University of Washington (Erwin Reifler), University of California at Los Angeles (Victor Oswald, Stuart Fletcher), RAND Corporation and Massachusetts Institute of Technology (MIT). It was in 1951 at MIT that the first appointment of a MT researcher[3] was made: Yehoshua Bar-Hillel in MIT's Research Laboratory of Electronics directed by Jerome B.Wiesner. His primary task was to survey the prospects (Bar-Hillel 1951) and to promote development in the field; in particular to convene the first MT conference.

All those known to be active or interested at the time – still a very small number – were invited to the conference at MIT in June 1952 (Hutchins 1997b). At this time there had been few examples of MT in practice. There had been only the punched card simulations by Richard

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[1] This article was completed in November 2005, and further revised in March 2006. It is a much expanded version of the paper presented at the AMTA conference in September 2004 (Hutchins 2004).

[2] A list of contemporary reports is provided in Appendix I. Copies of some reports are reproduced on the Machine Translation Archive (http://www.mt-archive.info).

[3] Strictly speaking the appointment was not for MT research but to investigate potential linguistic applications of computers, among which MT was seen as the one of most interest. As Bar-Hillel himself pointed out (Bar-Hillel 1964): he "never wrote a program for MT, never collaborated with a group that designed mechanical translators, and never induced a student to write a thesis on MT."

Richens and Andrew Booth which demonstrated that morphological stem-splitting could contribute to a dictionary-based word-for-word 'translation' (at the conference Booth read the paper later published as Richens and Booth 1955), and the model of German syntactic analysis by Victor Oswald and Stuart Fletcher (1951), intended for implementation on the SWAC computer in Los Angeles developed by Harry D. Huskey[4] (mentioned briefly by Oswald in one of his presentations at the conference.) Otherwise, the conference consisted of presentations speculating about future techniques, e.g. Yehoshua Bar-Hillel on 'operational syntax' and the treatment of idioms, Erwin Reifler on post-editing and universal MT, Stuart Dodd on regularising English ('Model English'), and various papers on developments in computer design.[5]

At the close of the conference there was a discussion about the next steps. It was agreed that sources of financing had to be explored, and Duncan Harkin of the US Department of Defense believed that his department and probably other US agencies would be forthcoming with funds for projects[6]. Jerome Wiesner added that finance and assistance might also be forthcoming from the Research Laboratory of Electronics at MIT.

Leon Dostert had been invited for his experience with mechanical aids for translation. He had been Eisenhower's personal interpreter during the war (1944-1945), had been liaison officer to the French commander in Algiers, Charles de Gaulle, and had worked for the Office of Strategic Services (precursor of the Central Intelligence Agency).[7] In October 1945 he was asked to set up the interpretation system for the Nuremberg war crimes tribunal and to train the interpreters and translators required. He adopted a system of simultaneous interpretation, an innovation at the time that many thought would be unworkable, but which proved a major success.[8]. In April 1946 – while the trial was still in progress – he was invited to install a similar interpretation system at the United Nations. The equipment at both the Nuremberg trial and at the United Nations was donated by International Business Machines (IBM) – Dostert had been a friend of IBM's founder, Thomas J.Watson, since the 1930s. In 1949 he was invited to Georgetown University, where he had studied during the 1930s, to establish the Institute of Languages and Linguistics at the University's School of Foreign Service. The primary aim of the Institute was to train linguists for government service, and it pioneered the use of language laboratories. Dostert continued as its director until 1959.

Dostert admitted that he had gone to the conference as a sceptic regarding the automation of translation, but by the end he had become convinced of the real possibilities. On leaving the conference, he came to the conclusion that "rather than attempt to resolve theoretically a rather vast segment of the problem, it would be more fruitful to make an actual experiment, limited in scope but significant in terms of broader implications." (Dostert 1955). He was (and remained) a strong advocate of practical solutions and was not particularly tolerant of theoretical linguistics speculation.

In early 1953, Dostert consulted linguists and engineers and they gave him the opinion that machine translation was indeed a feasible objective;[9] so he contacted Watson at IBM and they agreed to collaborate. The project was headed by Cuthbert Hurd, head of the Applied Science Department at IBM, and by Dostert himself. At this time, IBM was only beginning to develop computers for non-military applications – the experiment was to be conducted on the "701" model launched the previous year. Programming required someone with intimate

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[4] The launch of this computer (Standards Western Automatic Computer) on 31 May 1949 was reported in the *New York Times* and the *New York Herald Tribune* with the suggestion by Huskey that the machine could be used for translation. The reports prompted a letter by Max Zeldner 13 June 1949 in the *New York Herald Tribune*, which doubted the feasibility of mechanical translation, and which Weaver cited in his 1949 memorandum. (Hutchins 1997a).

[5] Reports of the conference were given by Reynolds (1954) and Reifler (1954)

[6] As reported by Reynolds (1954)

[7] For biographical information of Dostert see Macdonald (1976), Zarechnak (1979) and Vasconcellos (2000).

[8] For a full account of Dostert and the installation of the simultaneous interpretation system see Gaiba (1998).

[9] According to Macdonald (1963: 3) a summation of these opinions was made by Paul Garvin in April 1953: "Statement of opinion concerning machine translation"

knowledge of the design and construction of specific computers. Programs were written in machine code – specifying every single operation of the central computer processing unit (CPU) in terms of binary digits. All operations had to be reduced to processes of addition, subtraction, comparison and of movement to and from specific addresses in the limited internal memory. The man chosen by IBM to do the programming was Peter Sheridan.[10]

Dostert looked for someone with the knowledge to carry out the language side of the process, since he could not expect a computer mathematician to have much knowledge of translation. For obvious political reasons Dostert decided that the demonstration should translate from Russian into English. Since the end of the War, the enemy was no longer German but Russian, and the lack of knowledge about activities in the Soviet Union was already a matter of major concern. He chose a lecturer in his Institute with a thorough knowledge of Russian and linguistics, Paul Garvin. Garvin was born in Karlovy Vary (Karlsbad), Czechoslovakia, studied in Prague and emigrated to the US in 1941. He was associate professor at the Institute, a theoretical linguist with knowledge of many languages, Russian in particular.[11]

Dostert and Garvin decided to demonstrate automatic translations on a small number of sentences from organic chemistry and a few other sentences on general topics. The aim was to illustrate some grammatical and morphological problems and to give some idea of what might be feasible in the future. The experiment was necessarily on a small scale, with a vocabulary of just 250 lexical items (stems and endings) and a limited set of just six rules.

3. Reports of the demonstration

The demonstration took place on 7th January 1954 at the New York headquarters of IBM. Reports by journalists appeared the next and following days (many on the front page) and were syndicated to numerous other newspapers throughout the United States. The demonstration was also widely reported in the foreign press. (See Appendix II.)

The newly invented computers were treated with much awe in those days. They were frequently referred to as 'giant brains' and 'robots', and so we find that typical headlines were "Electronic brain translates Russian", "The bilingual machine", "Robot brain translates Russian into King's English", and "Polyglot brainchild". Each reporter had his own slant on the proceedings but there is enough similarity and agreement in the reports for us to gain a good impression of what took place. Many reports were based on IBM's press release (IBM 1954); and many quoted it verbatim, particularly statements by Dostert and Hurd.

In all, according to most reports and the IBM press release, there were "more than sixty" sentences included in the demonstration.[12] Most of them were very short statements describing processes in organic chemistry, but there were also a few (about a dozen) longer sentences of general interest. Evidently, the demonstration began with the chemistry sentences. These were reported in most accounts:

(a) "Kachyestvo uglya opryedyelyayetsya kaloryiynostjyu", translated as "The quality of coal is determined by calory content."

(b) "Kraxmal virabativayetsya myexanyichyeskyim putyem yiz kartofyelya", translated as "Starch is produced by mechanical methods from potatoes."

A few other organic chemistry examples were also mentioned:

(c) "Zhyelyezo dobivayetsya yiz rudi xyimyicheskyim protsyessom", translated as "Iron is obtained from ore by chemical process."

(d) "Dyinamyit pryigotovlyayetsya xyimyicheskyim protsyessom yiz nyitroglyitsyeryina s pryimyesjyu yinyertnix soyedyinyenyiy", translated as "Dynamite is prepared by chemical process from nitroglycerine with admixture of inert compounds."

(e) "Obrabotka povishayet kachyestvo nyeftyi", translated as "Processing improves the quality of crude oil."

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[10] Sheridan was later a member of the team at IBM led by John Backus which developed the first 'high-level' programming language, FORTRAN.

[11] For biographical details on Garvin see Montgomery (2000) and the references there.

[12] In all cases, the Russian source sentences are given in the transliteration scheme devised by the Georgetown researchers (and also used by the Georgetown group in its later projects).

Fortunately for the journalists (who naturally had an eye on making an impact in their newspapers), the demonstration passed onto sentences of a more general interest:

> And then just to give the electronics a real workout, brief statements about politics, law, mathematics, chemistry, metallurgy, communications, and military affairs were submitted in the Soviet language... (Kenny, *Christian Science Monitor*)

Nearly all the newspapers quoted these:

> (f) "Mi pyeryedayem mislyi posryedstvom ryechi", translated as "We transmit thoughts by means of speech."
>
> (g) "Vyelyichyina ugla opryedyelyayetsya otnoshyenyiyem dlyini dugi k radyiusu", translated as "Magnitude of angle is determined by the relation of length of arc to radius."
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> (h) "Myezhdunarodnoye ponyimanyiye yavlyayetsya vazhnim faktorom v ryeshyenyiyi polyityichyeskyix voprosov", translated as "International understanding constitutes an important factor in decision of political questions."

These three sentences had been highlighted by IBM in its press release (IBM 1954). But some journalists had the initiative to record other 'general-interest' sentences:

> (i) "Dorogi stroyatsya yiz byetona", translated as "Roads are constructed from concrete"
>
> (j) "Voyenniy sud pryigovoryil syerzhanta k lyishyenyiyu grazhdanskyix prav", translated as "A military court sentenced a sergeant to deprival of civil rights."
>
> (k) "Vladyimir yavlyayetsya na rabotu pozdno utrom", translated as "Vladimir appears for work late in the morning."
>
> (l) "Komandyir poluchayet svyedyenyiya po tyelyegrafu", translated as "A commander gets information over a telegraph"

The fullest lists of translated sentences appeared in magazine articles, such as those by Neil Macdonald in the February 1954 issue of *Computers and Automation* (Macdonald 1954) and the later articles by Schweisheimer in *Mechanical World* (Schweisheimer 1955) and by Ornstein in *Science* (Ornstein 1955).[13]

Nearly all the newspapers and magazine articles gave the impression that research on mechanical translation had been in progress for some years:

> This may be the cumulation of centuries of search by scholars for "a mechanical translator." So far the system has a vocabulary of only 250 words. But there are no foreseeable limits to the number of words that the device can store or the number of languages it can be directed to translate. (Plumb, *New York Times*)
>
> The joint effort… capped more than a decade of independent research by a scattered handful of men (*Chemical Week*)
>
> A handful of men had been individually engaged in research at various institutes for almost a decade to make a machine convert the meaning of words clearly from one language to another. No practical results were achieved until Georgetown a year and a half ago enlisted the aid of the most versatile electronic 'brain' extant, the IBM 701. (*Journal of the Franklin Institute*, taken verbatim from the IBM press release)

Reference to a 'more than a decade' (or 'almost a decade') of work was derived from the IBM press release, whose writer(s) presumably had in mind the fact that MT had first been mentioned in 1947 (by Warren Weaver in a letter to Norbert Wiener, and by Weaver in conversation with Andrew Booth – see Hutchins 1997a). We must assume that this information had been given to the writer(s) of the IBM press release by Dostert (and perhaps also by Garvin). By the reference to a 'year and a half' was meant almost certainly the period since the MIT conference in June 1952 – this does not appear in the press release, but Macdonald (1954) does refer to the conference and to Dostert's consequent determination to begin a practical experiment. Apart from this, only two journalists made any references to earlier MT research: the *Science News Letter* mentioned Huskey's plans for German-English translation on the SWAC computer in Los Angeles[14], and *Chemical Engineering News* referred to James Perry's

[13] It is surprising that although apparently over sixty sentences were demonstrated the total reported in all contemporary sources was no more than twelve. It may, therefore, be possible that the demonstration was truncated for some reason.

[14] It is possible that the journalist had seen the article in *Modern Language Forum* the previous year by Oswald and Lawson (1953) which describe procedures for a micro-glossary of the German vocabulary of brain surgery, which assumed the validity of the syntactic procedures outlined by Oswald and Fletcher

paper simulation of translation from Russian, as reported in *Industrial and Engineering Chemistry* in December 1952[15]

The demonstration had a great impact. It was undoubtedly the first that most members of the general public had even heard of the idea of computers ('electronic brains') translating language. The newspaper reports from Los Angeles (May 1949) about Huskey's plans had seemingly been forgotten; and the report in a British newspaper (December 1949) on Andrew Booth's activities at Birkbeck College London (Hutchins 1997a) was obviously unknown in the United States. This time it was different – probably because the demonstration was made in New York on a new commercial machine from the already well-known firm of IBM.

The demonstration featured also in prominent European newspapers, such as *Le Monde, Financial Times, The Times, News Chronicle, Berliner Zeitung*. It was reported also in popular magazines. Andrew Booth mentioned it in a general article about MT in *Discovery* (Booth 1954) and in *Civiltà delle Macchine*, Paulo Sardi's general article on MT (Sardi 1954) included the Georgetown experiment[16] – although mistakenly attributing its design to James W.Perry instead of Dostert and Garvin.

4. Contemporary predictions and comments

All the newspaper reports repeated predictions that machine translation would be a major facilitator of international communication in the near future.

> It is expected by IBM and Georgetown University, which collaborated on this project, that within a few years there will be a number of "brains" translating all languages with equal aplomb and dispatch. (Kenny, *Christian Science Monitor*)
>
> Scholars and scientists who worked on it believe that within a few years the system may greatly increase communication, particularly in technical subjects, by making translation quick, accurate and easy. (Plumb, *New York Times*)

Reporters were impressed by the fact that the operator[17] understood no word of Russian, and most of them also by the speed at which translations were produced:

> The girl who operated 701 did not understand a word of Soviet speech and yet more than 60 Soviet sentences were given to the "brain" which translated smoothly at the rate of about 2½ lines a second. (Kenny, *Christian Science Monitor)*
>
> In the demonstration, a girl operator typed out on a keyboard the following Russian text in English characters: "Mi pyeryedayem mislyi posryedstvom ryechi". The machine printed a translation almost simultaneously: "We transmit thoughts by means of speech." The operator did not know Russian. Again she types out the meaningless (to her) Russian words: "Vyelyichyina ugla opryedyelyayetsya otnoshyenyiyem dlyini dugi k radyiusu." And the machine translated it as: "Magnitude of angle is determined by the relation of length of arc to radius." (Plumb, *New York Times*)

But they were equally impressed by the machine's potential:

> The "brain" didn't even strain its superlative versatility and flicked out its interpretation with a nonchalant attitude of assumed intellectual achievement. (Kenny, *Christian Science Monitor*)

Even if it took some time:

> For nine silent seconds the machine mulled over the message. Then its automatic typewriter pounded out the English translation. (*Newsweek*)

Many reports emphasised that input could be a bottle-neck and would slow down the production of translations:

> "…disappointingly slow. The reason was that the computer has to take time to sort through the stack of punched cards before coding the sentences…" (*Newsweek*)

Above all, the punching of texts onto cards was recognised as a major problem:

(1951). Both papers were written with Huskey's SWAC computer in mind, but it is clear that both were paper simulations with no prospect of immediate implementation. In 1954 Huskey left UCLA to teach numerical analysis and computer design at UC Berkeley. (For more details see Hutchins 1997a)

[15] For details of the article "Lingua ex machina" see Hutchins 1997a. Perry's account, given limited circulation in September 1952, was later published in the journal *Mechanical Translation* (Perry 1955).

[16] Unusually for a foreign-language article on MT at this date, Sardi was familiar with the work of most current researchers (Booth, Richens, Perry, Bar-Hillel and Oettinger)

[17] Her name was given as Miss Lynne Polle (*Brooklyn Eagle*, *Daily Mail*)

> Devices that can 'read' a printed page automatically will be needed before translations from one language to another by electronic 'brains' will be of any practical value... (*Science News Letter*)

However, it was a common assumption (shared by Dostert) that fast accurate automatic print readers (i.e. optical character readers) would appear in the very near future.

All the reports, and subsequent commentaries, emphasised the limited nature of the experiment – in particular the limitation to 250 words and six rules of syntax. Nevertheless, there was optimism about rapid development in the near future and that MT systems capable of translating almost everything would be available within five years.

> "Those in charge of this experiment," the professor continued, "now consider it to be definitely established that meaning conversion through electronic language translation is feasible." Although he emphasised it is not yet possible "to insert a Russian book at one end and come out with an English book at the other", the professor forecast that "five, perhaps three, years hence, interlingual meaning conversion by electronic process in important functional areas of several languages may well be an accomplished fact." (Kenny in *Christian Science Monitor* (1954), also cited by Schweisheimer 1955, and others, all quoting word for word from the IBM press release)

Such optimistic predictions were to become common in the MT field. There was also great optimism about the creation of systems for other language pairs. Like many others of the time it was believed that the current computers, having been developed for numerical calculations, were "over-engineered" for language applications, while at the same time equipment was needed to deal with large bodies of linguistic information (dictionaries as well as texts submitted for translation).[18] In this first demonstration of MT, it was Cuthbert Hurd, the computer specialist, who expressed the prediction that special-purpose machines would be developed:

> Dr.Hurd said that the corporation would now design a machine particularly fit for translating rather than for general computing utility. Such a device should be ready within three to five years, when the Georgetown scholars believe they can complete the "literary" end of the system.….As soon as cards for Russian are completed, sets will be made for German and French. Then other Slavic, Germanic and Romance languages can be set up at will. (Plumb, *New York Times*)

Predictions of how much work might be required to deal with larger quantities of text were remarkably optimistic. Dostert himself predicted at the demonstration that "100 rules would be needed to govern 20,000 words for free translation".[19] Presumably this sounded reasonable enough for the journalists – it was reported by nearly all of them – but how confident Dostert himself might have been with these guesses is not known.

Even more optimistic were the predictions by Earl Ubell in the *New York Herald Tribune* that:

> Eventually, the machine will be able to translate from Russian: "She taxied her plane on the apron and then went home to do housework." In such a sentence with double-meaning words, the machine will be able to tell what meaning of apron and taxi would be needed in that particular context.

There is no evidence that this was a prediction made by either Dostert or Garvin at the demonstration. Possibly some such remark was made when the researchers were describing how the system might deal with ambiguities (see below), but since this prediction occurs in no other newspaper report the likelihood is that it was the journalist's own.

Initial newspaper reports invariably followed the optimistic tone of the IBM press release (IBM 1954), but later there were more cautious comments by newspaper editors. Noteworthy is the editorial in the *Christian Science Monitor* a week later, on the 13th January:

> Such an accomplishment, of course, is far from encompassing the several hundred thousand words which constitute a language. And with all the preparations for coping with syntax, one wonders if the results will not sometimes suggest the stiffness of the

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[18] The comment was picked up by Jacob Ornstein (1955). It may have been made by either Dostert or Hurd.

[19] This prediction was not included in the IBM press release, so presumably it was given in answer to journalists at the demonstration itself.

starch mentioned in one of the sentences as being produced by mechanical methods. Nevertheless, anything which gives promise of melting some of the difficulty which writers and speakers of different languages encounter in understanding each other - particularly as between English and Russian today - is certainly welcome.

Equally sober were the observations made by Neil Macdonald in the following month (Macdonald 1954). The prospects were exciting, but progress will be slow:

> Many exciting possible developments are indicated by the success of the trial... Linguists will be able to study a language in the way that a physicist studies material in physics, with very few human prejudices and preconceptions... The technical literature of Germany, Russia, France, and the English-speaking countries will be made available to scientists of other countries as it emerges from the presses... But of course, it must be emphasized that a vast amount of work is still needed, to render mechanically translatable more languages and wider areas of a language. For 250 words and 6 syntactical structures are simply a “Kitty Hawk” flight.

The analogy to the Wright brothers’ early experiments was made by Dostert himself (in the IBM press release), as the newspapers reported:

> The experimental demonstration today can be rated only as a scientific sample, or, as Doctor Dostert neatly phrased it, “a Kitty Hawk of electronic translation.”

Very few of the reporters, however, picked up on the comments in the press release on the difficulties and problematic nature of dealing with language as opposed to applications in physics and mathematics:

> From the viewpoint of the electronic ‘brain’, the language translation also has tremendous significance. It has been learned, for instance, that the formulation of logic required to convert word meanings properly even in a small segment of two languages necessitates two and a half times as many instructions to the computer as are required to simulate the flight of a guided missile.

Those that did repeat this analogy included the anonymous reporter for the *Journal of the Franklin Institute* and Jacob Ornstein in *Science*.

5. Newspaper descriptions of the processes involved

Most of the newspaper reports are illustrated with a photograph of a punched card with a Russian sentence. The most common one was the following, which shows the card for inputting the Russian sentence “качество угля определяется калорийностью” in the Georgetown transliteration (Kachyestvo uglya opryedyelyayetsya kaloryiynostjyu). Below it is the English translation which is to be produced by the system. (“The quality of coal is determined by calory content.”) Clearly this punched card was handed out to observers of the demonstration since it includes a brief summary of the process of translation.

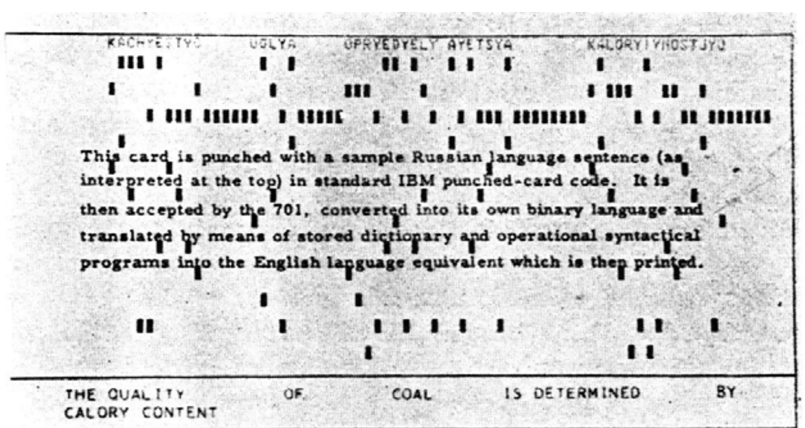

Fig. 1: example of a punched card

Nearly all the reports also included photographs of the machines and of the Georgetown and IBM personnel. This one [Fig.2] shows (left to right) Cuthbert Hurd, Leon Dostert and Thomas J.Watson at the IBM printer.

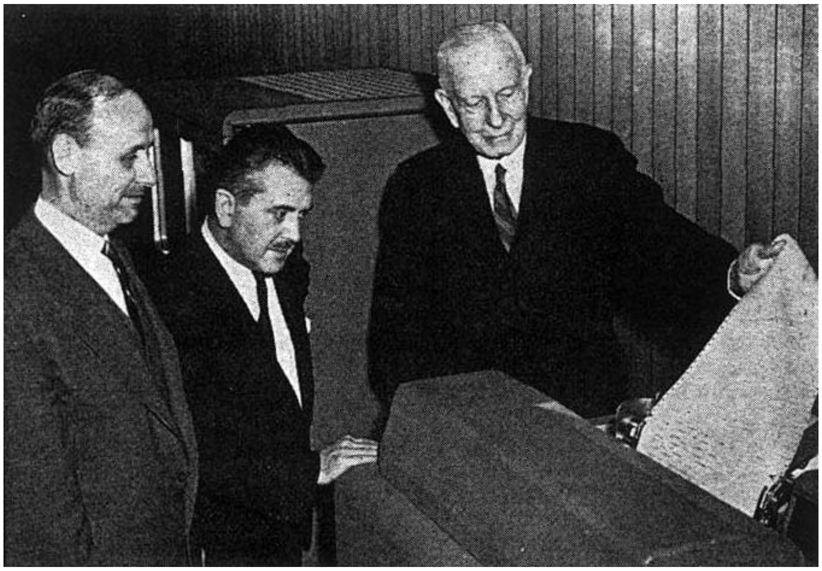

Fig. 2: Hurd, Dostert and Watson at the demonstration

Few reporters, however, gave any indication of how the program worked. For example, Robert Plumb of the *New York Times* writes only:

> In translating, for instance, a word "A" which precedes a word "B" in Russian, may be reversed in some cases in English. Each of the 250 words is coded for this inversion. Sometimes words must be inserted in the English text, sometimes they must be omitted, following code instructions. When there are several possible English meanings for a Russian word, the instructions tell the machine to pick out the meaning that best fits the context.

Another example reported in some accounts illustrated in laymen's terms the processes involved in the interpretation of ambiguous input:

> …the IBM crew included the Russian word root *ugl*, which may mean *coal* or may mean *angle*. Dr. Paul Garvin … worked out rules of context and syntax which determine how *ugl* should be interpreted. These were stored as magnetic impulses on a drum inside the "701." The result was that the machine correctly read *angle* for *ugla* and *coal* for *uglya*. (*Newsweek*)

This description was not derived from the press release but came evidently from a handout given at the demonstration which illustrated the analysis and translation of a Russian sentence containing the ambiguous stem "ugl-". Earl Ubell in the *New York Herald Tribune* described the disambiguation process in slightly more detail:

> The word root "ugl" in Russian means either "angle" or "coal" depending upon its suffix. This root is stored in the form of electrical impulses on a magnetic drum together with its English meanings and the Garvin rules of syntax and context which determine its meaning. The code is so set up so that when the machine gets electrical impulses via the punched cards that read "ugla" it translates it as "angle", when "uglya" the translation is "coal". Electrical code impulses activate the typewriter keys.

The IBM press release had in fact described translation processes in terms of the codes used. It was only the more 'serious' weeklies and monthlies – *Computers and Automation* (Macdonald 1954), *Journal of the Franklin Institute*, *Mechanical World* (Schweisheimer 1954), *Discovery* (Booth 1954) and *Science* (Ornstein 1955) – which made any attempt to describe the computer operations. Even these tended to reproduce the wording of the IBM press release, e.g. the description of inversion by the *Journal of the Franklin Institute*:

> We begin with the Russian *gyeneral mayor.* These two words must be reversed to arrive at the proper translation in English: *major general.* The switch is assured in advance by attaching the rule sign 21 to the Russian *gyeneral* in the bilingual glossary which is stored in the machine, and by attaching the rule-sign 110 to the Russian *mayor.* The stored instructions, along with the glossary, say "whenever you read a rule-sign 110 in the glossary, go back and look for a rule-sign 21. If you find a 21, print the two words that follow it in reverse order." So the instant

> the "brain" is given *gyeneral mayor* to translate, it looks in the glossary, finds the two words there, reads the rule-sign 110, goes back and finds rule-sign 21, and automatically acts accordingly—all in the twinkle of an eye.

Whether the anonymous author seriously believed that readers would make sense of this is perhaps doubtful. Schweisheimer (1955) based his account also on reproducing the descriptions in the IBM press release, but Macdonald (1954) and Ornstein (1955) made more effort to describe the coding in somewhat clearer terms. Macdonald avoided all reference to code numbers and based his account on a flowchart of the dictionary lookup procedure, definitions of the six rules (section 10 below), a table showing the operations involved in translating "vyelyichyina ugla opryedyelyayetsya otnoshyenyiyem dlyini dugi k radyiusu" (section 11.1 below)[20], and an extract from the dictionary.[21] Ornstein included the same definitions of the six rules, but he did provide operational descriptions of the interaction of codes both for the inversion example (*gyeneral mayor*)[22] – in slightly less forbidding terms than the quotation above – and for the interpretation of the preposition in the phrase *nauka o* as *science of*, taken from the IBM press release but more clearly expressed.

> The Russian word *o* can mean either *about* or *of*. In the Russian-English glossary *nauka* has affixed to it the rule-tag 242 and *o* carries the rule-tag 141. The instructions indicate to the machine that whenever rule-tag 141 is encountered, it is necessary to go back and search for 241 or 242. If 241 is found, the first English translation is selected and both words are printed in the order in which they appear in the Russian sentence. If 242 is encountered, the second English meaning is selected. Consequently, the computer reads the 141, looks for and finds 242, chooses the second meaning for *o*, which is *of*, and prints correctly *science of*.

The only contemporary account of the system by someone with first hand knowledge of the MT field was given by Booth (1954) in an article in the monthly magazine *Discovery,* which provided an overview of progress in MT research up to the middle of 1954. The article is disappointingly sparse in detail. Like the articles by Macdonald (1954) and Ornstein (1955) it reproduces the six rules and the table illustrating the analysis of a sentence, but unlike them Booth has only this paragraph:

> The second example shows the result of supplying a message in Russian to the I.B.M. '701' data processing machine. Some of the stages involved are shown opposite in Table 4. "Vyelyichyina ugla opryedyelyayetsya otnoshyenyiyem dlyini dugi k radyiusu." The message is punched upon a card and processed in various pieces of equipment shown in fig.2. Eventually the output – "Magnitude of angle is determined by relation of length of arc to radius" – appears on the typewriter. This particular system was developed by Dr. Leon Dostert, who appears as the central figure in the fourth photograph on p.284.[23]

6. Description of the system

Three of the principals involved in the development and the demonstration of the Georgetown-IBM experiment wrote accounts which provide most of the details required to give a good description of how the system worked. Sheridan gave an account of the experiment on 24 June 1954 at the conference of the Association for Computing Machinery in Ann Arbor, Michigan (*Mechanical Translation* 1(2), August 1954, p.19), and Dostert presented a paper "Characteristics of recent mechanical translation experiments" on 14 September 1954 at the American Chemical Society's meeting in New York of the Division of Chemical Literature

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[20] The transliteration in the table contained a small (unimportant) error: *dugi* should be *dugyi* (дуги). The error is repeated in all the reports.

[21] The flowchart and the table illustrating the sentence coding were evidently reproduced from handouts at the demonstration – probably used by Peter Sheridan since they appear also in his later detailed descriptions (Sheridan 1955). The flowchart appears here as Fig.7.

[22] The transliteration (presumably as presented at the demonstration) was incorrect. It should have been *gyenyeral mayor*.

[23] Booth's table 4 consists of the table reproduced by Macdonald and Ornstein – given here in section 11.1 below – and the six rules (section 10 below); his figure 2 is a reproduction of a punched card [i.e. Fig. 1 here], and his photograph appears here as Fig. 2.

(*Mechanical Translation* 1 (3), December 1954, p.55). However, these oral accounts do not appear to have been preserved.

The linguistic aspects of the experiment were given in a contemporary account by Dostert himself (1955), where he identified "the primary problem [as] one of linguistic analysis, leading to the formulation in mechanical terms of the bilingual transfer operations, lexical or syntactic." The aim was a system requiring no pre-editing of the input, and producing "clear, complete statements in intelligible language at the output", although "certain stylistic revisions may...be required..., just as when the translation is done by human beings." Although Dostert gives an informal account of the six rules of 'operational syntax' and something about how ambiguities were resolved,[24] he does not in fact give sufficient detail of the actual linguistic operations, such as dictionary construction, dictionary look-up, Russian sentence analysis, selection of target language (English) words and production of English output.[25] For such details we must turn to the retrospective assessment of the experiment provided by Paul Garvin (1967), which gives examples of dictionary entries and outlines the operation of the rules.

Some of the technical problems were covered by Macdonald (1954), Booth (1954) and Ornstein (1955), each including photographs taken at the demonstration. However, for much more detail of the computational side we must go to the account given by Peter Sheridan (1955). As the first substantial attempt at non-numerical programming, every aspect of the process had involved entering quite unknown territory. Decisions had to be made on how alphabetic characters were to be coded, how the Russian letters were to be transliterated, how the Russian vocabulary was to be stored on the magnetic drum, how the 'syntactic' codes were to operate and how they were to be stored, how much information was to go on each punched card, etc. Detailed flow charts were drawn up for what today would be simple and straightforward operations.

7. The sentences

Of the "more than 60 sentences" mentioned in the IBM press release (1954), Garvin (1967) lists 49 and provides the dictionary entries corresponding to them[26] – these amount to 137 stems or endings (of the total 250 entries in the experiment). Garvin does not, however, give the English translations for the Russian sentences. These have been reconstructed by the present author on the basis of the rules and dictionary entries included in Garvin's article (and by reference to the sentences in contemporary reports.). A further eleven sentences were listed in the ALPAC report (1966), but without the Russian originals (or dictionary entries)

As noted above, only 12 sentences were included in newspaper reports – in the following table an asterisk (*) indicates that the sentence was recorded by one or more newspaper. The sentences have been grouped in sets according to their verbs: (1) *prepare* (plural form) and its passive *is prepared*, translations of приготовляют (pryigotovlyayut) and its reflexive приготовляется (pryigotovlyayetsya); (2) *obtain* (plural form) and its passive *is obtained*, translations of добывают (dobivayut) and its reflexive добывается (dobivayetsya); (3) *produce* (plural) and its passive *is produced*, translations of вырабатывают (virabativayut) and its passive вырабатывается (virabativayetsya); (4) *determines* (singular form) and its passive *is determined*, translations of определяет (opryedyelyayet) and its reflexive определяется (opryedyelyayetsya); (5) *are constructed*, translation of строятся (stroyatsya); and (6) the remainder in a miscellaneous group. Each group can be subdivided into chemistry sentences (1a, 2a, etc.) and non-chemistry sentences (1b, 2b, etc.). Most of the sentences in (5) and all those in (6) are non-chemistry sentences. The English translations are listed here; for the original Russian see appendix I under the corresponding number: [Garvin #1, #2, etc.] The ALPAC examples are indicated thus: [ALPAC #1, #2, etc., as listed in section 15 below; and the newspaper examples are indicated by [R. (a), R. (b), etc. as listed in section 3 above.] Some

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[24] See section 12 below.

[25] Leonard Brandwood, a colleague of Booth's at Birkbeck College, University of London, was therefore fully justified in 1956 to complain of the lack of information about how the Georgetown system worked (Brandwood 1956).

[26] See Appendices I and II.

of the ALPAC examples and many of the newspaper ones are variants of Garvin's sentences (as discussed below.)

(1) *prepare* and *is prepared*:
(a) They prepare TNT. [Garvin #1]
They prepare TNT out of coal. [Garvin #2]
TNT is prepared out of coal. [Garvin #3]
TNT is prepared from coal. [ALPAC #11]
TNT is prepared out of stony coal. [Garvin #6]
They prepare ammonite [ALPAC #7]
They prepare ammonite out of saltpeter. [Garvin #9]
Ammonite is prepared out of saltpeter. [Garvin #10]
TNT is prepared by chemical method out of coal. [Garvin #15]
Ammonite is prepared by chemical method out of saltpeter. [Garvin #16]
Gasoline is prepared by chemical methods from crude oil. [ALPAC #6]
Dynamite is prepared out of nitroglycerine with admixture of inert material. [Garvin #24]
Dynamite is prepared by chemical method out of nitroglycerine with admixture of inert material. [Garvin #37]
* Dynamite is prepared by chemical process from nitroglycerine with admixture of inert compounds. [R. (d)]
(b) Fighter is prepared for battle. [Garvin #4]
(2) *obtain* and *is obtained*:
(a) They obtain gasoline out of crude oil [Garvin #7]
Gasoline is obtained out of crude oil [Garvin #8]
They obtain dynamite from nitroglycerine. [ALPAC #4]
Ammonite is obtained from saltpeter [ALPAC #5]
Iron is obtained out of ore. [Garvin #22]
They obtain iron out of ore. [Garvin #33]
Copper is obtained out of ore. [Garvin #23]
They obtain copper out of ore. [Garvin #34]
Iron is obtained out of ore by chemical process. [Garvin #35]
* Iron is obtained from ore by chemical process. [R. (c)]
Copper is obtained out of ore by chemical process. [Garvin #36]
(3) *produce* and *is produced*:
(a) They produce alcohol out of potatoes. [Garvin #11]
Alcohol is produced out of potatoes. [Garvin #12]
They produce starch out of potatoes. [Garvin #13]
Starch is produced out of potatoes. [Garvin #14]
Starch is produced by mechanical method out of potatoes. [Garvin #17]
* Starch is produced by mechanical methods from potatoes. [R. (b)]
TNT is produced from coal. [ALPAC #3]
Gasoline is produced by chemical methods from crude oil. [ALPAC #8]
(4) *determine* and *is determined*:
(a) *The quality of coal is determined by calory content. [Garvin #5; R. (a)]
Calory content determines the quality of coal. [Garvin #20]
Calory content determines the quality of crude oil. [ALPAC #10]
The quality of crude oil is determined by calory content. [ALPAC #1]
The quality of saltpeter is determined by chemical methods. [ALPAC #2]
(b) The price of potatoes is determined by the market. [Garvin #18]
The price of wheat is determined by the market. [Garvin #27]
The price of wheat is determined by the demand. [Garvin #28]
The price of potatoes is determined by the demand. [Garvin #29]
The price of crude oil is determined by the market. [ALPAC #9]
Elevation is determined by leveling. [Garvin #25]
Angle of site is determined by optical measurement. [Garvin #26]
* Magnitude of angle is determined by the relation of length of arc to radius. [Garvin #19; R. (g)]
(5) *are constructed*
Roads are constructed out of stone. [Garvin #30]
*Roads are constructed from concrete [R. (i)]

Houses are constructed out of brick. [Garvin #38]
Houses are constructed out of concrete. [Garvin #39]

(6) miscellaneous

(a) * Processing improves the quality of crude oil. [Garvin #21; R. (e)]
The science of oxygen compounds constitutes an important section of chemistry. [Garvin #42]

(b) Troops line up in wedge formation. [Garvin #31]
*We transmit thoughts by means of speech. [Garvin #32; R. (f)]
*A military court sentenced a sergeant to deprival of civil rights. [Garvin #40; R. (j)]
* A commander gets information over a telegraph [R. (l)]
Penal law constitutes an important section of legislation. [Garvin #41]
* Vladimir appears for work late in the morning. [Garvin #43; R. (k)]
Vladimir gets (a) large salary. [Garvin #49]
* International understanding constitutes an important factor in decision of political questions. [Garvin #44; R. (h)]
Negotiations are conducted about an armistice. [Garvin #45]
The federation consists out of many states. [Garvin #46]
The radiostation transmits last/latest communications about weather. [Garvin #47]
The radiostation transmits last/latest political bulletins. [Garvin #48]

As noted previously, the newspaper reporters tended to choose only non-chemistry examples, since these gave impressions of the quality of the translations which could be more readily appreciated by readers than the chemistry ones. The total number of sentences listed here is 65. There are some minor discrepancies between the examples given in the newspapers, the ALPAC examples and the examples listed by Garvin. In particular, where Garvin gives "out of" as the translation of Russian из ('yiz'), the newspapers and ALPAC give "from". Another difference is that where Garvin has the phrase "by mechanical/chemical method" it appears as "by mechanical/chemical methods" in the newspapers and in ALPAC. We do not know what has gone on in these cases. Perhaps Garvin was using a later (improved) version of the dictionary in his 1967 article. If this is the case, then the dictionary used in the demonstration (and for the ALPAC examples – see section 15 below) gave a plural English form "methods" for a singular Russian form 'putyem' (путем).[27] If these differences and variants are ignored in the count, then the total number of sentences is 61 – which corresponds to the "over 60" of the IBM press release used by journalists. We may note also at this point that the fact that the forms in the ALPAC examples correspond to the demonstration examples rather than to Garvin's later examples serves to confirm the assertion by ALPAC that the sentences were translated by the Georgetown system in 1954 (cf. section 15 below.)

8. The dictionary

The lexicon of just 250 words comprised only the vocabulary required to translate the carefully selected sentences. We do not have the complete dictionary used in the demonstration. Garvin's later article (1967) provides only an extract, although a fairly extended one since it includes a total of 137 entries – sufficient to give a good idea of how it operated.[28]

Dictionary entries (for both stems and endings) included three codes. The first code, Program Initiating Diacritic (PID) was one of '110', '121', '131', '141'or '151'. These indicated which of the six rules was to be applied. The second and third codes were Choice Determining Diacritics (CDD). The second code (CDD_1) was one of '221', '222', '241', '242'; it indicated what contextual information should be sought to determine selection of target words. The third code (CDD_2) was one of '21', '23', '25'; it indicated whether words were to be inverted or not in the output.

Typical dictionary entries were:

[27] This is an example of how the output had been 'adjusted' (see section 12 below).
[28] See appendix II.

Russian word	English equivalents I	English equivalents II	PID	CDD_1	CDD_2
doma	at home	houses	151	241	--
kachyestvo	quality	the quality	151	222	--
pravo	right	law	141	242	--
stroyatsya	are constructed	line up	141	242	25
-im	by	--	131	--	23
-ix	of	--	131	---	23
myest-	place	site	151	---	23
ryeshyenyi-	solution	decision	121	221	--

As can be seen from these few examples, the English 'equivalents' covered not only different translations of the Russian but also dealt with the inclusion or omission of articles.

In his later description Garvin (1967), words with two English equivalents were given two entries with two different PIDs, the first as above, the second '122', '132', '142' or '152'. Since the second and third codes (CDD_1 and CDD_2) for the 'English equivalent II' did not differ from those assigned to the 'English equivalent I', the following description adopts the coding used in the 1954 demonstration.

9. The computer

An account of the technical and programming problems which had to be surmounted was given by Peter Sheridan (1955). As the first substantial attempt at non-numerical programming, every aspect of the process sent the programmers into unknown territory: decisions had to be made about the coding of alphabetic characters, how the Russian letters were to be transliterated, how the Russian vocabulary was to be stored on the magnetic drum, how the 'syntactic' codes were to operate and how they were to be stored, how much information was to go on each punched card, etc. Detailed flow charts were drawn up for what today would be simple and straightforward operations, such as the identification of words and their matching against dictionary entries.

The IBM 701-type machine had been developed for military applications and was first installed in April 1953.[29] It was hired out initially at $15,000 per month, and later sold at $500,000 – and was at that time only one of about 100 general-purpose computers in existence. Its huge size was equally impressive; it was likened to "an assortment of 11 complicated electronic units, not unlike modern kitchen ranges, connected by cables to function as a unit" and "which occupy roughly the same area as a tennis court" (Ornstein 1955). [See Fig. 3]. Cuthbert Hurd (1980: 391-392) described the setup:

> The IBM Type 701 Electronic Data Processing Machine consisted of a set of interconnected boxes called the 701 Electronic Analytic Control Unit, 706 Electrostatic Storage Unit, 711 Punched Card Reader, 716 Alphabetic Printer, 721 Punched Card Recorder, 726 Magnetic Tape Readers and Recorders, 731 Magnetic Drum Reader and Recorder, and a Power Supply and Distribution Box. Separate numbers were chosen because there were separate boxes that could, in principle, be ordered separately.

The division of units was also adopted so that improvements could be introduced for each unit separately. It was considered by IBM (1954) to be "the most versatile electronic 'brain' extant". Like other computers of the day its main tasks were the solution of problems in nuclear physics, rocket trajectories, weather forecasting, etc. A similar-sized machine, the 702, was also developed for business applications. Its successor in late 1955 was the 704 model, a substantial improvement on the 701 and which sold in large numbers.[30]

[29] Development began in 1951 and the first customer machine was shipped to Los Alamos in January 1953. For technical details, origins and development of the IBM 701 see Hurd (1980).

[30] Both the 702 and 703 were produced in limited numbers for specific customers. The 704 was a general-purpose machine, and ushered in IBM's participation in the world market for large machines (Hurd 1980: 411-412), which IBM was to dominate during the 1960s and 1970s.

Figure 3: the 701 at IBM's New York headquarters

The 701 could perform 33 distinct operations: addition, subtraction, multiplication, division, shifting, transfers, etc. – all coded in 'assembly language'. Multiplication was performed at 2,000 per second. It consisted of two types of storage. Electrostatic (high-speed) storage was in the form of banks (units) of cathode ray tubes; each unit could accommodate up to 2048 "full words", where a "full word" comprised 35 bits (binary digits) and one sign bit – 36 bits in all. Each full word could be split (stored) as two "half words", each of 17 bits and one sign bit. Although the 701 had two electrostatic units, only one was used in the MT experiment. Average access time was 12 microseconds. The second type of storage (with lower access speed, 40 milliseconds) was a magnetic drum unit comprising four 'addressable' drums, each accommodating up to 2048 "full words". The magnetic drum was used to store dictionary information; the reading and writing (input and output) rate was 800 words per second.

Figure 4: Operating the computer

Input to the 701 was by card reader. Information from 80 column cards was converted to internal binary code at a rate of 100 to 150 per minute. Although cards had 80 columns, only 72 were in fact used, so each card had a maximum capacity of 72 upper case (capital letter) alphabetic or numeric characters divided as two 36-bit "words". Output was by a line printer (120 characters per line, capital letters only) at a rate of 150 lines per minute.

The program used a seven-bit code for characters: six bits for distinguishing 40 alphanumeric and other characters, plus one sign bit used for various tests (see below). This means that each "full word" location could contain up to five alphanumeric characters.

The Russian-English dictionary was input by punched cards and stored on the (low-speed) magnetic drum. A Russian word and its English equivalents (two maximum) were stored on consecutive locations, separated by "full words" (36 bits) containing zeros. They were followed by diacritics (PID, CDD_1, CDD_2) on consecutive drum locations – the three-digit PID occupying the next "full word", and the three-digit CDD_1 and two-digit CDD_2 occupying together the final "full word". Dictionary entries were terminated by zeros in two "full words". Each "word" included a 'sign bit', either + or -, which indicated whether the entry was for a stem or for an ending, respectively. For example, the line containing the Russian stem ugl- was:

+	+	+	+	+	+	+	+	+	+
ugl-0	00000	coalø	00000	angle	00000	00121	***25	00000	00000
3262	3264	3266	3270	3272	3274	3276	3300	3302	3304

where the numbers refer to actual addresses in the drum (in octal).

Fig.5: Keypunching cards

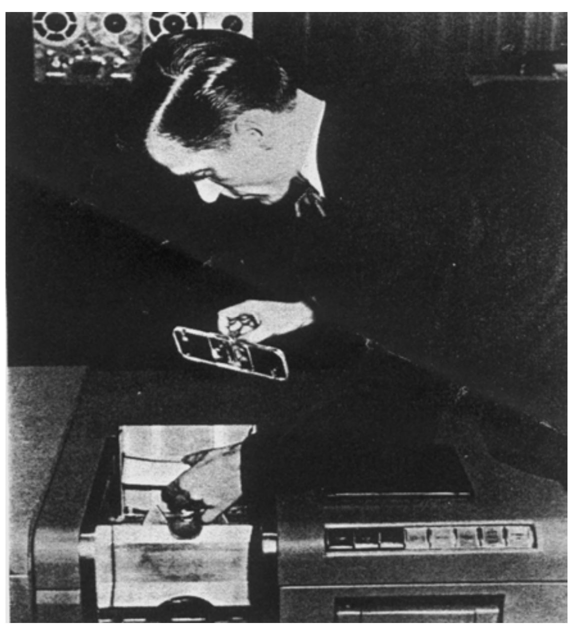

Fig. 6: Input of punched cards

Sentences were punched onto cards [Fig.5], entered in the computer by a card reader [Fig.6], and read into the electrostatic storage, separated by strings of zero-filled "words". The input words were then each looked up in the drum storage, first by consultation of a "thumb index" which gave the address (location) of the first word in the dictionary with the same initial letter – i.e. the address of one of the four drums (Dx) and the location on the drum (Lx). The lookup routine searched for the longest matching string of characters (whether complete word or stem plus hyphen), extracted the (two) English equivalents, copied them onto a separate area of the store, and then copied their associated 'diacritics' onto another area of the store.[31] A special area was also set aside for the temporary (erasable) location of word-endings. Each of these areas and addresses had to be specified either directly (specifically by store address) or indirectly (using variables) in the program (called 'Lexical Syntax Subprogram'). Sheridan describes the operations of comparison in terms of successive and repeated processes of logical multiplication, addition and subtraction using 'masks' (sequences of binary digits). When a diacritic (CDD_1 or CDD_2) indicated which English equivalent was to be selected, the program went back to the addresses in the separate store area, and copied the one selected to a (temporary) area of the electrostatic store, from which it could then be printed out [Fig. 2].

10. The six rules

Before the procedures were given to Sheridan for programming, they were tested by hand on a set of cards (Dostert 1955; Macdonald 1954, Macdonald 1963).These tests were performed by people who did not know Russian[32]. The sentences were written in Russian characters on the cards. The tests involved finding the corresponding cards for each word and following the instructions:

Rule 1. Rearrangement. If first code is '110', is third code associated with preceding complete word equal to '21'? If so, reverse order of appearance of words in output (i.e., word carrying '21' should follow that carrying '110') – otherwise, retain order. In both cases English equivalent I associated with '110' is adopted.

Rule 2. Choice-Following text. If first code is '121', is second code of the following complete, subdivided or partial (root or ending) word equal to '221' or '222'? If it is '221', adopt English equivalent I of word carrying '121'; if it is '222', adopt English equivalent II. In both cases, retain order of appearance of output words.

Rule 3. Choice-Rearrangement. If first code is '131', is third code of preceding complete word or either portion (root or ending) of preceding subdivided word equal to '23'? If so, adopt English equivalent II of word carrying '131', and retain order of appearance of words in output – if not, adopt English equivalent I and reverse order of appearance of words in output.

Rule 4. Choice-Previous text. If first code is '141', is second code of preceding complete word or either portion (root or ending) of preceding subdivided word equal to '241' or '242'? If it is '241', adopt English equivalent I of word carrying '141'; if it is '242' adopt English equivalent II. In both cases, retain order of appearance of words in output.

Rule 5. Choice-Omission. If first code is '151', is third code of following complete word or either portion (root or ending) of following subdivided word equal to '25'? If so, adopt English equivalent II of word carrying '151'; if not, adopt English equivalent I. In both cases, retain order of appearance of words in output.

Rule 6. Subdivision. If first code associated with a Russian dictionary word is '***', then adopt English equivalent I of alternative English language equivalents, retaining order of appearance of output with respect to previous word.

According to Sheridan, the rules formulated in this manner were easily converted into program code. Evidently it was felt that such rules could be understood by the laymen since they were reproduced word for word in the reports which gave fullest details (e.g. Macdonald 1954, Booth 1954, and Ornstein 1955).

[31] Figure 7 shows the flowchart for part of the dictionary lookup program.

[32] According to the IBM press release (1954) they were "government officials and others in Washington".

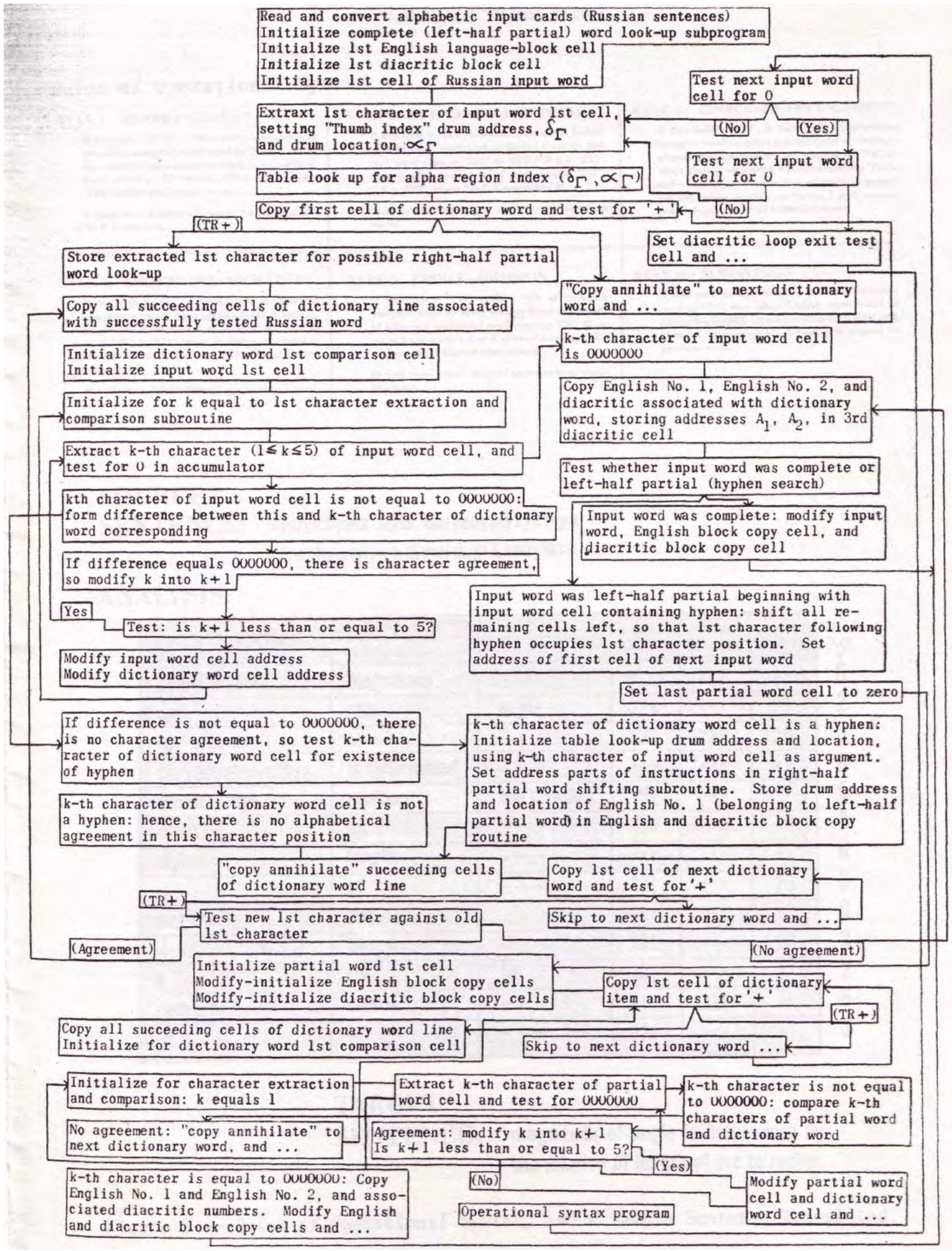

Fig. 7: Flowchart of part of the dictionary lookup procedures (from Sheridan 1955)

A little later, however, Dostert gave a more simplified version of the workings (in his summary of the achievements of the experiment (Dostert 1955), see §13 below), and Garvin (1967) also provided a more easily comprehended version[33]:

> *Rule 1.*Look for cue diacritic 21 in the diacritic part of a complete-item entry immediately to the left of the decision point.
> Yes – invert the order of the translations of the items concerned
> No – retain order
>
> *Rule 2*. If the decision point is a complete item, look for cue diacritics 221 or 222 in the diacritic field of a complete-item entry, or of either partial entry for a subdivided item, immediately to the right of the decision point. If the decision point is a left partial, look for cue diacritics in the corresponding right-partial entry. Select as follows:
> 221 – choose the first equivalent of the decision point entry.
> 222 – choose the second equivalent of the decision-point entry.

And so on for the remaining rules. However, the ways in which rules and dictionary items interact may be more readily understood by working through some sentences in the next section.

11. The rules and dictionary in operation

11.1 First example.

The operations can be illustrated with the following table for one of the journalists' favourite sentences: *Magnitude of angle is determined by the relation of length of arc to radius* (5: translation of величина угла определяется отношением длины дуги к радиусу). The table is adapted from Sheridan (1955); it was reproduced by Macdonald (1954), and by Ornstein (1955). It corresponds to Garvin's sentence #19.

Russian input	English equivalents		1st code	2nd code	3rd code	rule
	Eng_1	Eng_2	(PID)	(CDD_1)	(CDD_2)	
vyelyichyina	magnitude	---	***	***	**	6
ugl-	coal	angle	121	***	25	2
-a	of	---	131	222	25	3
opryedyelyayetsya	is determined	---	***	***	**	6
otnoshyenyi-	relation	the relation	151	***	**	5
-yem	by	---	131	***	**	3
dlyin-	length	---	***	***	**	6
-i	of	---	131	***	25	3
dug-	arc	---	***	***	**	6
-yi	of	---	131	***	25	3
k	to	for	121	***	23	2
radyius-	radius	---	***	221	**	6
-u	to	---	131	***	**	3

The first word величина ('vyelyichyina') has just one English equivalent (*magnitude*) and its PID (***) refers to rule 6 – i.e. the result is simply copied out and there is no change of word order. The next word (угла) has been subdivided into its stem (ugl-) and a suffix (-a). The stem 'ugl-' initiates rule 2 by its PID '121'; rule 2 searches for code '221' or '222' in the CDD_1 of the following entry, the suffix -a; it finds '222', and therefore the second equivalent of 'ugl-' is chosen (Eng_2 *angle*). The next entry, the suffix '-a' (of угла) with PID '131', triggers rule 3, which searches for '23' in the CDD_2 of the preceding entry – which since it is absent prompts selection of the first equivalent (Eng_1 *of*) and a reversal of word order (i.e. producing *of angle*).[34]

The next entry is the verb form 'opryedyelyayetsya' with PID '***', hence rule 6 is applied: selection of first equivalent (Eng_1 *is determined*) and no change of word order. The

[33] In these descriptions, 'decision point' refers to the next word stem or ending reached in the processing of a sentence.

[34] It should be noted that in fact, 'ugl-' is not strictly a homonym, there are two separate Russian words: угол (*corner* or *angle*) and уголь (*coal*). Garvin's procedure is based on the fact that the genitive for угол is угола and the genitive for уголь is уголя.

next word (отношением) has been subdivided: the stem (‘otnoshyenyi-’) initiates rule 5 (PID ‘151’) searching for code ‘25’ in the CDD_2 of the following entry (i.e. in its ending) or in the CDD_2 of the next following word (stem or ending). The ‘25’ is found in the ending ‘-i’ of the word (длины), so the second equivalent (Eng_2) of ‘otnoshyenyi-’ is selected (i.e. *the relation*) and the word order is retained. The process now continues with the next entry after ‘otnoshyenyi-’, i.e. its instrumental ending (-yem’), where the PID ‘131’ initiates rule 3, with a search for ‘23’ in preceding entries. None is found, so the first equivalent (Eng_1: *by*) is chosen and word order is reversed (i.e. producing *by the relation*). Next comes the entry ‘dug-’ (stem of дуги) with PID ‘***’, i.e. selection of Eng_1 (*arc*), and no change of order. Then comes its ending (‘-yi’) with PID ‘131’ (rule 3) searching for ‘23’ in preceding entries and failing, so Eng_1 (*of*) is chosen and word order is reversed (i.e. *of arc*). The process now comes to the preposition ‘k’ which has two equivalents – out of the many possible translations of the Russian word – viz. *to* and *for*. Rule 2 (PID ‘121’) searches for ‘221’ or ‘222’ in the CDD_1 of the following stem or ending, and finds ‘221’ in the relevant CDD of ‘radyius-’; thus, the first equivalent (Eng_1: *to*) is selected. The entry for the stem ‘radyius-’ (PID ‘***’) initiates no change. Finally, the PID ‘131’ of its ending ‘-u’ searches for ‘23’ in one of the two preceding entries, finds it in the entry for the preposition ‘k’, selects the second equivalent (Eng_2), i.e. blank, and retains word order.

The inclusion of the full verb form (‘opryedyelyayetsya’) in this example was the option followed by Garvin for all the sentences listed above (in section 7, sentences (1)-(4)) which have similar Russian reflexive forms translated in English by passives (‘*is prepared’*, ‘*is obtained’*, ‘*is produced’*, ‘*is determined’*) – each occurring only in the singular. The same option of not dividing verb forms into stems and suffixes was made for their corresponding non-reflexive forms (translated as ‘*they prepare’*, ‘*they obtain’*, ‘*they produce’* – all plural – and ‘*determines*’).[35] The translation of Russian reflexives into English passives raised a number of complexities for later Russian-English MT programs. Garvin avoids them all by not doing any morphological analysis of any verb forms (no segmentation into stems and endings).

11.2 Second example

A second example is a table illustrating the translation of Наука о кислородных соединеиях является важным отделом химии as *The science of oxygen compounds constitutes an important section of chemistry*. This example was not given in full by reporters, who confined comments to the treatment of *nauka* and it following preposition (as seen above in section 5). It is Garvin’s sentence #42:

Russian word	English equivalents		1st code	2nd code	3rd code		
	Eng_1	Eng_2	(PID)	(CDD_1)	(CDD_2)		
nauka	a science	the science	***	242	**	II	6
o	about	of	141	***	23	II	4
kyislorodn-	oxygen	[none]	***	***	**	I	6
-ix	of	---	131	222	23	II	3
soyedyinyeyi-	compound	compounds	121	242	**	II	2
-yax	---		***	222	**	I	6
yavlyayetsya	appears	constitutes	141	***	23	II	4
vazhn-	an important	important	***	***	**	I	6
-im	by	---	131	***	23	II	3
otdyel-	section	[none]	***	***	**	I	6
-om	by	---	131	***	**	II	3
xyimyi-	chemistry	[none]	***	***	**	I	6
-yi	of	---	131	***	25	I	3

As in the previous example, the first entry (nauka) has ‘***’ as its PID, and therefore refers to rule 6, i.e. there is no change of word order. There are two possible English equivalents (differing only by the article form), but Garvin does not explain how selection between them is determined. The presence of CDD_1 ‘242’ in the entry is required by the selection of either *about*

[35] In (5) there is a reflexive (строятся: ‘*are constructed’*) without corresponding non-reflexive. It is dealt with below in comments on the second example sentence.

or *of* in the next entry. This is the preposition *o*; its PID '141' initiates rule 4, which requires the search for '241' or '242' in the CDD_1 of the preceding entry. In this case '242' is found and the second equivalent (Eng_2 *of*) is selected – if it had been '241' the first equivalent (Eng_1 *about*) would have been chosen. The next word 'kyislorodnix' has only one English equivalent (*oxygen*) for its stem, selected by rule 6 from PID '***'. Its ending '-ix' initiates rule 3 (from '131') and looks for '23' in the preceding entry (i.e. the word stem); since it is found, the rule specifies selection of the second equivalent (Eng_2, i.e. ---, a blank) with no change of word order. The next word 'soyedyinyeyiyax' has two possible outputs (singular or plural of *compound*). Rule 2 (initiated by '121') prompts the search for '221'or '222' in the following entry (i.e. the word's ending '–yax'). Finding '222', the plural form (Eng_2) *compounds* is selected. The ending '-yax' itself does not require any selection and in fact its PID '***' indicates no change of order. So far the outcome of the process is '*The science of oxygen compounds…'* What is strange for present-day readers is that there is no link of any kind between the plural (instrumental) form of the adjective 'kyislorodnix' and the plural (instrumental) form of the noun which governs it, 'soyedyinyeyiyax'.

The next word 'yavlyayetsya' является is one of those problematic Russian verbs – problematic for both human and machine translation – firstly because of the numerous possible English translations[36] and the frequent need to change the structure of the sentence in the English output text. Garvin avoids the problems by selecting just two possible equivalents and ensuring that English output does not require any changes of word order. In this case, PID '141' initiates rule 4 searching for '241'or '242'in the CDD_1 of the preceding stem form, and since '242' is found, the choice of English equivalent is '*constitutes'* (Eng_2). The next word (stem and ending) is an adjective in the instrumental case (vazhnim); the rule '131' looks for '23' in the preceding entry (for 'yavlyayetsya') and finding it outputs the second equivalent (blank) and retains the word order (*constitutes an important*).

There are just three other sentences which include 'yavlyayetsya' and in two of them (Ugolovnoye pravo yavlyayetsya vazhnim otdyelom zakonodatyeljstva, [Garvin #41] *Penal law constitutes an important section of legislation*, and Myezhdunarodnoye ponyimanyiye yavlyayetsya vazhnim faktorom v ryeshyenyiyi polyityichyeskyix voprosov [Garvin #44] *International understanding constitutes an important factor in decision of political questions*) the verb is followed by an instrumental form, indeed the same word as in this example: 'vazhnim'. Only in the third sentences 'Vladyimyir yavlyayetsya na rabotu pozdno utrom' ([Garvin #43, *Vladimir appears for work late in the morning*) differs; here the verb is followed by a prepositional phrase and is to be translated as 'appears'.

The choice between '*appears'* and '*constitutes'* is determined by code '141' looking for '241' or '242' in the preceding word. 'Vladimir' is coded for '241', so the first equivalent '*appears'* is selected. The second equivalent ('*constitutes'*) is determined by the presence of '242' in preceding nouns: 'compounds' (soyedyinyeyiyax), 'law' (pravo), and 'understanding' (ponyimanyiye). It should be noted, however, that in this example II, grammarians and linguists would say that the noun governing the verb 'yavlyayetsya' is 'nauka' ('science') and not 'soyedyinyeyiyax' ('compounds' in instrumental case). So there is a bit of trickery here – as Garvin would no doubt have agreed.

As it happens, 'yavlyayetsya' is one of only two verbs in the set of sentences which has been given two equivalents that reflect a genuine ambiguity in the Russian original. The other is the plural verb 'stroyatsya' (строятся) translated as either 'are constructed' (sentences in (5), Garvin #30, 38, 39) or 'line up', as in 'Troops line up in wedge formation' (sentence (6b), Garvin #31). As with 'yavlyayetsya' the choice is determined by a rule ('141') which searches for '241' or '242' in a preceding word or segment. Finding '241' in 'dorogi' (дорогы , "roads")

[36] E.g. dictionaries offer: (1) appear, report, present oneself (он является кстати, he appeared at the opportune moment), (2) occur (у него явилась мысль, an idea occurred to him); (3) be (это явилось причиной его смерти, that was the cause of his deeath; он является директором, he is the director), and (4) represent (это явилось серьёзным препятствием, it represented a serious obstacle).

and ‘doma’ (дома, “houses”) produces the required ‘are constructed’; and finding ‘242’ in ‘voyska’ (войска, “troops”) produces the second equivalent ‘line up’.[37]

11.3 Third example

A number of sentences (mainly chemistry ones) contain instrumental phrases, such as ‘by mechanical method’, ‘by chemical process’, etc. Each are generated in the same way, by the production of the preposition ‘by’ out of the case ending of the adjective rather than the normal approach which would derive it from the noun – since adjectival forms are held to be dependent on the nouns they are modifying.

Russian word	Eng_1	Eng_2	PID	CDD_1	CDD_2
xyimyichyesk-	chemical	---	***	242	**
-yim	by	---	131	***	23
put-	path	method	141	***	**
-yem	by	---	131	***	**

The entry ‘xyimyichyesk-’ is subject to no rule and produces its sole equivalent ‘chemical’. The suffix ‘-yim’ initiates rule ‘131’ and a search for code ‘23’ in the preceding entry, which is not there; consequently, Eng_2 is selected (‘by’) and the word order is inverted (i.e. *by chemical*). The next entry ‘put-’ has two possibilities ‘path’ and ‘method’; it activates rule ‘141’ which searches for a ‘241’ or ‘242’ in the second code of the preceding stem or ending. CDD_1 ‘242’ is found in the entry for ‘xyimyichyesk-’; as a result the second equivalent Eng_2 (*method*) is produced. Finally, the suffix ‘-yem’ initiates rule ‘131’ again – searching for code ‘23’, this time successfully, so that the second equivalent Eng_2 (‘---’) is generated. Obviously the desired result is achieved here (*by chemical method*) and in the other instrumental phrases. But from a linguistic point of view the coding and procedure is contrary to normal grammatical interpretation, namely that the preposition is determined by the noun form (and not the adjective which modifies it). We might also note an apparent arbitrariness in the different coding for the instrumental cases: for the adjective ending ‘-yim’ the CDD_2 is ‘23’, while for the noun ending ‘-yem’ it is blank (‘**’).

Examination of entries in Garvin’s dictionary (1967) reveals that this treatment is given to all instances involving case endings: -а, -ами, -и, -им, -имы, -их, -ью, -ого, -ом, -ов, -у, -ы, -я, -е, -ем, -ыи, -ым, -ых, -ю. The output is either a preposition (‘of’, ‘by’, etc.) to be placed before the adjective (as in Example 3), or a blank to be placed between the adjective and a following noun (as in Example 2). Entries for these endings specify the application of rule 3 (PID ‘131’), which seeks either for code (CDD_2) ‘23’ to select the first equivalent (preposition) and reverses word order; or for code ‘25’ to select the second equivalent (blank) and retains word order.[38] Furthermore, as Garvin later admitted (Garvin 1967: 52), the experiment implemented only the first stage of what should be a two stage process: a decision whether a case ending should be rendered by a preposition or not, and the selection of the right preposition. Instead, only one preposition was offered, “that which impressionistically seemed the most frequent.”

Although Russian nouns are always marked for case, Garvin chose, in most instances, to avoid morphological analysis (i.e. in terms of stems and endings) by entering full forms: e.g. цена, дома, мыслы (plural), отделение, решение. Only a few examples of segmentation are to be found: места (gen. ‘site’) segmented as мест- and –а; путем (instr., ‘method’) as пут- and –ем; работу (‘work’) as работ- and –у; and пшеницы (gen., ‘wheat’) as пшениц- and -и. However, segmentation would seem to be superfluous since these nouns appear in example sentences only with these particular case endings.

11.4 Fourth example

Russian word	Eng_1	Eng_2	PID	CDD_1	CDD_2
ugol	angle		***	***	**

[37] Garvin also includes in his dictionary the singular form of the same verb (строится) with two translations ‘is constructed’ and ‘lines up’, but there are no illustrative sentences.

[38] It would seem that ‘-yem’ is exceptional in having not ‘25’ but ‘**’ for its code CDD_2.

myest-	place	site	151	***	23
-a	of	---	131	222	25
tsyel-	target	---	131	***	25
-yi	of	---	131	***	25
opryedyelyayetsya	is determined		***	***	**
optyichyesk-	optical		***	***	**
-yim	by	---	131	***	23
yizmyeryenyi-	measurement		***	***	**
-yem	by	---	131	***	**

The first word 'ugol' (угол) has just one English equivalent ('angle'), unlike its genitive form ('ugla') which has both 'coal' and angle' (see above Example 1). The word места (genitive form) is subdivided as 'myest-' and '-a'; and it is given two equivalents ('place' and 'site'). Rule 5 (PID '151') searches for a CDD_2 '25' in the next word (either stem or ending). It is found, and so the second equivalent Eng_2 ('site') is selected. The suffix '-a' initiates rule 3 (PID '131') which searches for CDD_2 '23' in the preceding word stem and finds it. This prompts the selection of Eng_1 ('of') – and order is reversed (i.e. *of site*). The next word цели (genitive form) is subdivided as 'tsyel-' and '-yi'; and 'tsyel-' has two outcomes: Eng_1 ('target') and Eng_2 (blank). Again rule 3 is initiated (PID '131') and searches for a CDD_2 '23'; it does not find it in the preceding suffix (i.e. '-a') but it does find it in the stem ('myest-'); so the second equivalent Eng_2 ('---') is chosen. The suffix '-yi' then initiates '131' to search for '23' in preceding stems and suffixes, firstly in 'tsyel-' and then in '-a', where it is not found, and lastly in the stem 'myest-' where it is found of course. Hence, Eng_2 ('---') is chosen and the words inverted (i.e. the output is left as *of site*). All this seems excessively complex, arbitrary and contrived, and merely to ensure that the translation is not *place of target* but *site*.

The rest of the sentence is more straightforward: 'opryedyelyayetsya' has just one equivalent ('is determined') and the instrumental phrase is generated as in example 3, that is: the suffix '-yim' of 'optyichyesk-' ('optical') initiates rule 3 ('131'), fails to find CDD_2 '23', so it outputs Eng_1 ('by') and inverts word order (i.e. *by optical*). Finally, 'yizmyeryenyi-' has one equivalent ('measurement') and its suffix '-yim' invokes rule 3 ('131'), finds a CDD_2 '23' in the preceding subdivided word (the entry for the suffix '-yim'), selects a blank for Eng_2 ('---') and retains the word order (*by optical measurement*).

11.5 Other comments

Russian prepositions are provided with two English equivalents. Obviously in reality there would be more. Most are selected on the basis of the following words – which were also obviously selected to produce good results. Examples are: к ('to' or 'for'), на ('on' or 'for'), о ('about' or 'of'), при ('at or 'in'), в ('in' or 'to'). Each initiates rule 2 (by PID code '121'), which looks for code '221'or '222' in the following word; '221' selects first equivalent, '222' the second equivalent. There is just one example of selection based on a preceding word – example 2 above, where the preposition о ('about'/'of') initiates rule 4 (code '141') – but this procedure does not seem to occur elsewhere.

As Zarechnak later observed (Zarechnak 1979), the experiment avoided the problem of inserting articles (definite and indefinite) in English. Russian has no articles, so the insertion of *the*, *a* and *an* in English are problems for any MT system. Garvin got around these problems by including very few in the sample sentences. There are just four instances. Two were explained in the comments to examples 1 and 2 above; however, the rules involved differ: '*the science'* is selected by rule '141' operating on the following preposition, '*the relation*' by rule '151' locating a '23' in the suffix two words later. The other two examples are '*the price'* and '*the quality'* in some sentences in (4a) and (6a). The translations with articles are determined by the occurrence of a code '25' in following entries, e.g. 'nyeftyi' ("oil"), 'uglya' ("coal"), 'pshyenyitsi' ("wheat"), 'kartofyelya'("potatoes").

Problems with pronouns are also avoided; in Russian they are often omitted when verb forms are unambiguous. In Garvin's selection of sentences English pronouns occur only in translations of verbs in the third person plural (приготовляют 'they prepare', etc. as discussed in 11.1 above). There is just one exception: the translation of мы ('we') in the sentence *We* *transmit thoughts by means of speech*. Actually the dictionary entry for the verb ‘pyeryedayem’ (передаем) gives two possibilities ‘we transmit’ and ‘transmit’. The rule initiated by the verb form is rule 3 (PID ‘131’) which requires a search for ‘23’ in the preceding word. This word is мы (‘we’), and it does contain the code ‘23’, so the second equivalent (‘transmit’) is selected. Since, however, ‘pyeryedayem’ does not occur elsewhere in the selection of sentences, the procedure is effectively superfluous – and only justified if the dictionary and the sentences were going to be augmented by many more examples.

From the above comments it is clear that many operations are specific to the particular words and sentences in the selected examples, and the rules are applied as seem appropriate in specific instances. In particular, there was no analysis in terms of grammatical categories (noun, verb, adjective) and no derivation of either agreement relations, or dependency relations, or phrase/clause structures. In essence, the approach is most similar to the ‘lexicographic’ approach of Reifler – first suggested in 1956, but elaborated later (Reifler 1960) – where dictionary entries (source language, Russian) indicate the context (two or three words either before or after) in which a particular output (target language word or phrase) is to be generated and the operations (movement, replacement, etc.) which must then be performed on the resulting phrase (or sentence).

12. Assessments by Dostert and Garvin

A year after the demonstration Dostert gave an assessment of the significance of the experiment, and suggested future ideas for MT development (Dostert 1955). While in most respects his description of the experiment adds little to the newspaper and magazine accounts – and is less complete in detail than Garvin’s (1967) description, it does include an interesting variation in the formulation of the six rules of the “operational syntax”.[39] Dostert chooses on the one hand to describe them informally and on the other to introduce some symbolism.

> Operation 0. The machine, in a sense, encounters no problem. In this situation, a one-for-one equivalence in meaning and identical linear sequence exists between the items of the source language and those of the target language. This may be represented as follows: Operation 0: 1 = 1 ——.
>
> Operation 1 involves a change in the order in which the language items are to appear in the output from the order in which they occur in the input. It is the rule of rearrangement or inversion and can be formulated by the symbols: Operation 1: AB > BA ⌐¬⌙⌟
>
> Operation 2 involves a problem of choice. In this particular operation the choice is based on the post-determiner and may be represented by this sign: →—┐
>
> Operation 3 also involves making the correct choice on the basis of a contextual determiner, but in this case we have a pre-determiner in the sense that the machine must look backward instead of forward, to be represented by the sign: ┌—←
>
> Operation 4 involves the omission of a language item that is present in the input but superfluous, and therefore would be confusing if rendered in the output language. This, in effect, means that there is a blank in the lexicon corresponding to this particular item in the input language; thus no item is inserted in the output language. This can be represented by the following symbol: Ө
>
> Operation 5 is the reverse of the preceding one: It involves the insertion of an additional item essential in the output language which is not present in the source language. This can be represented by the symbol: ⊕

What is notable in this simplified description of the rules (cf. section 10 above) is that there is no mention of alternative translations, different English ‘equivalents’ for Russian words, and no mention that some entries are full word forms, some are stems and some are endings. Rather, Dostert seems to be intent on elevating the six rules to some status of universal applicability; which he underlines by the inclusion of ‘universal’ symbols. Dostert does not illustrate the application of any of the rules with examples from the experiment. Instead he discusses in very general terms various approaches to “meaning determination”, various types of ambiguity, and the possibilities of a “core syntax, common to several languages”. Only some

[39] The term ‘operational syntax’ was first used by Bar-Hillel in his 1951 article and in a paper at the 1952 conference (Bar-Hillel 1951, 1952). Garvin does not use the term.

types of meaning determination are claimed to have been tackled in the experiment – but without giving any examples.

It is evident that Dostert took a greatly optimistic view of the achievements of the experiment. At the end of his article he asserts that the experiment had "given practical results by doing spontaneous, authentic, and clear translation", had shown that "the necessity of pre- and post-editing has not been verified", had demonstrated that "the primary problem in mechanical translation… is a problem of linguistic analysis…", and had formulated "the basis for broader systematic lexical coding", in that it had defined "four specific areas of meaning determination… from which fruitful results may be expected". He evidently believed that his speculations about a system of "functional coding" to deal with problems of meaning and about coding for "multilingual syntax operations" had also advanced as a result of the experiment.

However, these were claims with little foundation, and clearly could not be justified on the basis of this small-scale experiment. Rather they were expectations Dostert had for future research. The claim of "authentic and clear translation" was true only for the highly restricted conditions of this particular experiment; later MT research (including that at Georgetown University) showed that good quality MT output is very difficult to achieve, particularly for general-purpose systems. The claim that pre- and post-editing was not essential has likewise been found to be true only for MT in highly restricted domains (e.g. weather reports). The claim that the primary MT problems were linguistic rather than technical was only partly true during the following years of MT research – although now it is virtually accepted as a truism. Finally, claims for the general validity of the coding methods were negated by Georgetown research itself in the following years (see next section.)

The retrospective assessment by Garvin (1967) was much more modest than Dostert's. Garvin characterised the basic features of the system under five headings:

> (1) The scope of the translation program was clearly specified. Any sentence meeting its narrow specifications could be translated, provided the required entries were present in the dictionary. The glossary could be expanded without difficulty…
> (2) The lookup routine was designed for maximum efficiency of the translation algorithm, in that the splitting routine was applied only to those cases were it would serve to simplify the operation of rules…
> (3) The translation algorithm was based on the collocation of decision points and decision cues, rather than directly on the linguistic factors involved, although the decision points and cues themselves were established by linguistic analysis. The same rule was thus used to solve problems of different linguistic structure, but with similar decision structure…
> (4) The word length of a sentence turned out to be operationally trivial, since the rules allowed the translation of consecutive strings of similar constructions, provided they were within the specifications.
> (5) Selection and arrangement were confirmed as the basic algorithmic operations. "Omission" and "insertion" emerged as simple variants of the selection problem…

These are positive features: potential expandability (1), computational efficiency (2), linguistic justification for what might otherwise seem arbitrary procedures (3), less limitation on sentence length than might appear (4), and generality of the operations (5). Garvin freely admitted the limitations of the system – the consequence of restricting the algorithm to "a few severely limited rules, each containing a simple recognition routine with one or two simple commands" – but he insisted that the experiment was "realistic because the rules dealt with genuine decision problems, based on the identification of the two fundamental types of translation decisions: selection decisions and arrangement decisions."

The limitations mentioned by Garvin were principally: the restriction of the search span to immediately adjacent items, the restriction of target words to just two possibilities, and the restriction of rearrangements to two immediately adjacent items. The choice of target language equivalents was restricted to those which were idiomatic for the selected sentences only. The limitation of the procedure for Russian case endings was severe: either a case suffix was not translated at all or it was translated by one "arbitrarily assigned" English preposition. Further limitations were highlighted by Michael Zarechnak (1979, 2000), a member of the Georgetown group. None of the Russian sentences had negative particles; all were declaratives; there were no interrogatives or compound sentences (coordinate or subordinate clauses); nearly all the verbs were in the third person; and English articles were inserted to fit the particular words of the corpus.

Does this mean that the experiment was fixed, a deception? Naturally members of the Georgetown group deny it – pointing out that the program "was thoughtfully specified and implemented; the program ran, the translation was generated according to the program, which was developed based on… linguistic principles." (Montgomery 2000). This was basically true, however, only for the chemistry sentences and the rules and dictionary entries which were applied for their translation. Clearly, with an expansion of the dictionary, many other chemistry sentences could have been covered by the system – but only as long as the sentences conformed to the patterns of those in the sample ("X is determined/prepared/produced by Y methods", "They produce/prepare X out of Y", etc.). Garvin's point (1) applied therefore only to the chemistry sentences. There are many chemistry sentences that would obviously not be covered by the rules. Although organic chemistry might constitute a sublanguage and its vocabulary might be captured in a 'micro-glossary' (as others advocated at the time – Oswald and Lawson 1953) with few ambiguities, this program in 1954 did not cover all of the field, nor indeed a substantial proportion of it. As for the non-chemistry sentences, these were clearly produced by dictionary entries and codes specifically designed for this particular demonstration; and there could have been no question of expanding general coverage on the lines of this program – as indeed was found in the later research at Georgetown.

The absence of morphological analyses for all non-invariant Russian words may have been well motivated by concerns for computational efficiency – point (2) above – but this lack of morphological segmentation does not suggest that dictionary entries or grammar rules could be easily expanded. Likewise the decision to base the algorithm on similarities of 'decision structure' rather than on similarities of linguistic structure – point (3) – a feature noted in many of the examples in section 11 – reduced the expandability of the system; and it also suggested to observers that the rules were arbitrarily devised solely to deal with these particular sentences. Whether the algorithm could really deal with longer sentences, even if of similar structures – Garvin's point (4) – seems a rather dubious claim, since examination of the rules and 'decision cues' indicates that the interaction of the rules must have been limited to two or three adjacent words at most. Finally, regarding the generality of the operations – point (5) – while we may agree that selection and arrangement are basic operations for any non-numerical application and are particularly pertinent for translation processes, there could be no convincing demonstration of this claim since operations were restricted to immediately adjacent words and selection to just two possible outcomes.

Although the limitations of the experiment made it possible for the output to be impressively idiomatic, it should always be remembered that neither Dostert nor Garvin claimed much more than that it was a first effort (a "Kitty Hawk" experiment) – not even a prototype system. In later years, they might well have agreed that the demonstration had been premature; certainly it was made public at a stage much earlier than other contemporary MT researchers would have contemplated. However, there was another, probably much more important aim for Dostert; it was to attract funds for further research at Georgetown, and in this the experiment succeeded. [40]

13. The implications

All previous work on MT had been theoretical in the sense that none of the proposals had in fact been implemented as computer programs.[41] Other MT groups considered the publicity premature, and they disliked three things. One was the communication of research through newspapers; another was the demonstration of what was obviously an incomplete system (not even a 'prototype' system); and the third was the passing-off as true 'translations' sentences which could only have been extracted as wholes from computer memories – as mentioned above

[40] This point was emphasised by many commentators at the time and in later years: Ornstein (1955), Panov (1960), Mounin (1964: 22), Montgomery (2000), etc.

[41] See section 2 above, and Hutchins 1997a

this was true for the non-chemistry sentences but only partially so for the chemistry ones. The other MT groups were far from even thinking of demonstrating their results – and remained unprepared to do so for many years to come.

The immediate result of the demonstration was the receipt of funds from the Central Intelligence Agency for MT research at Georgetown University – Dostert was a good friend of its director Allen Dulles during and since the War. The funds came indirectly via the National Science Foundation, initially some $400,000 over three years, and subsequently nearly $1,500,000 (Vasconcellos 2000). A full-scale project for Russian-English translation was organized with more than twenty researchers (Macdonald 1963)[42]. Initially two groups were set up: one for developing a dictionary, the other for linguistic analysis. After examining the coding of the 1954 experiment for a few months, the group decided to abandon continuation on these lines.[43] There was considerable divergence of opinions; Dostert decided to give each of the proposed methods a chance to show its capability in 'free competition'. By January 1957 there were four groups, known as 'code-matching', 'syntactic analysis', 'general analysis', and 'sentence-by-sentence'. The first group, headed by Ariadne Lukjanow, assigned codes to dictionary entries which indicated grammatical and association functions, and which were compared and matched during analysis. The second group under Paul Garvin developed a method of dependency syntactic analysis later known as the 'fulcrum method'. The third group under Michael Zarechnak formulated a method of sentence analysis at various levels (morphological, syntagmatic, syntax), i.e. a variant of 'phrase structure' analysis. The fourth 'group' was a one-man project of French-English translation by A.F.R.Brown where procedures developed first for one sentence were tested on another, more procedures were added, tested on another sentence, further procedures were added, tested, and so forth. In due course, Lukjanow and Garvin left the Georgetown project to continue elsewhere[44] and the 'general analysis' method was adopted together with Brown's computational techniques for all subsequent MT research at Georgetown (Macdonald 1963, Zarechnak 1979, Hutchins 1986, Montgomery 2000, Vasconcellos 2000)

The demonstration was also the stimulus for the commencement of MT research by other groups in the United States and Europe, e.g. at the Massachusetts Institute of Technology (Victor Yngve) in the same year, and in the following year at the University of Washington (Erwin Reifler), at Ramo-Wooldridge (Don Swanson), at Birkbeck College, at the University of Milan (Silvio Ceccato), and at the Cambridge Language Research Unit (Margaret Masterman). Within the next few years nearly all the major research groups were well established.[45]

An important by-product of the demonstration was that it encouraged more widespread publication of MT research. Later in the same year, William Locke and Victor Yngve at MIT decided that the time was opportune to found a journal devoted to MT – this was *Mechanical Translation*, whose first number appeared in March 1954. The demonstration had come as a surprise to MT researchers; the newspaper reports of the Georgetown project were the first news many of them had had that Dostert had begun research at his institute. It illustrated in their view that personal contacts were no longer sufficient for researchers to know what each other were doing. The aim of the journal was to provide a forum for researchers to record progress. Its first issue consisted of a bibliography of papers – many then still unpublished – and its next issues were devoted to the printing of the most significant ones written so far.

14. The impact in the Soviet Union

Reports of the demonstration had a major impact in the Soviet Union. It was a propitious time for the development of computers and their applications. After Stalin's death in 1953, the previous prohibitions in this area of technology were lifted, and the first survey of the prospects

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[42] Throughout the late 1950s and early 1960s the Georgetown research group was the largest in the United States and probably in the world.

[43] The fact that the work from1956 onwards at Georgetown was unconnected with the 1954 experiment is often forgotten by critics of the Georgetown group.

[44] Lukjanow set up her own company to develop an MT system; and Garvin transferred with other members of his group to develop his fulcrum method at Ramo-Wooldridge.

[45] For details of this activity see Hutchins (1986) and Hutchins (2000).

was given by Dimitrij Panov, then director of the Institute of Scientific Information, in October 1954. His survey prompted the KGB to support MT research at the Institute for Precision Mechanics and Computer Technology (ITMVT) where Panov had now become deputy director (Gerovitch 2002: 233). A large computer, the BESM, was under construction from 1954 at ITMVT – although this activity was shrouded in secrecy until October 1955.[46] Work on MT using the BESM began in late 1954 (Panov 1960) and the first trials were made soon after the BESM became operational in late 1955.

In early 1954 Panov visited the IBM headquarters in New York and apparently saw a demonstration (Hurd 1980: 406). The next year reports of the Georgetown-IBM experiment began to appear in the Soviet Union. One appeared in June 1955 by Berkov and Ershov (1955)[47]. This was essentially an account much on the lines of those by Macdonald and Ornstein, explaining the basic processes, listing the six rules, including the table for the "Magnitude of angle.." sentence (example 1 in section 11 above, a favourite of US journalists), and explaining how the system dealt with inversion using the *major general* example. In one respect the authors deviated from US reports by describing the selection of prepositions using a their own Russian example, the translation of к as "to" or "for" according the preceding noun: one of these was отношение к "relation to" (as in the demonstration), but the other was любовь к ("love for"), which occurs neither in the 1954 demonstrations nor in Garvin's examples (Garvin 1967). The second article appeared in October 1955 written by two leading figures in Soviet MT research, Ljapunov and Kulagina (1955)[48]. This article also gave examples of translated sentences, the processes involved in translating "Magnitude of angle…" and the six rules; but the authors put the experiment into the context of current work on cybernetics and computer developments – necessary for Russian readers at this time. They report that work on MT had been going on for "almost fifteen years"[49] and that researchers had gathered at a conference in 1952 – which had been mentioned by Macdonald (1954), the principal source for the authors. They end by emphasising the problems of dictionary size, fast access speeds, the need for special-purpose computers to deal with language rather than computation, and the need for automatic print readers.

The ITVMT group developed a system for English-Russian translation, with Izabella Bel'skaja as the chief linguist of the project. By 1956 the institute was ready to demonstrate a prototype system[50]. Like the Georgetown-IBM system it was on a small scale with just 952 English words and 1073 Russian words, and it consisted of a basic set of simple rules for substitution movement and morphological splitting (Zelenkevič et al.1956, Panov 1960). Like the Georgetown system, target language equivalents were reached by a series of binary choices. For example, the rules for translating *much* and *many* were as follows (where the two letters in brackets indicate the next rule if the answer is 'yes' or 'no' respectively, and where a zero (0) indicates the end of the processing for this word.)[51]

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[46] In this month, the BESM was announced at a conference in Darmstadt, West Germany, and shortly afterwards to the Soviet press. Attempts to lift the secrecy earlier had been made by Dimitrij Panov in December 1954, but without success until the political "thaw" under Khrushchev (Gerovitch 2002: 149). One American participant at the conference considered that the BESM compared "favorably in speed and capacity with any American or other European machine" (Gerovitch 2002: 157)

[47] Berkov was a MT researcher who contributed a number of papers to the conferences held in Leningrad in 1958 and 1959, and who, as a member of N.D.Andreev's group in Leningrad, wrote at least one paper jointly with Andreev on interlingual MT; Ershov appears to have made no further contribution to MT after this article. [Information from Mel'čuk & Ravič 1967]

[48] Aleksej Ljapunov was the leading advocate of cybernetics in the Soviet Union, and he was head of the MT group at the Steklov Mathematics Institute, where Olga Kulagina was the chief MT researcher and who remains active in the field to the present day (Kulagina 2000, Mel'čuk 2000)

[49] The period of "fifteen years" does not appear in the authors' Ameican sources. It may indicate that Petr Trojanskij's patent of 1933 and his later research (cf. Hutchins and Lovtskii 2000) were already known before the first mention in 1956 by Panov et al. (1956).

[50] For details of the early Soviet research on MT see Panov et al. 1956 (cf. also Hutchins 1986)

[51] This example is from Panov 1960.

a(b,c) Check preceding word (directly) for *how*
b(0,0) сколько (numeral, not declined)
c(d,e) Check preceding word (directly) for *as*
d(0,0) столько (numeral declined)
e(g,i) Check given word for *much*
f(0,0) Not translated (adverb)
g(f,k) Check preceding word (directly) for *very*
h(0,0) многий (adjective, hard stem, with sibilant)
i(h,j) Check preceding word for preposition and succeeding word for noun
j(0,0) много (adverb)
k(l,j) Check succeeding word for noun
1(0,0) много (numeral, declined)

Superficially there would seem to be some basic similarity of approach in so far as choices of target language equivalents were made through rules of context (i.e. immediately adjacent words). However, whereas the Georgetown system incorporated grammatical and translation rules as part of the dictionary information for specific words and endings and it allowed for only two target language equivalents, the ITMVT system separated grammatical rules from dictionary rules, it allowed for multiple equivalents, and it separated English analysis and Russian synthesis. The most important difference, however, was that the ITMVT system included grammatical information (noun, verb, adjective, strong/weak stem, etc.) in the coding of vocabulary items. This meant that the system could be readily expanded for different subject fields (and even literary translation was attempted, Bel'skaja 1957). Whereas the Georgetown experimenters could and did not continue on the same lines (as described in sections 12 and 13 above), Panov was able to draw some general principles from the early trials which guided subsequent research (Hutchins 1986:133-136) – principally, the separation of the dictionary from the translation program, the separation of analysis and synthesis, the storage of lexical items under stem forms, the inclusion of grammatical information in dictionaries.

15. Longer-term consequences

A persistent and unfortunate effect of the demonstration was the impression given to many observers outside the field of MT that fully automatic translation of good quality was much closer than in fact the case. It was an impression which was to last – in the minds of the general public and indeed with computer scientists outside the MT filed – for many years. Ornstein (1955) had emphasized that such expectations were mistaken:

> The demonstration… represented the successful completion of the first phase of the joint experiment as well as tangible proof that machine translation is possible. The enthusiasm of the publicity surrounding the demonstration tended to create the impression that the problems of automatic translation had largely been solved. This does not correspond to the reality of the situation. Much still remains to be done. Dostert, wishing to curb the tendency to describe the results of the demonstration in excessively glowing terms, has repeatedly referred to it as the "Kitty Hawk" of the experiment.

But Ornstein was almost alone in publications for the general public. The impression given to many observers outside the field of MT was that truly automatic translation was much closer than in fact the case. Even US governmental bodies – such as the Department of Defense and the US Army and Navy, as well as the CIA – accepted optimistic predictions far too uncritically. Sponsorship and funding for US projects were more liberal (and unquestioning) than they ought to have been (Hutchins 1986). The results from MT research in the next 10 years were inevitably disappointing. As a consequence the funders set up an investigation committee, the Automatic Language Processing Advisory Committee (ALPAC), to consider the prospects for MT. Its negative conclusions are now well known (Hutchins 1996); the committee concluded that current MT systems were inadequate and uneconomic and that there was "no immediate or predictable prospect of useful machine translation".

One of the principal arguments used by ALPAC was that MT output had to be extensively post-edited. They pointed out that the output from the Georgetown-IBM experiment was of a quality that had not needed to be edited or corrected, while output from more recent

Georgetown systems did have to be edited. The "deceptively encouraging" early results had not been maintained. The committee compared the quality of a text translated at EURATOM, where a system from Georgetown had been installed in 1963 (Hutchins 1986: 76), with sentences translated by the 1954 experimental system. However, none of the cited examples (ALPAC 1966: 23) were in fact any of those from contemporary reports or in Garvin's article (1967):

> [#1] The quality of crude oil is determined by calory content.
> [#2] The quality of saltpeter is determined by chemical methods.
> [#3] TNT is produced from coal.
> [#4] They obtain dynamite from nitroglycerine.
> [#5] Ammonite is obtained from saltpeter.
> [#6] Gasoline is prepared by chemical methods from crude oil.
> [#7] They prepare ammonite.
> [#8] Gasoline is produced by chemical methods from crude oil.
> [#9] The price of crude oil is determined by the market.
> [#10] Calory content determines the quality of crude oil.
> [#11] TNT is prepared from coal.

Undoubtedly these sentences could have been generated in 1954 from the rules and dictionary entries given by Garvin (1967).[52] One explanation may be that they derived from another demonstration of the system – perhaps later in the year.[53] The discrepancy is not important, however, since the comments by ALPAC were still relevant. Output of this quality did not need any post-editing. What ALPAC can be criticised for is the failure to recognise that the 1954 experiment was specifically designed for a small range of sentences. The committee used the public achievements of the Georgetown-IBM experiment as a touchstone when assessing the output quality of subsequent systems, and in doing so, failed to acknowledge the artificiality of this small-scale demonstrator system. It had not been a 'prototype' system but a 'showcase' intended to attract attention to this new and still largely unknown area of research.

The system demonstrated in 1954 was undoubtedly preliminary, and the output was undoubtedly, in part (the non-chemistry sentences), 'designed' for the particular occasion. In subsequent years it has not been uncommon for vendors of promoters of systems to introduce grammar and vocabulary rules specifically formulated to deal with sentences of a particular demonstration text sample, with the aim of showing their system in the best possible light. It may be done for particular clients or in an exhibition or in a conference demonstration. Vendors may often (justifiably) claim that the extra rules would be incorporated in the final system (as delivered to a user or customer) – and this may well be the case, in the past and in the present. The use of made-up sentences and texts in demonstrations is naturally disliked since the system is not being tested for its true capabilities. The practice may actually rebound upon the practitioners – as it did in the case of the Georgetown-IBM experiment, since in later years members of the Georgetown researchers were often suspected of adjusting their systems for demonstrations.[54]

In retrospect, the Georgetown-IBM demonstration was damaging both to MT at Georgetown and to MT in general. Many researchers and commentators during the 1960s and later have believed that the later Georgetown systems were based upon the methods used in this 1954 system, criticised the group for pursuing crude 'word-for-word' approaches, and this mistaken view has affected the reputation of Georgetown to the present day (see Vasconcellos 2000). As for MT in general, the demonstration created the expectation among the public that good-quality MT was achievable within a matter of years; and it led to an unstated assumption among many MT researchers that high quality MT should be the principal goal of MT

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[52] Except for the translation of singular "putyem" as plural "methods", as noted in section 7 above.

[53] According to the News section of vol.1 no.3 (December 1954) of *Mechanical Translation* a demonstration was given at the American Chemical Society meeting in New York on 14 September 1954.

[54] However, perhaps the only clear case was the notorious demonstration given in September 1961 at the international conference in Teddington (UK) by a group under Ariadne Lukjanow, who had recently left Georgetown to set up her own company. The demonstration produced excellent translations from *Pravda*, but all efforts to test the system on other Russian texts were rejected by the demonstrators – there had clearly been deception (see the accounts by Booth 2000 and Lehmann 2000). However, it was certainly not sanctioned by the Georgetown University MT group.

research[55] – work on aids for translators was considered unimportant and unnecessary.

In recent years MT researchers have been much more circumspect when demonstrating experimental systems and have been less willing to indulge in speculations for journalists. The painful lessons of the Georgetown-IBM demonstration seem to have been learned. On the other hand, there are still many MT systems being publicised and sold (particularly on the internet) with equally exaggerated claims and with potentially equally damaging impact for the future of machine translation.

Fifty years later, the historical significance of the demonstration remains that it was an actual implementation of machine translation on a commercial computer. Before 1954, all previous work on MT had been theoretical, or conducted on paper and punched card simulations. Considering the state of the art of electronic computation at the time, it is remarkable that anything resembling automatic translation could have been achieved at all. Despite all its limitations, the demonstration in January 1954 marked the beginning of MT as a research field seen to be worthy of financial support.

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[55] This assumption was famously attacked by Bar-Hillel (1960), but his argument was accepted generally only after the ALPAC report (1966), when more modest aims were adopted and aids for translators were also developed.

[56] Anonymous accounts in contemporary publications are listed in Appendix III.

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Appendix I:
Garvin's example sentences (Cyrillic, transliterated, and English translations)

[*= reported in contemporary newspapers; # = example in this paper]

1. Приготовляют тол.
PRYIGOTOVLYAYUT TOL
They prepare TNT.
2. Тол приготовляют из угля.
TOL PRYIGOTOVLYAYUT YIZ UGLYA
They prepare TNT out of coal.
3. Тол приготовляется из угля.
TOL PRYIGOTOVLYAYETSYA YIZ UGLYA
TNT is prepared out of coal.
4. Боец приготовляется к бою.
BOYETS PRYIGOTOVLYAYETSYA K BOYU
Fighter is prepared for battle.
5*. Качество угля определяется калорийностью.
KACHYESTVO UGLYA OPRYEDYELYAYETSYA KALORYIYNOSTJYU
The quality of coal is determined by calory content
6. Тол приготовляется из каменного угля.
TOL PRYIGOTOVLYAYETSYA YIZ KAMYENNOGO UGLYA
TNT is prepared out of stony coal.
7. Бензин добывают из нефти.
BYENZYIN DOBIVAYUT YIZ NYEFTYI
They obtain gasoline out of crude oil.
8. Бензин добывается из нефти.
BYENZYIN DOBIVAYETSYA YIZ NYEFTYI
Gasoline is obtained out of crude oil.
9. Аммонит приготовляют из селитры.
AMMONYIT PRYIGOTOVLYAYUT YIZ SYELYITRI
They prepare ammonite out of saltpeter.
10. Аммонит приготовляется из селитры.
AMMONYIT PRYIGOTOVLYAYETSYA YIZ SYELYITRI
Ammonite is prepared out of saltpeter.
11. Спирт вырабатывают из картофеля.
SPYIRT VIRABATIVAYUT YIZ KARTOFYELYA
They produce alcohol out of potatoes.
12. Спирт вырабатывается из картофеля.
SPYIRT VIRABATIVAYETSYA YIZ KARTOFYELYA
Alcohol is produced out of potatoes

13. Крахмал вырабатывают из картофеля.
KRAXMAL VIRABATIVAYUT YIZ KARTOFYELYA
They produce starch out of potatoes.
14. Крахмал вырабатывается из картофеля.
KRAXMAL VIRABATIVAYETSYA YIZ KARTOFYELYA
Starch is produced out of potatoes.
15. Тол приготовляется химическим путем из каменного угля.
TOL PRYIGOTOVLYAYETSYA XYIMYICHYESKYIM PUTYEM YIZ KAMYENNOGO UGLYA
TNT is prepared by chemical method out of stony coal.
16. Аммонит приготовляется химическим путем из селитры.
AMMONYIT PRYIGOTOVLYAYETSYA XYIMYICHYESKYIM PUTYEM YIZ SYELYITRI
Ammonite is prepared by chemical method out of saltpeter.
17*. Крахмал вырабатывается механическим путем из картофеля.
KRAXMAL VIRABATIVAYETSYA MYEXANYICHYESKYIM PUTYEM YIZ KARTOFYELYA
Starch is produced by mechanical method out of potatoes.
18. Цена картофеля определяется рынком.
TSYENA KARTOFYELYA OPRYEDYELYAYETSYA RINKOM
Price of potatoes is determined by the market.
19*(#1). Величина угла определяется отношением длины дуги к радиусу.
VYELYICHYINA UGLA OPRYEDYELYAYETSYA OTNOSHYENYIYEM DLYINI DUGYI K RADYIUSU
Magnitude of angle is determined by the relation of length of arc to radius.
20. Калорийность определяет качество нефти.
KALORYIYNOSTJ OPRYEDYELYAYET KACHYESTVO NYEFTYI
Calory content determines the quality of coal.
21. Обработка повышает качество нефти.
OBRABOTKA POVISHAYET KACHYESTVO NYEFTYI
Processing improves the quality of crude oil.
22. Железо добывается из руды.
ZHYELYEZO DOBIVAYETSYA YIZ RUDI
Iron is obtained out of ore.
23. Медь добывается из руды.
MYEDJ DOBIVAYETSYA YIZ RUDI
Copper is obtained out of ore.
24. Динамит приготовляется из нитроглицерина с примесью инертного материала.
DYINAMYIT PRYIGOTOVLYAYETSYA YIZ NYTROGLYITSYERINA S PRYIMYESJYU YINYERTNOGO MATERYIALA
Dynamite is prepared out of nitroglycerine with admixture of inert material.
25. Возвышение определяется нивелированием.
VOZVISHYENYIYE OPRYEDYELYAYETSYA NYIVYELYIROVANYIYEM
Elevation is determined by leveling.
26 (#4). Угол места цели определяется оптическим измерением.
UGOL MYESTA TSYELYI OPRYEDYELYAYETSYA OPTYICHYESKYIM YIZMYERYENYIYEM
Angle of site is determined by optical measurement.
27. Цена пшеницы определяется рынком.
TSYENA PSHYENYITSI OPRYEDYELYAYETSYA RINKOM
The price of wheat is determined by the market.
28. Цена пшеницы определяется спросом.
TSYENA PSHYENYITSI OPRYEDYELYAYETSYA SPROSOM
The price of wheat is determined by the demand.
29. Цена картофеля определяется спросом.
TSYENA KARTOFYELYA OPRYEDYELYAYETSYA SPROSOM
The price of potatoes is determined by the demand.
30. Дороги строятся из камня.
DOROGI STROYATSYA YIZ KAMNYA
Roads are constructed out of stone.
31. Войска строятся клином.
VOYSKA STROYATSYA KLYINOM
Troops line up in wedge formation.
32*. Мы передаем мысли посредством речи.
MI PYERYEDAYEM MISLYI POSRYEDSTVOM RYECHYI
We transmit thoughts by means of speech.
33. Железо добывают из руды.
ZHYELYEZO DOBIVAYUT YIZ RUDI
They obtain iron out of ore.
34. Медь добывают из руды.
MYEDJ DOBIVAYUT YIZ RUDI

They obtain copper out of ore.

35*. Железо добывается из руды химическим процессом.
ZHYELYEZO DOBIVAYETSYA YIZ RUDI XYIMYICHESKYIM PROTSYESSOM
Iron is obtained out of ore by chemical process.

36. Медь добывается из руды химическим процессом.
MYEDJ DOBIVAYETSYA YIZ RUDI XYIMYICHESKYIM PROTSYESSOM
Copper is obtained out of ore by chemical process.

37*. Динамит приготовляется химическим путем из нитроглицерина с примесью инертного материала.
DYINAMYIT PRYIGOTOVLYAYETSYA XYIMYICHESKYIM PUTYEM YIZ NYITROGLYITSYERYINA S PRYIMYESJYU YINYERTNOGO MATYERYIALA
Dynamite is prepared by chemical method out of nitroglycerine with admixture of inert material.

38. Дома строятся из кирпича.
DOMA STROYATSYA YIZ KYIRPYICHA
Houses are constructed out of brick.

39. Дома строятся из бетона.
DOMA STROYATSYA YIZ BYETONA
Houses are constructed out of concrete.

40*. Военный суд приговорил сержанта к лишению гражданских прав.
VOYENNIY SUD PRYIGOVORYIL SYERZHANTA K LYISHYENYIYU GRAZHDANSKYIX PRAV
Military court sentenced the sergeant to deprival of civil rights.

41. Уголовное право является важным отделом законодательства.
UGOLOVNOYE PRAVO YAVLYAYETSYA VAZHNIM OTDYELOM ZAKONODATYELJSTVA
Penal law constitutes an important section of legislation.

42 (#2). Наука о кислородных соединениях является важным отделом химии.
NAUKA O KYISLORODNIX SOYEDYINYENYIYAX YAVLYAYETSYA VAZHNIM OTDYELOM XYIMYIYI
The science of oxygen compounds constitutes an important section of chemistry.

43. Владимир является на работу поздно утром.
VLADYIMYIR YAVLYAYETSYA NA RABOTU POZDNO UTROM
Vladimir appears for work late in the morning.

44*. Международное понимание является важным фактором в решении политических вопросов.
MYEZHDUNARODNOYE PONYIMANYIYE YAVLYAYETSYA VAZHNIM FAKTOROM V RYESHYENYIYI POLYITYICHYESKYIM VOPROSOV
International understanding constitutes an important factor in decision of political questions.

45. Ведутся переговоры о перемирии.
VYEDUTSYA PYERYEGOVORI O PYERYEMYIRYIYIY
Negotiations are conducted about an armistice.

46. Федерация состоит из многих штатов.
FYEDYERATSYIYA SOSTOYIT YIZ MNOGYIX SHTATOV
The federation consists out of many states.

47. Радиостанция передает последние сообщения о погоде.
RADYIOSTANTSYIYA PYERYEDAYET POSLEDYEDNYIYE SOOBSHCHYENYIYA O POGODYE
The radiostation transmits last/latest communications about weather.

48. Радиостанция передает последние политические известия.
RADYIOSTANTSYIYA PYERYEDAYET POSLEDYEDNYIYE POLYITYICHYESKYIYE YIZVYESTYIYA
The radiostation transmits last/latest political bulletins.

49. Владимир получает большое жалование.
VLADYIMYIR POLUCHAYET BOLJSHOYE ZHALOVANYIYE
Vladimir gets (a) large salary.

Appendix II: Garvin's dictionary entries (selection)[57]

Entry	Equivalents	Codes
-A	OF	131 222 25
	—	132 222 25
-AMYI	BY	131 222
	—	132 222
BO-	BATTLE	222

[57] From Garvin (1967). Evidently, these entries are a later version than those used in the demonstration, since additional codes 122, 132, 142, 152 are provided. These, however, serve merely to distinguish second equivalents (Eng_2) from first equivalents (Eng_1), and have been ignored in the presentation.

BOLJSH-	A LARGE			
	LARGE			
BOYETS	FIGHTER	242		
BYENZYIN	GASOLINE	241	21	
BYETON-	CONCRETE			
DLYIN-	LENGTH			
DOBIVAYUT	THEY OBTAIN	110		
DOMA	AT HOME	151	241	
	HOUSES	152	241	
DOROGI	ROADS	241		
DUG-	ARC			
DYINAMY1T	DYNAMITE	241	21	
FAKTOR-	FACTOR			
FYEDYERATSYIYA	A FEDERATION			
	THE FEDERATION			
GRAZHDANSK-	CIVIL			
-I	OF	131	25	
		132	25	
-IM	BY	131	23	
	—	132	23	
-IMYI	BY	131	222	23
	—	132	222	23
-IX	OF	131	222	23
	—	132	222	23
-IY	—			
-IYE	—	222		
-JYU	BY	131		
	—	132		
K	TO	121	23	
	FOR	122	23	
KACHYESTVO	QUALITY	151	222	
	THE QUALITY	152	222	
KALORYIYNOST-	CALORY CONTENT			
KALORYIYNOSTJ	CALORY CONTENT			
KAMN-	STONE			
KAMYENN-	STONY	151		
	—	152		
KARTOFYEL-	POTATOES			
KLY1NOM	BY A WEDGE	131		
	IN WEDGE FORMATION	132		
KRAXMAL	STARCH	21		
KYIRPYICH-	BRICK			
KYISLORODN-	OXYGEN			
LYISHYENYI-	DEPRIVAL	221		
MATYERYIAL-	MATERIAL			
MI	WE	23		
MISLYI	THOUGHTS			
MNOG-	MANY			
MYEDJ	COPPER	21		
MYEST-	PLACE	151	23	
	SITE	152	23	
MYEXANYICHESK-	MECHANICAL	242		
MYEZHDUNARODN-	INTERNATIONAL			
NA	ON	121	23	
	FOR	122	23	
NAUKA	A SCIENCE	242		
	THE SCIENCE	242		
NYEFT-	CRUDE OIL			
NYITROGLYITSYERYIN-	NITROGLYCERINE			
NYIVYELYIROVANYI-	LEVELING			
O	ABOUT	141	23	
	OF	142	23	
OBRABOTKA	PROCESSING			
-OGO	OF	131	23	
	—	132	23	
-OM	BY	131		
	—	132		
OPRYEDYELYAYET	DETERMINES			

OPRYEDYELYAYETSYA	IS DETERMINED			
OPTYICHYESK-	OPTICAL			
OTDYEL-	SECTION			
OTDYELYENYIYE	DIVISION	121	242	
	SQUAD	122	242	
OTNOSHYENYI-	RELATION	151		
	THE RELATION	152		
-OV	OF	131	222	
	—	132	222	
-OYE	—			
POGOD-	WEATHER			
POLUCHAYET	GETS			
POLYITYICHYESK-	POLITICAL			
PONYIMANYIYE	UNDERSTANDING	242		
POSLYEDN-	LAST			
	LATEST			
POSRYEDSTVOM	BY MEANS OF	23		
POVISHAYET	INCREASES	121		
	IMPROVES	122		
POZDNO	LATE			
PRAV	OF RIGHTS	131		
	RIGHTS	132		
PRAVO	RIGHT	141	242	
	LAW	142	242	
PROTSYESS-	PROCESS			
PRYI	AT	121	23	
	IN	122	23	
PRYIGOTOVLYAYETSYA	IS PREPARED	141		
	PREPARES SELF	142		
PRYIGOTOVLYAYUT	THEY PREPARE	110		
PRYIGOVORYIL	SENTENCED	23		
PRYIMYES-	ADMIXTURE			
PSHYENYITS-	WHEAT			
PUT-	PATH	141		
	METHOD	142		
PYERYEDAYEM	WE TRANSMIT	131		
	TRANSMIT	132		
PYERYEDAYET	TRANSMITS			
PYERYEGOVORI	NEGOTIATIONS	110	241	
PYERYEMYIRYI-	AN ARMISTICE			
	THE ARMISTICE			
RABOT-	WORK	222		
RADYIOSTANTSY1YA	A RADIO STATION			
	THE RADIO STATION			
RADYIUS-	RADIUS	221		
RINK-	THE MARKET			
RUD-	ORE			
RYECH-	SPEECH			
RYESHYENYI-	SOLUTION	121	221	
	DECISION	122	221	
S	WITH	23		
SHTAT-	STATE	121		
	STATES	122		
SOOBSHCHYENYIYA	COMMUNICATIONS	241		
SOSTOYIT	CONSISTS			
SOYEDYINYENYI-	COMPOUND	121	242	
	COMPOUNDS	122	242	
SPROS-	THE DEMAND			
SPYIRT	ALCOHOL	21		
STROYATSYA	ARE CONSTRUCTED	141	242	25
	LINE UP	142	242	25
STROYITSYA	IS CONSTRUCTED	141	222	23
	LINES UP	142	222	23
SYELITR-	SALTPETER			
SYERZHANT-	A SERGEANT			
	THE SERGEANT			
TOL	T.N.T.	241	21	

TSYEL-	TARGET	131 25
	—	132 25
TSYENA	PRICE	151
	THE PRICE	152
-U	TO	131
	—	132
UGL-	COAL	121 25
	ANGLE	122 25
UGOL	ANGLE	
UGOLOVN-	PENAL	242
UTROM	IN THE MORNING	
V	IN	121 23
	TO	122 23
VAZHN-	AN IMPORTANT	
	IMPORTANT	
VIRABATIVAYETSYA	IS PRODUCED	
VIRABATIVAYUT	THEY PRODUCE	110
VLADYIMYIR	VLADIMIR	241
VOPROS-	QUESTION	121
	QUESTIONS	122
VOYSKA	TROOPS	242
VOZVISHYENYIYE	ELEVATION	
VYEDUTSYA	ARE CONDUCTED	21
VYELYICHYINA	MAGNITUDE	
XYIMYI-	CHEMISTRY	
XYIMYICHYESK-	CHEMICAL	242
-Y	OF	131 222
	—	132 222
-YA	OF	131 221 25
	—	132 221 25
YAVLYAYETSYA	APPEARS	141 23
	CONSTITUTES	142 23
-YAX	—	222
-YE	TO	131 221
	—	132 221
-YEM	BY	131
	—	132
-YI	OF	131 25
	—	132 25
-Y1M	BY	131 23
	—	132 23
-YIX	OF	131 222 23
	—	132 222 23
-Y1YE	—	222
YIZ	OUT OF	23
YIZMYERYENYI-	MEASUREMENT	
YIZVYESTYIYA	BULLETINS	
-YU	TO	131
	—	132
ZAKONODATYELJSTV-	LEGISLATION	
ZHALOVANYIYE	SALARY	
ZHYELYEZO	IRON	21

Appendix III: Selection of contemporary reports

[* = available in Machine Translation Archive (http://www.mt-archive.info]

United States

Albuquerque Tribune, 8 Jan 1954: ‘Machine to ‘read’ needed to translate’

Binghampton Press, 8 Jan 1954: ‘Smartest electronic brain is learning, IBM computer now translates Russian’

Binghampton Sun, 8 jan 1954: ‘IBM unveils electronic translator, a 12-machine version of the old pony’

Boston Post, 7 Feb 1954: ‘It translates Russian!’, by Frank G.Jason

Boston Traveler, 8 Jan 1954: ‘Mechanical translator may hurdle language barrier in few seconds’

Brooklyb Daily, 13 Jan 1954: ‘Robot brain’ translates Russian’

Brooklyn Eagle, 8 Jan 1954: ‘Electric translator is latest ‘miracle’’ [*]

Cambridge Banner (Maryland), 30 Jan 1954: ‘Looking at life’, by Erich Brandeis [also syndicated by King Features Syndicate, Inc.]

Chemical and Engineering News, 25 Jan 1954, pp.340-341: ‘Electronic brain translates Russian’ [*]

Chemical Week, 30 Jan 1954, pp.46-47: ‘Polyglot brainchild’ [*]

Chicago News, 8 Jan 1954: ‘Electronic brain has vocabulary, translates, too’

Cincinnati Times-Star, 8 Jan 1954: ‘Even Russian is translated electronically’

Christian Science Monitor, 11 Jan 1954: ‘Robot translates nimbly’, by Harry C. Kenny [*]

Christian Science Monitor, 13 Jan 1954 [editorial, also syndicated] [*]

Computers and Automation, vol.3 (2), 1954, pp.6-10: ‘Language translation by machine - a report of the first successful trial’, by Neil Macdonald [*]

Dallas Times Herald, 13 Jan 1954: ‘Robot’ translates Russain language’

Denver Post, 31 Jan 1954: ‘Electronic machinery translates languages’, by Gene Lindberg

Detroit Free Press, 8 Jan 1954: ‘Translates: electronic brain now a linguist’ [syndicated by Associated Press]

Detroit News, 8 Jan 1954: ‘Smart in any language: iron brain thinks English on diet of Russian words’

Electrical Engineering, March 1954, pp.287-288: ‘Russian translated into English by electronic computer in a few seconds’ [*]

Fort Worth Press, [Jan?] 1954: ‘Machine must ‘read’, too’

Forth Worth Star Telegram, 8 Jan 1954: ‘New mechanical translator even understands Russian’

Framingham News (Mass.), 11 Jan 1954: ‘Electonic ‘brain’ to translate from Russian’

Gary Post Tribune (Indiana), 8 jan 1954: ‘Beats phone’

Glendale News Brief (California), 13 Jan 1954: ‘Where machine fails’ [also in: *Monrovia News-Post* (Ca.)]

Hunting Park Signal (California), 8 Jan 1954: ‘Language brain’

Jamestown Post-Journal (N.Y.), 15 jan 1954: ‘Electronic brain translates Russian into English’ [*]

Journal of the Franklin Institute, March 1954, pp.257-260: ‘Electronic translation’ [*]

Lewiston Sun (Maine), 14 Jan 1954: ‘Translating by machine’

Los Angeles Times, 9 Jan 1954: ‘Electronic brain may be near as translator’ [*]

Mechanical World, December 1955, pp.534-535: ‘Language translation by electronic computer’, by W. Schweisheimer [*]

Minneapolis Star, 8 Jan 1954: ‘Electronic ‘brain’ eats up Russian, spits out English’

Newsweek, 18 Jan 1954, p.83: ‘The bilingual machine’ [*]

New York Catholic News, 16 Jan 1954: ‘Electronic brain IBM and Georgetown revised can translate Russian’

New York Daily News, 8 Jan 1954: ‘Device ‘reads’ Russian lingo’

New York Herald Tribune, 8 Jan 1954, p.1: ‘It’s all done by machine: words go in in Russian, English sentences come out’, by Earl Ubell [also syndicated as ‘Electronic ‘brain’ translates Russian into English in seconds’] [*]

New York Herald Tribune, 10 Jan 1954: ‘Electronic linguistics’ [editorial] [*]

New York Herald Tribune, 15 Jan 1954: ‘A word on languages’, letter from Mario Pei [*]

New York Journal American, 8 Jan 1954: ‘Brain’ makes like wolf’

New York Journal of Commerce, 8 Jan 1954: ‘IBM electronic brain translates Russian’

New York Mirror, 8 Jan 1954: ‘IBM ‘brain’ translates Russ without red tape’, by Richard Wilson

New York Times, 8 Jan 1954, p.1: ‘Russain is turned into English by a fast electronic translator’, by Robert K.Plumb [*]

Oklahoman, 25 Jan 1954: ‘Electrical brain can now translate foreign languages’, by Alice Hughes [syndicated]

Owosso Argus-Press (Michigan), 14 Jan 1954: ‘Modern machines do wonders,but there’s possible errors’

Pittsburgh Press, 8 Jan 1954: ‘Translators,beware! You can be replaced’

Presque Isle Star Herald (Maine), 28 Jan 1954: ‘New IBM electronic machine changes Russian into English’

Scholastic, 20 Jan 1954: ‘Translating machine’

Science, 122, 21 October 1955, pp.745-748: ‘Mechanical translation: new challenge to communication’, by Jacob Ornstein [*]

Science News Letter, 23 Jan 1954: ‘Language translation by electronic “brain”’ [*]

Scranton Times (Pennsylvania), 8 Jan 1954: ‘Device hurdles word barriers’

St.Louis Post-Dispatch, 24 Jan 1954: ‘Machine that translates Russian into English’

St.Louis Register, 22 Jan 1954: ‘Mechanical translator’

Topeka State Journal, 8 Jan 1954: ‘Mechanical translator puts foreign language into English’

Wall Street Journal (New York), 8 Jan 1954: ‘IBM designs computer to translate Russian sentenecs into English’

Washington News, 9 Jan 1954: ‘Translating machine invented by experts’

Washington Post, 8 Jan 1954: ‘Brain’ types out English from Russian’

Washington Star, 19 Jan 1954: 'Breaking the language barrier'
Washington Times Herald, 8 Jan 1954: 'Robot brain' translates Russian into King's English', by Harry Gabbett [*]
Weeling Intellingencer (W.Virginia), 22 Jan 1954: 'Robot 'brain' being developed to translate Russian' [syndicated by United Press]
Worcester Telegram (Mass.), 8 jan 1954: 'Electronic brain now translates languages', by John Geiger
World-Telegram & The Sun (New York), 8 Jan 1954: 'IBM 'brain' now used to translate Russian', by Helen T. Emery.

Canada

Daily Gleaner (Fredericton), 6 Feb 1954: 'Translating device'
Le Droit (Ottawa), 12 Jan 1954: 'L'I.B.M. présente une machine qui peut faire dela traduction'
Globe and Mail (Toronto), 12 Feb 1954: 'Electronic translations possible in five years' [*]

United Kingdom

Daily Express, 12 Jan 1954
Daily Mail, 6 Feb 1954: 'Noel Barber meets the brain' [*]
Financial Times, 26 Jan 1954
Financial Times, 1 March 1954: 'The electronic translator' [*]
News Chronicle, 8 Jan 1954: 'This robot translates Russian'
Star, 8 Jan 1954: 'Auto-brain translates'
The Times, 9 Jan 1954: 'Language machine demonstration: texts translated' [*]

France, Germany

Berliner Zeitung, 25 Jan. 1954: 'Das übersetzende elektronische Gehirn'
Le Monde, 9 Jan 1954: 'Un traducteur éléctronique', by C.-G.B.
Der Zeitgeist, 26 Feb 1954: 'Eine neue Wunder-Maschine'