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Memorandum

A SHORT HISTORY OF CADET

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A SHORT HISTORY OF CADET

by

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ABSTRACT

Outlines the history of the first all-transistor digital computer providing a regular computing service. Gives final details of serviceability and transistor failures, including the state of all transistors when the computer was dismantled in December 1959.

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1. History

The experimental transistor digital computer CADET in Building 347.3 was dismantled in December 1959. It was almost certainly the first all-transistor general-purpose digital computer to operate in Britain, and was probably the first in regular service anywhere, including the U.S.A.

Electronics Division began to study the use of transistors early in 1953, when point-contact transistors first became available in this country. One outcome of this early work was a bistable circuit,(1) using only one transistor, which had obvious applications in digital computers. Assembly of a small computer(2) based on this circuit was started in the Spring of 1954, with the dual objects of producing a useful computer and also gaining experience of the use of transistors in what was then regarded as large numbers. The supply of junction transistors was then so precarious that it appeared to be a bold decision to rely on obtaining ten for use in the amplifiers of the magnetic drum store.

The arithmetic section of the computer was operating in conjunction with a makeshift store by the Autumn of 1954. In March 1955, just about a year after assembly had started, the computer was running on simple test programs. A year of intensive testing and development followed. A new magnetic drum store, to an N.P.L. design, was built at A.E.R.E. and installed during the first months of 1956. Several members of Theoretical Physics Division then began to give valuable assistance in developing the art of writing programs for CADET. Demonstration programs written for the A.E.R.E. Open Week, in May 1956, ran without mishap before 'full houses' for several days and showed that CADET was ready for serious computing work. A regular computing service opened on 2nd August 1956 with a program for Fourier Synthesis of crystal structure data. Later versions of this program provided the main load for the computer over the next three years.

During the Autumn of 1956 the mean interval between computing errors was barely enough to permit unattended operation throughout the night, which was desirable in a computer of quite modest speed. A determined effort, early in 1957, to detect and correct poor connections and minor design errors greatly improved the reliability, and continuous operation during nights and weekends became a regular feature. The early point-contact transistors were not hermetically sealed, but merely protected with an inert grease, and it was soon apparent that the incidence of transistor failures increased whenever the computer was switched off. Whenever it was idle the computer was therefore kept running on repetitions of previous work, so that not only was the transistor failure rate reduced but also the reliability of the computer under genuine working conditions was always under observation. A daily preventive maintenance routine tested:

a) the transistor circuits; by applying a 50 c.p.s. modulation to sensitive d.c. supply lines while the computer was running on test programs which generated random patterns of digits. This section of the maintenance routine was entirely self-checking and required no attention - but did not diagnose any faults which it detected.

b) the magnetic drum store; by (manually) varying the strobing of the read signals, using a standard test pattern of digits on all tracks of the drum.

2. Operating Performance

Table I summarises the operating performance[3] of CADET in the three years September 1956 to August 1959, i.e. omitting August 1956 for which there is not a complete record and September-December 1959 when the computer appeared to be serviceable but was not tested.

TABLE I

Operating Performance of Cadet

Period	% of Total Time							Transistor failures(2)		
	Serviceable			Unserviceable						
	Productive	Non-productive	TOTAL	Maintenance in progress	Maintenance required (1)	Switched off (1)	TOTAL	Detected During Maintenance	In Service	TOTAL
Sept. '56-Aug. '57	45	23	68	8	5	19	32	28	8	36
Sept. '57-Aug. '58	28	57	85	5	4	6	15	4	2	6
Sept. '58-Aug. '59	61	24	85	4	11	0 (3)	15	8	11	19
Sept. '56-Aug. '59	45	34	79	6	7	8	21	40	21	61

Notes: (1) In general both 'Maintenance Required' and 'Switched Off' refer to computer faults occurring outside staff working hours or requiring maintenance extending over several days.

(2) This excludes transistors which were destroyed by short-circuits etc. during maintenance work. A transistor was recorded as having failed when it had caused misoperation of the computer (in service or during preventive maintenance) and was subsequently found to have characteristics outside the initial acceptance limits.

(3) Cadet was actually switched off for only 17 hours during this year.

Transistor failures averaged 0.6% per 1000 hours during the three year period, but the first year was exceptional in that some weeding-out of inferior transistors was taking place and the computer was allowed to shut-down frequently. In the last two years the transistor failure rate was only .35% per 1000 hours, equivalent to roughly one replacement per month. The proportion of point-contact to junction transistors changed during the life of the computer (due mainly to modifications in the amplifier circuits), but on the basis of the final count of 299 point-contact and 102 junction transistors the respective failure rates over three years were 0.7% and 0.15% per 1000 hours.

3. Final state of transistors

Point-contact transistors used in CADET were tested in accordance with an acceptance specification formulated at an early stage of the work. It is therefore relevant to enquire how closely this specification represented the actual requirements of the computer circuits. Two questions should be asked: 'How many transistors which gave trouble were still within the limits set by the specification', and 'How many transistors which worked satisfactorily in the computer were actually outside specification'. With very few exceptions all transistors which gave trouble were found to be outside the specification limits, and most of the exceptions were obviously abnormal transistors e.g. extremely low I_{CO}. The second question could not be answered without seriously disturbing the computer, but all transistors were tested when CADET had been dismantled, with the results shown in Table II.

A less hurried test would probably have revealed more 'floating emitter' faults (see Proc. I.E.E. Part B, March '59 p.224). Nevertheless, the situation was obviously much more satisfactory than that in an early valve computer where, it was said, a similar test showed that half of the valves in the computer were outside specification and half of those which had been removed from the computer were still inside specification.

TABLE II

State of point-contact transistors within a few hours of final shut-down of CADET

CIRCUIT		DEFECTIVE TRANSISTORS		REASON FOR REJECTION		
TYPE	QUANTITY	TYPE	QUANTITY	V_o	I_{co}	FLOATING EMITTER
Standard Bistable	151	GEC (1)	2	1	1	0
		TP1 (2)	4	0	0	4
		STC	11	1	0	10
		TOTALS	17 (11%)	2	1	14
Standard Monostable	64	GEC (1)	1	1	0	0
		STC	1	0	0	1
		TOTALS	2 (3%)	1	0	1
Other circuits (Specification not relevant in many cases)	74	GEC (1)	5	3	2	0
		STC	7	4	0	3
		TOTALS	12 (16%)	7	2	3

Notes (1) GEC Types EW51 and EW61.

(2) STC Type TP1 Supplied by courtesy of Metropolitan-Vickers Ltd. Manchester. These had been recovered from the point-contact transistor versions of the Metrovick 950 computer.

4. Conclusions

In three years CADET ran for approximately 12,000 hours on useful computing work. The majority of this time was occupied with crystal structure work for Metallurgy and Chemistry Divisions. Other work included several smaller problems for the Cosmic Ray Group of N.P. Division, and a Monte Carlo problem for Electronics Division. Throughout its life CADET was a popular demonstration, and many visitors to A.E.R.E. have been on conducted tours to just three exhibits: BEPO, Isotope Handling Hall, and CADET.

The main lessons learnt from CADET were as follows:

a) Cadet showed conclusively that even poor transistors can be used to produce a remarkably reliable computer. Failures of resistors, capacitors, and diodes were negligible.

b) The general ease of application of transistor circuit techniques was shown by the reliable performance achieved in spite of very haphazard and piece-meal construction. The problem of suppressing interference from relay

circuits in the associated punched card machines proved to be much more difficult than was expected.

c) Design errors in the circuitry were corrected very easily compared with equivalent errors in the mechanical design of the magnetic drum store.

d) The programming aspects of a proposed logical design for a computer are often investigated in advance by dummy programming exercises, whereas assembly and logical design of Cadet proceded concurrently. The logic used certainly facilitated early completion of the project but it also made programming so difficult compared with Mercury Autocode that it was inevitable that Cadet fell into disuse.

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(3) Barnes, R.C.M., and Stephen, J.H. : "Operating Experience with a Transistor Digital Computer", ibid., Paper No. 2593M, April 1958 (106, Part B, p.222).

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