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Dept. 910, Bldg. 965
November 25, 1958

MEMO TO: Mr. S. W. Dunwell

SUBJECT: Card Punching on Project 7000 Systems

REFERENCE: 1. Your memo to Mr. D. W. Sweeney dated October 28, 1958
2. Your memo to Mr. H. K. Wild dated October 28, 1958

1. This memo attempts to compile those considerations pertinent to the review requested in reference 1. This review was intended to consider the feasibility of dropping the 250 card per minute punch from the planned program for Project 7000.

2. References 1 and 2 assume that the functions performed by a card punch are replacable by a variety of devices. These include the 024 punch, paper tape devices and/or a low cost tape recorder. It is implied that these devices give total equivalence to the punching function when used individually or collectively as required. Further, the assumption is made that a sufficiently low volume of punched output or equivalent is developed so that the speed of the output may be eliminated as an important parameter.

3. Any considerations involving attachment or removal of devices from the Project 7000 Systems must include the following:

   (a) Fundamental operating philosophy of Project 7000 Systems.
   (b) Usage of this attachment relative to this operating philosophy.
   (c) The attachment characteristics and base of usage.

4. The fundamental operating philosophy of Project 7000 Systems to date has been the ability to operate all equipment "on-line". Thus any attachment is capable of being operated in one of two modes. The first is direct use by the program in operation. The second is indirect use equivalent to peripheral operation through multiprogramming techniques. To aid in this goal much effort has been expended in multiplexing the Exchange, generalizing the interrupt system, full generality in I/O instructions and the control word functions, etc. Removal of a card punch and emphasis on the substitution of peripheral punching is certainly a direct contradiction of this philosophy.

5. Your memo, reference 2, notes the following four points as the uses of a card punch.

   (a) The punching of program cards, etc, for re-entry at a later time.
   (b) Preparation of returnable documents, such as checks, bills, etc.
   (c) Communication with EAM installations.
   (d) Manually accessed record files.

6. Points (a), (b) and (d) should be considered in two ways: Primarily, at present, we are concerned with scientific processing. Thus points (b) and (d) become the "etc". of point (a). Punching of program cards is not something which most customers will consider giving up. The binary card serves as a easily handled, compact storage device, which considered with 1000 card per minute reading ability becomes extremely useful. As is illustrated in the accompanying reports, the cost of tape reels in quantity both from usage and storage considerations in addition to low information volume is causing a return to punched cards.

Examination of the following tables shows the reasonableness of using punched cards for intermediate program storage. Table 1 gives the number of cards generated by 700 Systems and 7000 Systems for the indicated number of program binary words. The cards will also contain additional control information. Table 2 indicates the time used at the respective punches. Table 3 indicates the time required at the respective readers.

Table 1 No. Binary Cards

Wds.	700 Systems @22 wds/cd.	7000 Systems @ 14 wds/cd.
100	5	8
250	12	18
500	23	36
1000	46	72
2000	91	143

Table 2 Punching Time

Wds.	700 Systems @ 100 cds/min	7000 Systems @ 250 cds/min
100	3.0 sec.	1.92 sec.
250	7.2 sec.	4.32 sec.
500	13.8 sec.	8.64 sec.
1000	27.6 sec.	17.28 sec.
2000	54.6 sec.	34.32 sec.

Table 3 Reading Time

Wds.	700 Systems @ 250 cds/min	7000 Systems @ 1000 cds/min
100	1.20 sec.	.48 sec.
250	2.88 sec.	1.08 sec.
500	5.52 sec.	2.16 sec.
1000	11.04 sec.	4.32 sec.
2000	21.84 sec.	8.58 sec.

From tables 2 and 3 we note that a reasonable amount of information is discharged or returned to the system in a very reasonable amount of time. As the basic premise of the STRETCH operating philosophy is considered, i.e. multiprogramming of card input and output, these times become very desirable.

For comparison, we show the characteristics of alternative devices. Note the sharp increase in Memory time required for information discharge. For each of these devices some data handling ability is reduced.

Low Cost Incremental Tape Drive

Writing rate = 175 character per second
The information, in binary, must be expanded so that 6 bit groupings result. The following table considers the expansion and writing times.

Original	Expanded	Character	Time
100 words	134 words	1067	6.10 sec.
250 words	334 words	2668	15.25 sec.
500 words	667 words	5334	30.48 sec.
1000 words	1334 words	10667	60.95 sec.
2000 words	2667 words	21334	121.34 sec.

Thus putting the information on this type of tape requires 1/3 more storage and 4 to 6 times the time for discharging the information from memory.

Paper Tape

Writing rate = 20 characters per second
It is assumed here that eight bit bytes can be punched as is. Therefore the following observations can be made.

100 words	800 characters	40.0 sec.
250 words	2000 characters	100.0 sec.
500 words	4000 characters	200.0 sec.
1000 words	8000 characters	400.0 sec.
2000 words	16000 characters	800.0 sec.

024 Punch

Writing rate 18 columns per second. Each column contains 4 bits of punching. Thus, with no byte converter, we require spreading. Permits 4 information words and one control word.

100 words	200 words	1600 characters	125.00 seconds
250 words	500 words	4000 characters	315.00 seconds
500 words	1000 words	8000 characters	625.00 seconds
1000 words	2000 words	16000 characters	1250.00 seconds
2000 words	4000 words	32000 characters	2500.00 seconds

Micro-coding

Allows 2 words of information plus one control word. Printing rate of approximately 100 documents per minute.

100 words	50 documents	30.00 seconds
250 words	125 documents	75.00 seconds
500 words	250 documents	150.00 seconds
1000 words	500 documents	300.00 seconds
2000 words	1000 documents	600.00 seconds

The above ignores possibility of coincident printing.

Thus all the substitute devices require quite a bit of extra time compared to outright punching. Furthermore the following considerations apply. When information is written on tape, it must be stored in sequence. In order to use the information associated with a particular program, noting that for efficiency we stored small segments of information for many different programs, we must undertake a program analysis for retrieval and consequently most of the internal (or CPU) facilities of the system. The relatively simple operation of replacing a punched card in a manually accessed file (i.e. the program deck) is replaced by a complex tape file maintenance operation. These points do not facilitate speed or effectiveness of operation. Rather they substitute the fallacy of apparently rapid operations accomplishing something. As indicated in attached survey quotations, the volume of tapes in use currently for such purpose is becoming prohibitive.

Having considered the program processing of binary information, we should examine the record mode of considering points (a), (b) and (d) in terms of non-binary usage. Here we find use for intermittent punching of an occasional card for control purpose and progress analysis. These are the cards which generally fit as elements of manually accessed files. As indicated by the number of punches attached to 700 systems, it is clear that this function is basically required regardless of the availability of peripheral punching ability.

Finally, the use of the system for commercial processing, as indicated in your memo, reference 2, clearly does not warrant attaching the devices specified. Particularly micro-coding per returnable documents, where it is assumed that octal information can be imposed on the reader. This notion implies that the document receiver neither knows or cares what is printed (or punched). On the contrary, more and more people receiving such documents are interested in the relationship of the printed and punched information. Such an awareness is even considered an essential element of one or two accounting procedures on the theory that the consumer has his own interests most closely at heart.

7. Point (c) of your memo, reference 2, indicates that Project 7000 systems will have little or no communication with an EAM installation. If we consider only scientific systems, this point has a great deal of merit. However if Project 7000 Systems are used for commercial processing, this point is not in order. At present and for the for foreseeable future, commercial installations are supplemented by EAM installations. Punched cards in extreme volume are punched peripherally because on-line punching ties up the system completely. However with the Project 7000 Systems, eight tapes (729-IV) may be operating and one can still be punching cards on-line. Therefore, a return to on-line punching is both feasible and desirable. Further these points augment the need for a 250 card per minute punch. Clearly this tends to a cleaner systems problem and can eliminate the need for intermediate tape handling.

   Future developments of a less expensive Project 7000 System aimed at the commercial market will certainly find lack of punching a severe restriction.

8. Much of the basis for considering elimination of the 250 card per minute punch stems from cost considerations in terms of rental. You point out that "tape to card conversion can be accomplished with off-line equipment at a cost no greater than that of an on-line STRETCH card punch." As has been indicated earlier, a need exists for some form on-line punching particularly in scientific installations where installations records show an on-line punch in addition to (or in spite of) additional peripheral punching.

Rental for 100 card per minute peripheral punch is:

$1400 - Tape Control
$ 275 - Punch with column binary modification
$ 550 - 727 Tape Drive or $700 for 729-I Tape Drive.

Thus, the rental approximates $2225 or $2375 at first glance. Correspondingly for 250 card per minute peripheral reader:

$2400 - Tape Control
$ 225 - Reader with column binary modification
$ 500 - 727 Tape Drive or $700 for 729-I Tape Drive.

Thus, the rental approximates $3175 or $3325.

Relative to Project 7000 Systems these rentals contain an element of illusion. With the Reader we desire a 729-I so that Write-Read checking is possible. With the Punch we require only a 727. However, these tape drives are incompatible with the standard Project 7000 System Tape Drives namely the 729-II or 729-IV. Thus, we must use 729-I's on the Punch, for compatibility and a minimum of one extra drive for assured usage in the event one drive is down. Hence the total rental for the peripheral units becomes $6400. Compared to the approximation of $7000 to $8000 for Project 7000 on-line units we get 40% effectiveness in punching and 25% effectiveness in Reading for 80% to 91% of the Rental. When one considers the additional costs of tape handling, operator error, etc., the cost of off-line operation is probably appreciably in excess of the on-line operation.

As of September 17, 1958, associated with 80 - 704 main frames in operation were 76 - 721 punches and 27 - (758 - 722) punches. In total inventory i.e., installed, shipped and uninstalled and on order, 94 - 704 main frames associated with 104 - 721's and 34 - (758 - 722) punches.

The survey, attached, from the Western region points out that an analysis of costs indicates peripheral card punching equipment in particular is uneconomical with 704 systems. This raises the question of why are people using it? With 704's and 705's the answer is clear. The effect of system stoppage while punching provided the necessary impetus toward peripheral processing. Originally it was hoped that the DSU and control word of the 709 would cure this. However due to the inadequacies of the trapping control, the hoped for actions did not result. Instead, the customers agreed to peripheral mode with column binary RPQ's attached. Note that in this process even though mixed cards i.e. column binary and Hollerith, may be intermixed while reading, the operator must control punching with an external switch. Again full flexibility of operation is eliminated.

Note further from the Western survey that almost all 709's will have a tape-to-card; they will also have an on-line punch. A check of the orders on hand indicates this is true for all regions.

Clearly equivalent rental is not the only important point in costs. Additional tape unit requirements, processing time, handling errors etc., all enter into the cost picture. Furthermore, since a large element of the cost is in the electronics required for attachment, it is not evident that the substitute items will really be attachable at any real savings.

9. With reference to cost and the feeling that a 250 card per minute punch attachment to STRETCH is too expensive let us consider the effect of a 100 card per minute parallel punch. For consistency we assume 11 binary information words and one control word per card.

100 words	10 cards	6.00 seconds
250 words	23 cards	13.80 seconds
500 words	46 cards	27.60 seconds
1000 words	91 cards	54.60 seconds
2000 words	182 cards	109.20 seconds

The speed of operation appears quite reasonable until one considers the requirement of transposition imposed on the reading operation (or alternatively prior to the punching). For most uses, it was agreed long ago, such an operation is very undesirable. However, a modification of the present off-line punch might be feasible. Such a device would be required to switch to or from column binary electronically rather than under operator control. This modification might raise the cost and attachment costs must still be considered. Thus, this approach has questionable value.

In any case, the thesis of low or no operational cost, ignoring punch rental is valid only for an on-line punch.

10. It has been suggested that all programs in the system once entered will be retained on tape. This assumes something favoring one of the following two possibilities.

(a) The first possibility is that programs will be stored sequentially as independent files. This concept has some merit until one analyzes the file maintenance problem associated with any given program being run. Many programs (in fact most programs) are dynamic. As knowledge of the program output increases the program is altered, almost continuously in many cases. Thus, almost every time a program is run, one must rewrite the entire tape. Such a situation is most obvious when a given set of programs is in the debugging state.

(b) The second possibility derives from a solution to the difficulties encountered in the first. Namely write each program on a separate tape and let the programmer be responsible for it. As has been pointed out, with amplifications in the appendix, this leads to extremely large quantities of tape with only short sections used. The following table considers a range of programs up to 10,000 words or up to 20,000 instructions.

No. Words	No. Words 6 bit bytes	No. Words 8 bit bytes	Inches of 729-II 200 bpi	Inches of 929-IV 556 bpi	Inches of SWIFT 2200 bpi
100	1064	800	5.32	1.91	.36
250	2672	2000	13.36	4.81	.91
500	5336	4000	26.68	9.60	1.82
1000	10672	8000	53.36	19.19	3.64
2000	21336	16000	156.68	38.37	7.27
5000	53336	40000	266.68	95.93	18.18
10000	106672	80000	533.36	191.86	36.36

From this we can see the relatively low volume of tape used for even a large size program. The number of cards required to hold the same information is given below in two ways.

	12 info. words	14 info. words	Seconds of Punching Time	
No. Words	ECC Mode Cards	Non Ecc Mode Cards	ECC	Non ECC
100	9	8	2.16	1.92
250	21	18	5.04	4.32
500	42	36	10.08	8.64
1000	84	72	20.16	17.28
2000	167	143	40.08	34.32
5000	417	358	100.08	85.92
10000	834	715	200.16	171.60

Again, consideration of a multiprogrammed card punching operation makes all these times very reasonable. The reading time, at 1000 cards per minute, is in the worst case only 50.04 seconds for the 834 card deck. Again quite reasonable. Thus we may see that program storage on tape seems a relatively foolish thing to do. Certainly we, as system builders, should not try to force this course of action on our customers. Note further that while ECC mode requires a little more time it saves quite a bit of time when one gets the information into the system. In particular check summing techniques can be eliminated on read-in or punch-out.

II. Conclusions

(a) To fully utilize the generality of STRETCH, the ability to punch cards is mandatory.

(b) Functions performed by the miscellany of alternative devices proposed are not equivalent to the full functional and operational capability of a card punch.

(c) Communication with human beings and EAM equipment is still a paramount consideration. IBM's basic business is still in the punched card field.

(d) Adoption of higher speed magnetic tapes and disks immensely enchances the necessity for a high speed card punch of the 250 card per minute variety. This is particularly true of projected commercially oriented systems.

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EWC:pf

cc: Mr. D. W. Pendery
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APPENDIX

The attached quoted reports serve as a guide from the field for a re-awaking of interest in punched cards. They indicate generally that slowly a general problem relative to quantities of tape reels and tape-to-tape operating economics is developing.

Underlined items were done by me as were the supplemental comments.

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From Dr. H. G. Kolsky's meeting report dated October 23, 1958 after meeting with the STRETCH Mathematic Planning Group.

" 9. Punch Requirements on STRETCH.

The whole area of STRETCH I/O equipment is being reviewed at IBM. Some of the questions under discussion are: Is on-line card punching necessary on STRETCH? What are the main uses for punching? What is the "best" speed for a punch? How sensitive are the uses to punch speed.

In the discussion which followed, it was generally agreed that on-line card punching volume will be quite small, restricted mainly to control cards and file reference cards. It was also agreed, however, that these uses were very hard to accomplish any other way.

Another point made was that the distinction between "on-line" and "off-line" becomes a little obscure where one has a multiprogrammed card to tape operation going on at the same time another calculation is proceeding. Under these conditions, the higher the card punching rate the better.

If there is only a slow punch (in particular, 100 per minute) on the machine, the volume punching would be put on off-line tape to card equipment. A high speed punch would encourage multiprogrammed "off-line" operation on the machine. The extra space and cost of the peripheral card equipment was discussed.

As background information: LASL has an order a peripheral tape-to-card machines.

The reason for ordering the tape to card machine was not so much to speed up 704 operation as to reduce the impossible tape library situation which has developed. They have about 1500 tapes on file with more needed all the time. The only practical way to release these tapes is to provide for convenient card storage of the old tape information.

There has been a steady decrease in the amount of on-line punching on the 704's at LASL mainly because of machine speed considerations. Unfortunately this reduction in punching has generated the above tape file bottleneck."

The underlining is supplied by myself. It serves to call attention to inadequate usage of card storage generated by an attempt to minimize time on the 704 processing at a cost of $50.00 per tape reel. It is my understanding that many of these tapes are inadequately filled.

Note that this observation confirms the point made by Dr. Brooks in his "7000 operating techniques Memo No. 2 dated September 11, 1958 relative to the excessive tape handling in the Research Computing Center. Emphasis is placed on the short sections of tape actually used. A check of the PDL Computation Center also indicates a large humber of tapes used for which duplicate cards retained for insurance.

A survey of the Western Region determined the following:

"1. On-line punches are used almost exclusively for the punching of binary cards which are the result of either assembling or compiling. The punch process never overlaps any other machine function.

2. The approximate percentage of time used is not known specifically. Estimates run from less than 5% to approximately 12%.

3. It would appear that if we had faster punches, there would be less justification, at least financially for receiving an off-line punch.

4. The trend for 709's appears to be that all jobs will run completely tape to tape. While this aesthetically pleasing, there again appears to be some question as to whether or not it is justifiable economically. Almost every 709 in the Western Region will include a tape to card unit.

Don Furth made an attempt to determine a break-even point where the monthly cost of using the entire system as a card punch equalled the rental of off-line equipment. From this it does not appear that off-line equipment is justified for the 704 in spite of the fact that almost all installations have this equipment."

Note: This survey indicates the operational considerations pertinent to 704 operations and the projection to 709 operations. It is clear that the general problem of over abundant tape reel suplies may well become a focal point of cost reduction when systems personnel and cost accountants really start watching operations more closely.

Comments solicited from United Aircraft relative to on-line punching are summarized as follows:

1. Presently used on 704 only to produce binary program decks.

2. Used 10-20% of available time.

3. Feels the price of the 721 is low enough so that he would not consider a slower, cheaper punch.

4. Higher speed punch would depend strictly on whether or not its increased cost could be regained in 704 time saving.

5. Satisfied with 721 speed.

6. State that there exists no real need for ability to punch binary information into card in magnetic tape format (160 char/card). Would use cards to store information now requiring small space on tape reel. Present Chinese binary device to costly.