Kolsky

COMPANY CONFIDENTIAL

7000X COMMITTEE

INTERIM REPORT

December 31, 1958

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Poughkeepsie, N. Y.

December 31, 1958

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Contents

I. Introduction

A. Purpose

The 7000X Committee was set up November 5, 1958 by Mr. S. W. Dunwell and Mr. D. W. Pendery as a joint Product Development - Product Planning study group.

The purpose of the Committee was to study and report upon the desirability and characteristics of another computer system based on Stretch technology but having a lower cost and broader market than the 7000 Sigma system.

The Committee was instructed to keep an open mind in initially examining various machine possibilities both from the engineering and marketing points of view. It was also told, however, to select, if possible, a single specific proposal for recommendation to management, rather than listing a number of possibilities without comment.

B. Procedure

During the past two months the Committee has had many information-gathering meetings with representatives of different IBM machine projects and with people having knowledge of the need of future commercial and scientific applications. Meeting reports were written for most of these contacts. Many informal discussions with Project 7000 engineers and others have been very helpful in answering questions of detail for this study. The proposals for other intermediate machines which have been made at various times in the past have been examined in order to understand their desirable features and weaknesses. These included: Basic, 7000A (Junior), 709S, and the Alternate Main Frame.

C. Schedule

The Committee has divided its task into two phases. The first phase of information-gathering and study is culminated by this interim report which sets down a proposed form of 7000X and some of the reasoning used in arriving at this form.

The second phase will start with the discussion of this proposal with Product Development and Product Planning management and others interested in the program. Assuming there are no major objections or changes resulting from these discussions, the Committee will then proceed to lay out the design of the machine system in greater detail.

The goal will be to have a final report by March 1, 1959 which will contain enough of the preliminary planning that a machine construction program could be started shortly thereafter if management should so decide. In order to carry out this plan, the Committee will have to call upon increasing amounts of time from certain Project 7000 engineers and planners. The cooperation of many other people will be required in getting the desired cost estimates, market estimates, and price estimates for the report.

II. Market

A. General

A study of the high-speed computer market with the intention of specifying a new computer brings forth a number of interesting observations:

1. New Environment

Most striking is perhaps the contrast between the present situation in 1958-1959 and the probable situation in 1960-1961. At present, such "old-fashioned" machines as the 709, 705 III, and Transac S-2000 are just beginning to be installed. The market is really dominated by the 705's and 704's with many 702's and 701's still installed. In 1960-1961, on the other hand, the field will apparently contain the 7090, 7070, 7050, LARC, Transac S-4000, 7000 Sigma, and the Military Products SAC-SAGE machine -- not to mention a possible higher-performance model of the 7090, the Bell Lab Machine, 7070X, and LARC-II. A new computer must be able to hold its own in this new environment.

2. New Applications

Another striking feature of the market is that we seem to be close to satisfying the need for present-day uses of computers, but are standing on the threshold of a vast new area of applications. This new area can be characterized by the phrase "computers which interact with the outside world". This concept is called "Integrated Data Processing", "Real-Time Operation", "Process Control", "In-Line Operation", etc. Its characteristic feature is the ability of the computer to accept and send information directly to other devices. The use of computers in this fashion is being developed in the aircraft and missile industries. It is important to note that both scientific and commercial applications are going in this direction. For the really advanced applications the distinction between scientific and commercial data processing methods becomes increasingly vague. Examples of such applications are the real-time control of nuclear reactors, production control, and air traffic control.

3. New Technology

The new transistorized machines mentioned above will be built of components which have intrinsicly much better reliability and longer life than present tube machines. Yet a surprising number of them have obsolescence built into their design which will make their early replacement mandatory. The real mistake seems to lie in cheapening a machine design by removing features whose desirability is questioned, in the hope of getting a lower price. This results in a larger programming effort, inconvenience and discouragement for the customers, a flood of RPQ's and early proposals for a second model to try to repair some of the damage. The ultimate cost to the company of this mediocrity must be staggering.

B. Applications

1. Scientific

a. Requirements

Scientific applications have traditionally outstripped the capabilities of existing computers. Scientific problems such as those based on partial differential equations can use up almost any amount of computing speed and memory capacity.

b. Financial

Scientific computing installations also have relatively easy access to money for spending on equipment because of the intimate interplay of their design calculations with the development of manufactured devices. Note that a "small" scientific customer is small because he has less money, not because his differential equations are easier than a "big" customer's. The limits of future requirements in the scientific area are financial not scientific.

c. Reprogramming

Scientific customers are traditionally less worried about reprogramming efforts than commercial customers, since many jobs are of a research nature and will be done over from time to time anyway. This is obviously true of many small and "one shot" problems. In practice, however, there are many more machine hours spent on production-type scientific problems than on those of research-type at most scientific computing installations. These production problems can be as rigid and static as any commercial job. The scientists responsible for production work will complain about reprogramming just as violently as an accountant will under the same circumstances.

2. Commercial

a. Requirements

Commercial customers tend to be much more nearly satisfied with the speed and capabilities of existing equipment than are scientific customers. They are also traditionally very reluctant to reprogram or change procedures. This attitude must be qualified by three factors:

(i) The commercial computing installation is under continual financial pressure to reduce costs and equipment because the source of its funds is less directly tied to manufacturing budgets.

(ii) The emphasis has been on doing routine production work efficiently not on pushing research into new fields.

(iii) Commercial customers have rarely had access to machines capable of doing new advanced applications.

b. Future Trends

Experts in commercial data processing agree that huge new applications of in-line processing and control will come some time in the future. Unfortunately, no one at present, except the military, is willing to spend money to investigate this area. New developments will probably come as by-products of scientific and military work, not from commercial customers directly.

3. Joint Scientific-Commercial

There are a few customers who presently share either a 704 or 705 between scientific and commercial usage. These applications may not be common now but there are factors which tend to make them more common in the future. The first is, the desire for greater efficiency and lower cost in the range beyond the 7090 and 7050 which may cause customers to consolidate their applications and funds on a single machine. The second factor is the one already mentioned: future scientific problems and future commercial problems tend to look more alike as far as their computer requirements go.

C. High-Speed Computer Performance

1. Performance Chart

The accompanying chart shows both the present and planned machines in the high-speed computer "arena" of 1960-1961. The machines are related in families. An attempt has been made to show emphasis on scientific or commercial applications and program compatibility. The vertical scale giving approximate computing speed is a logarithmic scale. The speeds are for problems natural to the individual computer families. These problems may differ from one family to another.

2. The Market Opening for 7000X

In looking for an opening in the market for 7000X, the following considerations were kept in mind:

a. A small step forward in performance is not worth while unless the new machine has an advantage of new capability or cost.

b. A factor of 2 or perhaps 3 in performance is the minimum step which a new computer of the same type should take. A customer can get 2 or 3 times performance by going to extra shifts. Changing computers is such a difficult and costly procedure that he will hesitate to do so for a factor of 2 or 3 gain even though machine rental may be less.

c. A new IBM machine should not be too close to another IBM machine in performance or it will force early replacement of the old machine.

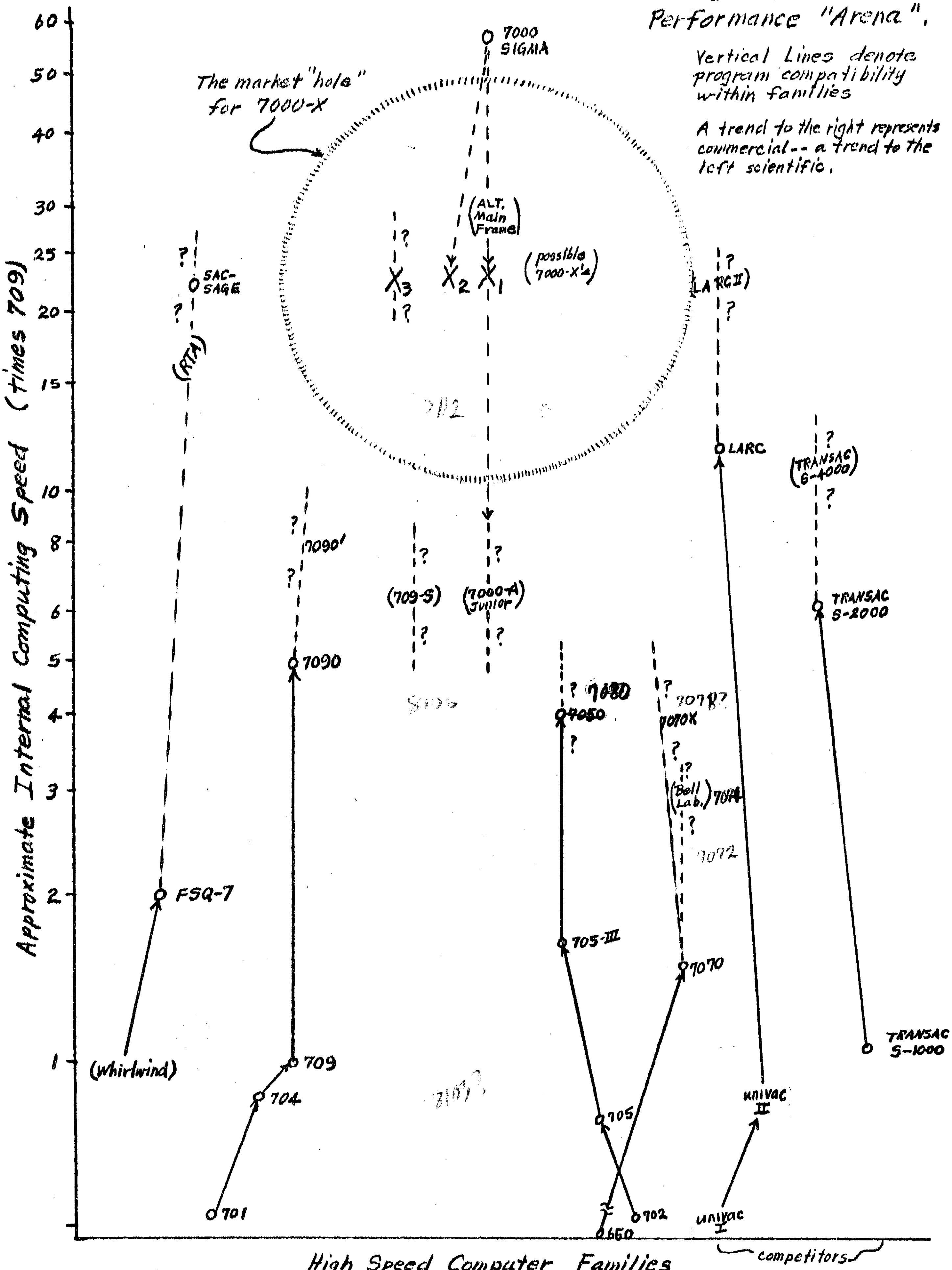
d. A new IBM machine should at least equal the performance of known competitors in the same price range.

e. A new computer can never be successful unless it can do old known applications at least as well as the machine it is supposed to replace.

Looking at the market arena with these points in mind, the vacant area seems to be bounded by about half 7000 Sigma performance on the top, and 2 or 3 times 7090, 7050 speeds on the bottom. The Military Products SAC-SAGE machine and the competing LARC's and Transac's can be considered as forming the limiting "sides" of the market.

The center of the performance area appears to be about 22 times 709 speed. It is interesting to note that if the 7090, 7050, and 7070X did not exist, a performance figure of around 8 times 709 speed would be more appropriate. Since this was indeed the situation when the 7000A and 709S were proposed, they were apparently placed correctly at that time.

The High Speed Computer Performance "Arena".



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D. Possibilities for 7000X

1. Existing Computer Families

The transistorized machines listed on the performance chart may be divided into two categories:

a. Re-engineered versions of tube machines, and

b. machines designed originally in the new technology (notably 7000S).

The first choice concerning 7000X was to decide into which of these categories it should fall. An examination of each of the families soon led to discarding the possibility of any further extension of old tube machines to the 20 times performance level. Some of the reasons for this decision were:

a. The only eligible tube machines are already being transistorized at a lower level.

b. Machine improvement programs for each of these transistorized tube models are already under study. None of them, except the Military Products SAC-SAGE machine, promises anything near a 20 times level.

c. More fundamentally, the tube machines represent old designs which lack many of the features that experience has since shown to be important. The legacies of old long-forgotten economy-cuts still scar most of these machines, giving them a short word length and an undesirable patchwork appearance.

d. In contrast, the 7000S is a modern design incorporating many advanced concepts never before available in such generality. Some of these features are:

64-bit word length
A general interrupt system
Automatic address comparison
Data flags
Both binary and decimal arithmetic
Square Root and Convert operations
Convenient double precision facilities
16 index registers
Generalized indexing (count and refills)
Complete set of logical tests, counts, and connectives
Error correcting
Special editing and bit addressing features

2. New Computer Family

Even after deciding that 7000X should not belong to one of the old tube computer families, there is still the possibility that it should start an entirely new family (marked X_3 on the chart), rather than be a direct 7000S derivative (X_1 or X_2).

A new family could be started in the spirit of the ill-fated 709S which attempted to get maximum performance, particularly in the scientific area, for minimum cost. This is an appealing path to take. (An all new design is always an appealing way to escape the known details which plague present designs.) Nevertheless, the decision was against taking this path for these reasons:

a. Not enough time has elapsed since 7000S was designed to know of any fundamental improvements which should be included in a new family. A new design would be found to have fewer features than 7000S, not more.

b. The market appears to have an opening for one new machine, but cannot sustain a new family. Note that in practice a new machine does result in a whole family of computers -- real or planned. For example, if X_3 were to be built, an astute project manager would soon realize that he could put in more overlapping hardware and a higher speed arithmetic unit and have an "X_3 Model II" which would compete with 7000S.

c. The desire of the company is to increase the return on its 7000S investment. A definite price and market advantage can be obtained by having two computers belonging to the same family. 7090 and 7050 have already felt this advantage to a considerable extent.

3. Decision

The recommendation of the Committee is that 7000X should be a true member of the 7000S family. The two remaining possibilities: X_1 - a strictly program-compatible machine, and X_2 - a partially program-compatible machine, will be examined in detail in Section III.

E. Auxiliary Equipment

The above discussion of performance was confined largely to that of the Central Processing Units. The input-output equipment and optional devices form an equally important (and costly) part of the computer systems.

1. 704-705 Systems

The following table lists the devices and their approximate rentals in thousands, making up typical 709 and 705 installations.

Typical 709 System

Unit	Rental	7070
A. Input-Output		
1 766 DSU	$ 3.5	3.5 / 4.5 DCh
2 755 TCU	3.6	3.9 Mplx
7 727 Tapes	3.9	4.7
7 729 Tapes	7.7	7.7
1 711 Cd Rdr (250 cpm)	0.8	0.8
1 716 Printer (150 lpm)	1.2	
Total	$ 20.7	$26.5 +28%
B. Main Computer		
1 709 CPU	$ 10.0	$18.2
1 738 32K memory	20.0	19.8
3 Power supplies (736, 741, 746)	4.0	1.6
Total	$ 34.0	$39.6 +16%
	$54.7	$66.1
C. Peripheral		
1 Tape to printer (500 lpm)(720A, 760, 727)	$ 4.9	
1 Tape to punch (100 cpm)(722, 759, 727)	1.6	
1 Card to tape (250 cpm)(714, 758, 727)	3.0	
Total	$ 9.5	
Total for whole system	$ 64.2	$75.6 +18%

Typical 705 III System

Unit	Rental
A. Input-Output	
2 777 TRC	$ 6.0
12 727 Tapes	6.6
6 729 Tapes	6.6
1/2 734 Drum at $2.8	1.4
1 714 Cd Rdr (250 cpm)	1.5
Total	$ 22.1
B. Main Computer	
1 705 CPU and memory	$ 15.0
1 745 power supply	1.5
1 782 console	1.1
Total	$ 17.6
C. Peripheral	
2 Tape to printer (720A, 760, 727)	$ 9.9
1 Tape to punch (722, 759, 727)	1.6
1 Card to tape (714, 758, 727)	3.0
Total	$ 14.5
Total for whole system	$ 54.2

We can see that the auxiliary equipment is an appreciable part of the total system cost even if the peripheral devices are not counted.

Firm prices for the 7090 and 7050 are not available at the moment, but they will probably run 15% above the 709 and 705 for the devices which are different.

2. 7000 Sigma Systems

The preliminary price estimates for 7000S show a similar pattern of costs with one important exception. This is the memory modularity concept of 7000S which allows from 1 to 16 memory units of 16K words each to be attached. An additional perturbation appears in the form of the four million word high-speed disk which can influence the size of core memory ordered.

Two typical 7000 Sigma systems are listed below:

A large system similar to the Los Alamos or Westinghouse proposals, and

a smaller system which might be typical of customers such as GE Knolls Atomic Power Laboratory.

The prices are the Committee's estimates derived from the following considerations:

a. An assumed market of 30 7000S's and 60 7000X's.

b. Official and unofficial price estimates made to date.

c. A large amount of equipment common between 7000X and 7000S.

d. Extended equipment life within the 7000 family.

Points (c) and (d) will be discussed in greater detail in Section III.

Estimated Monthly Rentals (in thousands) for Typical Sigma Systems

Unit	Large System		Small System	
CPU and Exchange	1 each	$ 65.	1 each	$ 65.
Console	1	2.	1	2.
2 usec Memory	6	96.	2	32.
H.S. Disk and Synchronizer	1	20.	1	20.
Card Reader (1000 cpm)	1	3.	1	3.
Card Punch (250 cpm)	1	2.	1	2.
Printer (600 lpm)	2	6.	2	6.
TCU	5	5.	3	3.
SWIFT Tapes	6	10.	--	---
729 Tapes	4	5.	6	7.
Totals		$ 214.		$ 140.

The typical large system cost is thus split $67,000 for the main computer, $31,000 for I/O peripheral, $96,000 for memory, and $20,000 for the disk. The small system pays the same for the main computer and disk but cuts the I/O peripheral to $21,000, and the memory to $32,000.

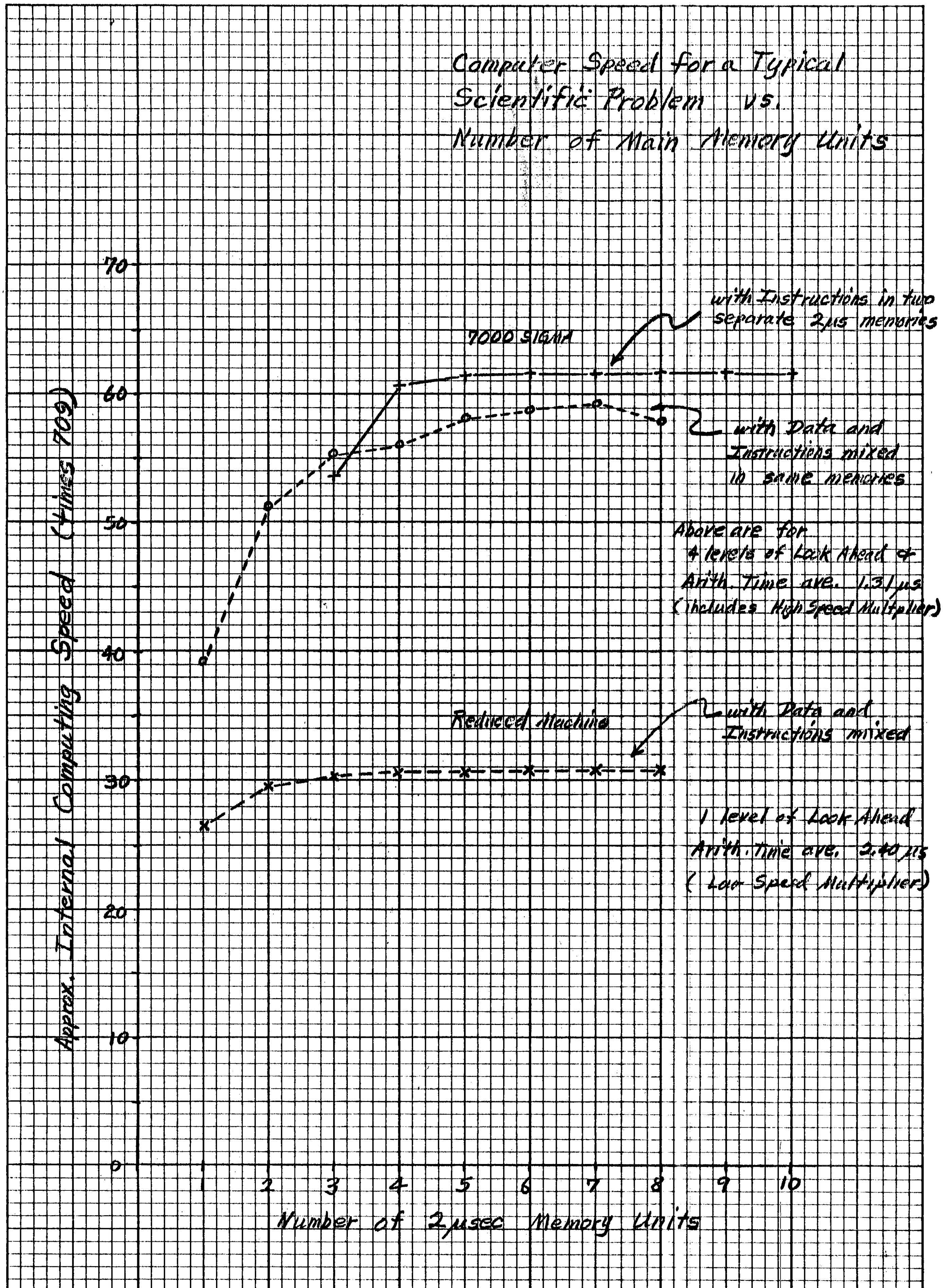
3. The Effect of Memory on Performance

The previous sections show that the temptation to save money by cutting down on the number of memory units will be very strong when the four million word disk is available as a backup at $20,000. An additional saving of $16,000 could be made by dropping back to one memory box, but the performance loss suffered by the system should discourage this practice.

At present, a price of $20,000 per memory unit is being discussed for 7090. If this price were adopted for 7000S, the above remarks apply to an even greater degree.

The accompanying graph shows how the computing speed for a given problem changes as the number of memory boxes is varied.

The big drop in performance in going from two boxes to one box is because of the loss of overlap in the computer. Overlap of function is one of the main features which distinguishes the 7000S design from earlier computers. A great deal of the design effort and hardware complications are due to the generality of the overlap logic required to match a fast computer to relatively slow memory devices. Without overlap, performance much above that shown is not possible unless a higher speed memory device such as cryogenics is available.


Computer Speed for a Typical Scientific Problem vs. Number of Main Memory Units
7000 SIGMA
with Instructions in two separate 2μs memories
with Data and Instructions mixed in same memories
Above are for 4 levels of Look Ahead & Arith. Time ave. 1.31μs (includes High Speed Multplier)
Reduced Machine
with Data and Instructions mixed
1 level of Look Ahead Arith. Time ave. 2.40μs (Low Speed Multiplier)
Approx. Internal Computing Speed (times 709)
0
10
20
30
40
50
60
70
1
2
3
4
5
6
7
8
9
10
Number of 2μsec Memory Units

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When only one memory unit is attached to 7000S much of the overlapping hardware is rendered ineffective. If a customer is willing to take the reduced performance, he might reasonably object to paying for this unused hardware. A suitable point of departure for the 7000X system might be to cut 7000S back to one logical memory and remove the hardware thus rendered useless. This procedure is consistent with 22 times 709 performance level.

F. Price Requirements

The graph of machine speed versus number of memories shows that a small 7000S system with only one memory box would have an internal speed of about 37 times 709. Its monthly rental would be about $124,000. To be a reasonable candidate, the 7000X system, with its 22 times performance, should have an appreciably lower rental.

The memory and I/O units are assumed to be the same for both. A saving in the High-Speed Disk Synchronizer hardware could reduce its rental from $20,000 to about $15,000. For the reduction in CPU hardware assumed, a rental of about $45,000 per month for the CPU and basic exchange is indicated.

The following table shows how the 7000X would compare in computing speed and cost with its three closest competitors. The 7090 I/O is assumed the same as that for 7000X for convenience. The High-Speed Disk for 7090 is only a tentative proposal at present, but it is included here to make the intercomparison more valid.

Approximate Speed and Rental Comparisons

	7000S Large	7000S Small	7000X*	7090
(1) Internal Computing Speed	60	37	22	5
(2) Rentals				
CPU*, Console, Basic Exchange	$ 67,000	67,000	47,000	21,000
Memory Units (6)	96,000 (1)	16,000 (1)	16,000	16,000
H.S. Disk & Sync.*	20,000	20,000	15,000	15,000
I/O Devices	31,000	21,000	21,000	21,000
Total monthly rentals	$ 214,000	$ 124,000	$ 99,000	$ 73,000

The starred (*) items are the new units proposed herein.

As one goes from right to left in the above table, in each case the additional rental buys an appreciable increase in performance. For Sigma, the increased memory improves performance by added convenience and capacity as well as by a speed increase. It then appears that the 7000X rental is properly placed according to its performance and those of its neighbors.

III. Machine Configuration

A. Goals

The conclusions of the preceding section may be summarized as follows:

1. A market opening exists for a combined technical-commercial computer in the area bounded by 7090, 7050, 7070X, SAC-SAGE computer, and 7000S.

2. The computer system would consist of: I/O package, 16K memory, CPU, and in most cases, high-speed disk unit.

3. Performance should be in the order of 22 times 709.

4. Systems rental should be in the order of $100,000 broken down into $21,000 for I/O, $16,000 for memory, $47,000 for CPU, and $15,000 for high-speed disk.

5. The computer should belong to the 7000S family.

The feasibility of a satisfactory machine configuration will be considered in view of these conclusions. The equipment and cost of a reduced 7000S system will be considered as a point of departure.

B. Equipment

A 7000S computer with a single memory unit makes inefficient use of its equipment in the following machine areas:

1. A powerful memory bus is used which is capable of selecting six memories and provides suitable priority, slot reservation, and return address controls. Of the 9K transistors used in this bus system, 5K are unnecessary when a single memory is used. Moreover, the redundant equipment actually slows down memory access. A bus designed for a single memory could be at least 10% faster.

2. The four stage look-ahead system is used while the computer obtains all data from a single memory unit. A simplified single level of look-ahead would be sufficient and could represent a sizable reduction in the present 22K transistors.

3. Separate error checking and correcting (ECC) circuits are available in: arithmetic unit, look-ahead, exchange and high-speed disk synchronizer. When multiple memories are used, the duplicate equipment is justified since the time required to pass data through the checker is about 20% of the memory cycle. For a single memory, one checker certainly is sufficient. The checkers which can be eliminated represent 3K to 7K transistors each.

4. Floating point multiply is performed in a separate high-speed unit at a cost of 10K transistors. An average multiply time of 1.75 usec is achieved by this unit. For a single memory machine, the time to obtain an instruction half-word and operand is 1.5 memory cycle or 3.15 usec. Clearly, the multiplication could be performed at lower speed in a less expensive unit and there appears to be no reason why the results would differ other than in execution time.

5. Strained controls are required throughout the computer. They include:

(i) Highly parallel circuits designed to minimize delay times,

(ii) separate equipment such as an instruction counter adder besides an index adder, and

(iii) "guess and correct" logic by which decisions are anticipated and later nullified when they prove to be incorrect.

Again this equipment becomes redundant due to lower effective memory speeds. In contrast to points 1-4, above, the control equipment is scattered throughout the computer. It is found in particular in the instruction and indexing unit (I box) and the floating point unit. The amount of equipment ranges from a few transistors to groups of 200 transistors. An example of a larger group of transistors is a set of shift gates in the floating point adder. A reduced number of shift gates results in increased times for floating point addition.

Points 1-5 show that a considerable equipment redundancy exists in 7000S when operating with a single memory unit. Several major machine portions, each consisting of one or more slides, could be eliminated or drastically reduced, without loss in performance. In a few cases even a gain in performance would be achieved. Besides these major machine portions there is a sprinkling of small circuits which similarly could be eliminated. The major portions represent considerably more equipment than the latter. For this reason it has been decided to concentrate the redesign on the former areas. It is important to note that none of the equipment discussed affects the instruction set or the results of instruction execution.

C. Cost

The desired rental for a CPU was quoted above as $45,000 in comparison to a tentative rental of $65,000 for the 7000S CPU. Rental is established as the sum of direct and indirect costs. The ratio between these costs will be assumed to be about 2 to 1. Direct costs include: manufacturing and customer engineering. Indirect costs include: development engineering, applied programming, marketing considerations and fixed charges.

The influence on costs of a partial or complete change of the 7000S CPU will be discussed briefly for each of these items.

1. Manufacturing costs are more or less linear with transistor count. However, the number of slides required to house the transistors influences this cost. Each time a slide is eliminated, the costs for that slide, including cabling and transistor drivers are eliminated. For that reason, it is more advantageous to eliminate one slide out of ten rather than to reduce the transistor contents of ten slides by one tenth each.

2. Customer engineering charges are affected by size of equipment, reliability and standardization. A reduction in transistor count may result in reduced C.E. charges. However, when this reduction in transistor count is obtained by an extensive redesign, the charges are burdened by added learning and diagnostic programming costs. The use of standard cards is assumed in this report. If it would be feasible to extend the use of standard equipment to major sections of existing computers, a noticeable advantage would be obtained.

3. Development engineering cost is an indirect charge which is proportional to the amount of new equipment which is introduced. Two major factors are involved: the design costs and the release costs. Isolated minor changes may amount to little design costs. When they result in a new panel layout, the release costs are the same as for an entirely new design. In order to reduce development costs, the engineering effort should be directed to those computer areas which result in major equipment savings. Isolated small changes should be avoided.

4. Applied programming cost is highly non-linear. A 7000X program-compatible with an existing machine reduces this cost to a minimum. The only consideration left is whether the I/O and memory package assumed for the existing machine is reasonable for 7000X.

The applied programming effort is affected in two ways by program compatibility. First, there is the cost of automatic programs for the 7000X computer. Partial compatibility still results in a reduced, even though pains-taking, effort. Small discrepancies result in a substantial programming effort, major discrepancies would require a completely new start. Secondly, there is the cost to the customer and the cost of customer assistance. (It was a customer who compared program compatibility with pregnancy: one is, or one is not.) Small discrepancies result in major reprogramming efforts. Applied programming would be called in to provide translation and simulation programs. A sales effort must be made to convince the customer of feasibility in the light of previous failures.

5. Marketing considerations may result in an indirect charge because of machine obsolescence and may affect the weight given to all indirect charges combined because of machine life.

The machine obsolescence charge is determined by the number of existing or planned machines which are replaced and their value to the company. As an example, consider the effect of 7090 on 7000S pricing. The 7090 market estimates have been made ignoring the 7000S, even though the latter machine antidates the former. When the 7000S is introduced, the market for 7090 will be reduced. This reduced market will represent a certain cost to the company, which cost will be charged to 7000S. It follows that machine obsolescence does not refer to existing machines only, but also to machines which were planned but not built.

Machine life is the average number of years the machine is expected to be rented. The longer its life, the more all indirect charges can be spread out and the lower the price. It may be observed that a certain amount of positive feedback takes place, since a low price results in a long life and a high price in a short life.

The 7000X will unquestionably result in some 7090 obsolescence, as is the case for 7000S. The effect of 7000X on 7000S, however, can be beneficial, (i) provided program compatibility exists, 7000X customers will be induced to switch to 7000S; (ii) provided a large degree of machine compatibility exists, the life of a 7000X may be quite extensive. In that case, a large number of the units which form the 7000X may be retained when the installation switches over to 7000S. The life of these units would extend throughout two generations. For the same reason, it is furthermore desirable to anticipate the next development in computer technology, which may be cryogenics.

In summary, it may be remarked that besides the linear effect on cost of a reduced transistor count, there are many highly discrete effects. These discrete effects emphasize the need to change a few machine portions as much as possible and leave the remaining machine portions unchanged. This approach may be called selective redesign. In particular, those machine portions which do not affect the instruction set could be redesigned without the heavy cost burden of applied programming. For that reason, a 7000X computer program-compatible and machine-compatible with 7000S provides a less costly solution than a computer belonging to a new family.

D. Proposed 7000X Computer

The preceding sections have pointed out the existence of redundant equipment and the desirability of selective redesign. In view of these conclusions, a proposal for 7000X will be outlined below. This outline may serve as a basis for detailed study in the coming months.

1. Program compatibility with 7000S
2. Single logical memory
3. 7000S exchange and I/O
4. 7090 H.S. disk synchronizer
5. 7000S CPU reduced from sixteen slides to twelve
6. Unchanged use of ten 7000S slides
7. Cryogenic memory when available.

Each of these points will be discussed briefly.

1. Four degrees of program compatibility with 7000S can be considered.

a. Upward program compatibility implies that programs for 7000X can run on 7000S. This still leaves room to omit functions in the smaller machine which belong to the larger machine. A possible list of these functions and their very approximate transistor count is as follows:

(1)	Geometric indexing	700
(2)	Rename	200
(3)	Store address	100
(4)	Square root	300
(5)	Execute, direct and indirect	500
(6)	Transmit half words	300
(7)	Progressive indexing	300
(8)	Load indirect	300
(9)	Cross word boundary on VFL	1000
(10)	Left Zero and All Ones counters	2500
(11)	Address comparison	2700
	Total	8900 Transistors

The list is in order of increasing desirability. Geometric indexing is provided in 7000S as a concession to LASL. It requires a relatively large amount of well-identifiable equipment, which makes it a very suitable candidate for elimination from 7000X. Nevertheless, 700 transistors are not sufficient justification for a difference between instruction sets, or a difference between machine units (I box) which otherwise would be identical. In order to justify this difference, the transistor reduction should be larger and the number of features stripped might as well be increased. For instance, all items (1)-(8) might be deleted from 7000X. This list yields 2700 transistors and still involves the I box only. At this point, however, several valuable features have been lost. For instance: Progressive indexing will be used extensively in editing procedures; Execute instructions are so valuable in debugging and subroutine linkages that they have been copied in the 709; some common types of technical programs save 40% of execution time because of the instruction Square Root; Load Indirect will be used extensively in subroutine linkages and is provided in the 709 and competing computers. This time the loss in features is not worth the savings.

The process of stripping might be continued even further by selecting more expensive features, such as items (9)-(11). The total count now becomes 9K, which is still less than 10% of the reduced CPU. These features, however, touch the core of the 7000S instruction set. Their loss would bring a wide discrepancy between programs written for 7000X and 7000S. Editing, logic, and multiprogramming would be crippled severely and must rely upon alternate procedures. Valuable advances made in 7000S would be lost. What makes it even worse, upward program compatibility prevents the introduction of alternate, though less desirable features, to compensate for some of these losses. For example, the instruction Store For Print which is found in the 705 is less general and less effective than the left zero count, but more desirable than no count at all. The conclusion, therefore, has been to preserve the complete instruction set of 7000S. This leads to:

b. Downward program compatibility. This type of compatibility implies that programs for 7000S can run on 7000X, provided both installations have the proper I/O and memory attached. Upward and downward compatibility are a very desirable sales feature. It is believed that the indirect savings which are obtained by this feature adequately compensate for the direct savings which could be obtained by departing from it.

c. Result compatibility is available when all instructions yield identical results on both computers. It is of great importance for installations having both type computers or switching from one type to the other. For 7000X, its direct price is about 2K transistors, which might be saved in the parallel floating point unit by performing operations in 48-bit adders rather than in 96-bit adders. Result compatibility in itself is well worth this cost. Since in addition the indirect costs are considerable, - an entire floating point unit of four slides has to be redesigned, - the decision has been to preserve this mode of compatibility.

d. Exception compatibility concerns treatment of program interruptions. The precise order of events in case of program interruption has been defined in the 7000S manual. The I box has been designed according to this description. In many isolated instances, hardware shortcuts were not taken because of these specifications. An estimated total expense of 400 transistors can be attributed to these specifications. The reasons for preserving this type of compatibility are the same as for result compatibility: considerable redesign in the I box, - four slides which otherwise could remain unchanged - would yield only a small amount of transistors. The loss to programmers would be large, since all exception routines are programmed very carefully in accordance with the present definition. An alternate definition not only requires reprogramming, but also doing it a more awkward way.

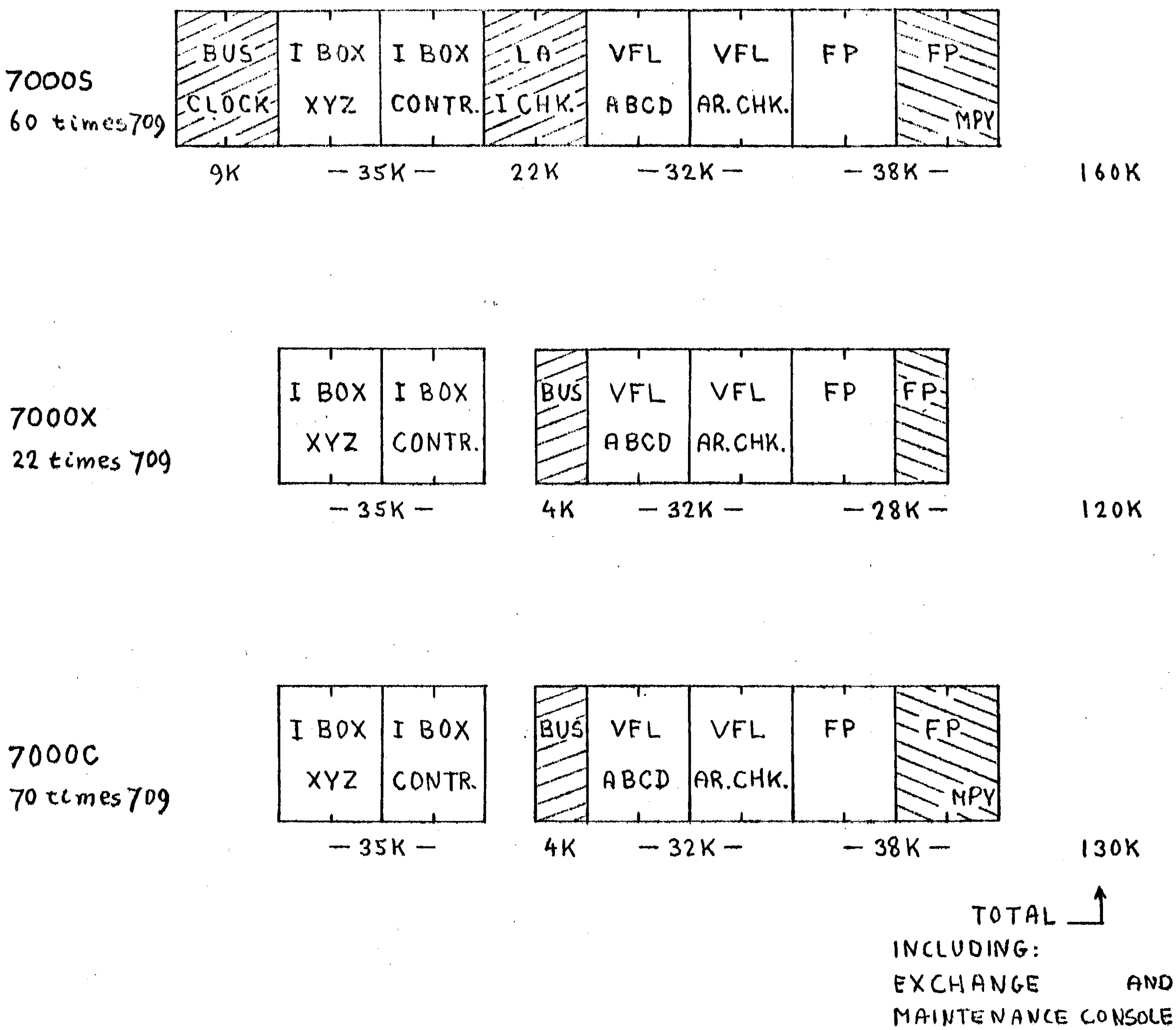
2. A single logical memory is realistic from a market point of view and permits substantial savings in the areas of bus system, look-ahead and ECC checking. Memories are standard 16K units. Several units, at least two, may be attached but operate as a single memory. As has been pointed out, the availability of large capacity disks makes a 7000X computer with a single logical memory quite attractive.

3. Use of 7000S exchange and I/O provides larger quantities for these units and should result either in lower rentals or increased profit. In the exchange, the ECC checker could possibly be eliminated. Tentatively, it is proposed to leave this unit unchanged.

4. Reduced equipment in the high-speed disk synchronizer can be obtained by using the proposed 7090 High-Speed disk synchronizer. It is assumed that the CPU cannot run while the disk is reading or writing. The 36-bit halfwords which are recorded in parallel on the disk are parity checked only. The parity check is provided for 7090 and not required for 7000X which can use double error correction for two errors in one track. The error correction is performed in the common checker which is provided on the memory bus. The transistor count for the 7000X disk synchronizer would be 11K as compared to 15K for 7000S. This hardware reduction is 25%, the same as the reduction shown below for the CPU.

5. It is possible to have 7000S CPU reduced from sixteen slides to twelve, and

6. make unchanged use of ten 7000S slides. The allocation of slides for 7000S and 7000X is shown in Figure 1. The four slides for memory bus and clock, look-ahead and I box ECC are combined to one slide. A simplified bus system is used. One check unit for CPU and high-speed disk is assumed. The exchange has its own check unit. A second, independent change is the elimination of the high-speed floating point multiplier which reduces the floating point unit from four slides to three. Figure 1 shows the rough transistor counts for 7000S and 7000X divided into major sections. Unchanged would be I box: 4 slides, VFL: 4 slides, and FP: 2 slides out of 4. A total transistor count reduction of 25%, from 160K to 120K, may be obtained.



ARRANGEMENT OF CPU SLIDES AND TRANSISTOR COUNTS FOR
7000 COMPUTERS

FIGURE 1

G.A.B.
12-31-58

7. The CPU configuration suitable for attachment of cryogenic memory, when available, is shown in the third diagram of Figure 1. The cryogenic memory is assumed to be faster than .3 usec. Since cryogenic memory represents a single logical memory, the simplified memory bus system can be used. The bus system can and should be designed with this extension in mind. At the new memory rate, the computer is no longer memory limited and the high-speed multiplier should be used. Equipment savings of 26K because of elimination of look-ahead and the complex bus can be thus achieved. What is more important, the useful life of the CPU units for 7000X and 7000S would extend throughout the first years of cryogenic technology.

IV. Summary

It is our recommendation that the 7000X computer system belong to the 7000 Sigma computer family having the following main properties:

A. Performance of approximately 22 times 709.

B. Typical systems rental of $100,000 broken down into $21,000 for I/O, $16,000 for memory, $47,000 for CPU, and $15,000 for high-speed disk.

C. Use of unaltered 7000S exchange and I/O units.

D. Use of the proposed 7090 high-speed disk and synchronizer.

E. A single logical memory consisting of one or more standard 16K memory units.

F. Attachment of cryogenic memory, when available, to the family of 7000 computers.

G. Strict program compatibility for 7000X with 7000S, including upward, downward, result and exception compatibility.

H. Selective redesign of the 7000S CPU, leaving 10 slides of the CPU unchanged and replacing the remaining 6 slides with 2 entirely redesigned slides. The redesign consists of two parts affecting (i) bus, look-ahead, ECC checkers, and (ii) high-speed floating point unit. The arithmetic, instruction and index units would remain unchanged, thus further guaranteeing program compatibility.

I. Lower direct costs by reducing the number of CPU slides from 16 to 12, and reducing the transistor count of the CPU and exchange from 160K to 120K.

J. Lower indirect costs by (1) restricting redesign to those areas which give maximum transistor gain, thus keeping Customer Engineer training, diagnostic programming, and development engineering to a minimum; (2) extending the life of a large area of the computer, including I/O, exchange, and CPU, by machine machine compatibility, and (3) minimizing applied and diagnostic programming costs by strict program compatibility.

K. An extended market becomes available by enabling customers to make a single transition from 700 to 7000 systems with only a modest increase in systems cost, then allowing them to grow from 7000X to the larger 7000S without facing another reprogramming effort.

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