PRELIMINARY BULK MEMORY STUDY REPORT

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INTRODUCTION

In order to satisfy customer requirements for both rapid response and thorough analysis, the Bulk Memory Study was separated into two phases, each of which is to culminate in the submission to IBM of a study report containing the results of CSC's investigation: first, a brief, preliminary analysis of the benefits to be derived from the availability of a high-speed, bulk memory device (to be submitted on March 25, 1964); and, second, a more detailed analysis of specific topics, which could be dealt with only in general terms in the preliminary report (to be delivered on April 8, 1964).

This document contains the results of the first phase of that study: a report on CSC's preliminary investigation into the use of a large, bulk memory on a high-speed, digital computer, and consists of a brief analysis of four topics:

1. The ways bulk memory could be used in conjunction with an on-line satellite Input/Output computer;
2. How the CSC-proposed programming system would benefit from the availability of bulk memory;
3. The type of applications bulk memory would benefit; and
4. Computer operating recommendations.

For the follow-on study, specific applications will be investigated; these applications will be selected from among those covered in this initial report. For each application studied there will be: a short description of the problem; a description of the techniques now used for solution; a discussion of the use of bulk memory; and a comparative timing study. For the timing study, representative cases will be chosen, and a reasonably detailed study will be made on the differences between bulk memory and drum. Basic assumptions and timing cases will be chosen which will result in the maximum completeness and accuracy achievable within the time-limits imposed by the report-delivery schedule.

RESTRICTIONS

The following restrictions were employed to reduce the problem to a solvable size.

1. Costs or relative costs were not considered.
2. Bulk memory and drum were considered to contain the same number of words.
3. The computer would have either bulk memory or drum, not both.
4. Bulk memory would be used for semi-permanent storage.

APPLICATIONS ANALYSIS

In general, the availability of bulk memory will tend to show an improvement in the processing of those types of problems that operate on large volumes of data. Since data-transfer rates from the various Input/Output devices are generally fairly high, the limiting time factor in obtaining data from the Input/Output or auxiliary memory device is the time required to gain access to any single piece of data. Obviously, data-access times would be shorter for bulk memory than for drum or disk storage.

On the other hand, if the problem is of the type that operates upon data already stored in the proper sequence, and the calculations are lengthy, the process can be "compute-bound"; effective buffering could allow it to be run just as efficiently using drum, disk or tape as it could be run using bulk memory. (Of course, it is easier to obtain optimum buffering in theory than it is in fact.)

The general areas of linear programming and dynamic programming, and the solution of partial differential equations and linear systems (simulated equations and Eigenvalue problems) are the areas most vulnerable to improvement as a result of using bulk memory. All these problems require the manipulation of large matrices; if sufficient primary storage is not available, these matrices must be partitioned and

saved on tape, drums, or disk. This not only requires additional Input/Output time; it also requires considerably greater programming effort to carry out the necessary computations on the partitioned matrices. Hydrodynamics or neutron diffusion problems, for example, magnify such difficulties, since solutions of these problems are frequently performed in more than one dimension.

Several general conclusions can be drawn concerning the usefulness of bulk memory, in solving specific types of problems; these will be followed by a list of specific applications which definitely would benefit from the availability of bulk memory:

1. Bulk memory will always mean faster solutions for problems that operate on a large file, and require:
   a. Many random accesses to the file for small increments of data; or
   b. Which use a file that is already correctly sequenced for processing, but which require so little calculation that processing is "Input/Output bound".
2. Bulk memory will improve the speed of those programs which require re-sequencing of a file for continued processing.
3. Bulk memory should be considered where the ability to achieve optimum buffering is marginal.
4. Bulk memory will not give a significant improvement for problems using large files, where the files are initially in correct sequence, and the calculation is so lengthy that the problem becomes "compute-bound".

The following general types of applications will benefit from bulk memory. These followed by an asterisk (*) will be covered in more detail in the follow-on report.

1. Linear Programming*
2. Matrix Arithmetic*
3. Sorting*
4. File Updating

5. Information Retrieval
6. Statistical Analysis
7. Real Time*
8. Dynamics (stress, heat, hydro)*
9. Nuclear
10. Monte Carlo

SATELLITE COMPUTER

The use of bulk memory as the working storage of a satellite Input/Output device or computer offers many advantages. This section discusses a possible configuration, techniques of use, and possible areas of application.

Figure 1 is a block diagram of a proposed bulk memory-oriented satellite system. The satellite device works directly into the bulk memory, and has access to all channels and Input/Output devices. Input/Output facilities can be removed from the main Central Processing Unit, and Input/Output operations, including trap processing, made a function of the satellite. A simplified channel-adapter could be associated with card equipment, printers, and inquiry station devices (assuming that separate paths between each device and the bulk memory multiplexer can be established); the satellite device could therefore be responsible for most Input/Output processes, including buffering, conversion, translation, blocking, deblocking, and most of the necessary editing. The main Central Processing Unit thus would be free to operate as a full-time problem solver, with only bulk memory, or other appropriate Input/Output devices, as its responsibility.

The proposed system has definite advantages for use in multi-programming:

1. The satellite system can handle all remote inquiries for information stored on disk.
2. It can also retain information necessary for later processing, and supply it to the main computer, upon demand.

3. For use in remote-console solution of engineering problems, the satellite system can receive the problem input; assemble the data with the program; stack the problems; and at a convenient time, transmit them to the main computer for solution. The satellite can then perform the task of following-through with the return of the output to the proper remote console.

4. For use with low-speed character equipment, assembly-disassembly can be avoided by receiving or transmitting one character per word, leaving formatting to the satellite system.

A real-time problem, using a satellite system similar to the one described above, will be reviewed in more detail in the follow-on report.

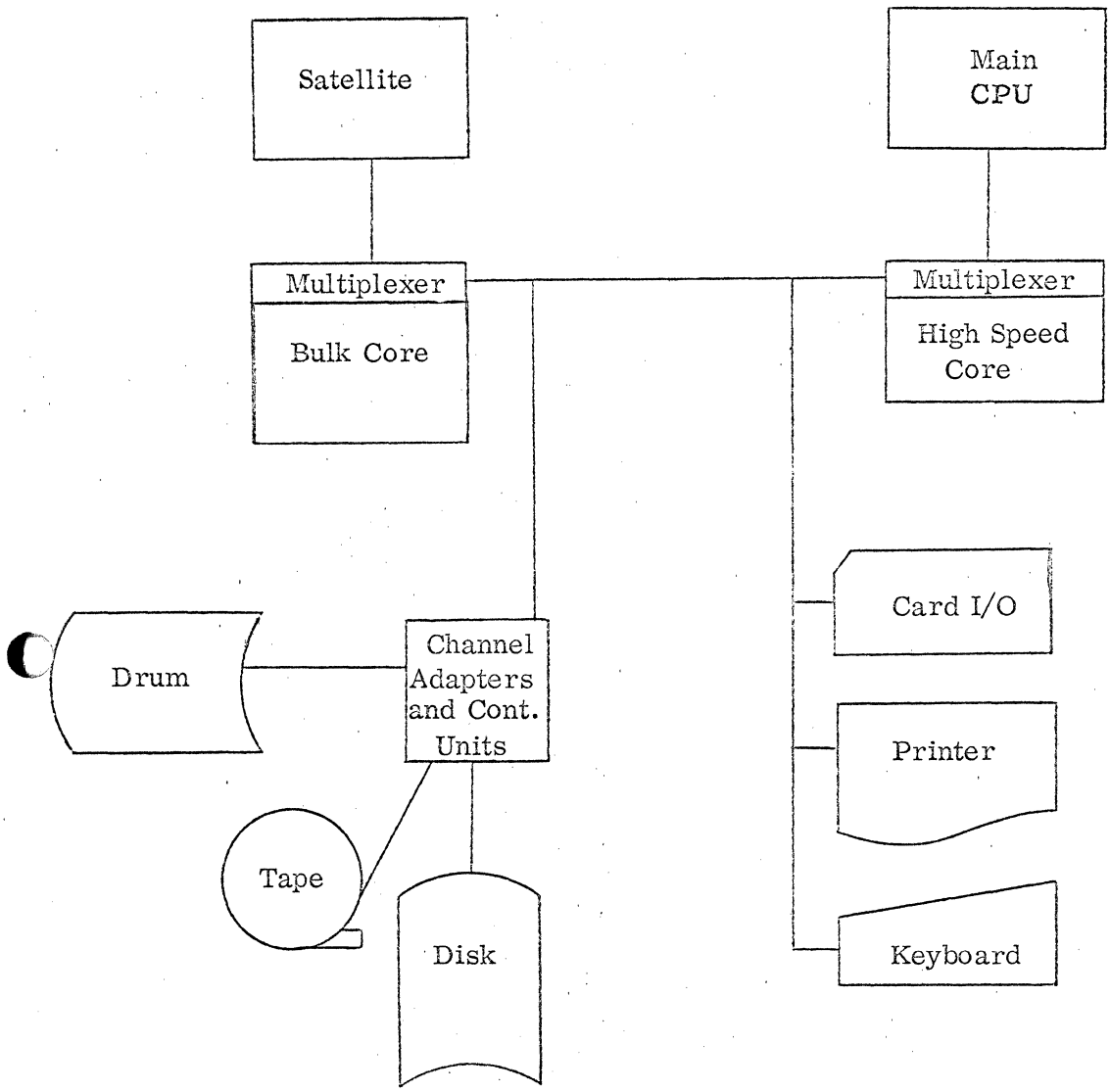

FIGURE 1

BULK MEMORY-ORIENTED SATELLITE SYSTEM

PROGRAMMING SYSTEMS

The primary advantage that bulk memory offers over drum storage, for use by programming systems, lies in its ability to buffer in blocks of data smaller than 960 words. There are many functions in the proposed 7095 Executive System, Loader, Assembler and Compiler that require files much shorter than the drums' 960 word buffer. Some of these files, and their estimated sizes are:

1. Unit assignment directory (100-200 words); no, part of system
2. Accounting information (5-20 words); ?
3. Control dictionary (25-200 words); and
4. Library calls (20-300 words). Can pack these.

The follow-on report will contain a more thorough analysis of the value of bulk memory to programming systems.

MACHINE RECOMMENDATIONS

The following are a list of recommendations for hardware configuration, and for instructions for the use of bulk memory:

1. The bulk memory should be capable of being used both as an Input/Output device, and as a word-addressed storage device.
2. Channel transmission for bulk memory should not interfere with Input/Output channel operations; they should, of course, be bi-directional; and, in order to obtain maximum advantage when used for matrix operations, the Channel or Block Transfer operations should allow incrementing of the access or storage locations by a value other than one--thus permitting transmission of an entire column (from a matrix stored row-wise) by means of a single command.

3. Indirect addressing is recommended as the means of referencing bulk memory directly, since it will provide uniform and unrestricted utilization. (Reference through index registers, though more flexible, would require larger index registers and, consequently, modification of many 7095 instructions.)

4. A flexible memory-lockout facility should be provided for the bulk memory.