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Subject: Unattended Operation of Stretch-Planning Considerations

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I Goals

In a design for an advanced machine, it seems reasonable to set several levels of goals for unattended operation, a system characteristic which will necessarily depend heavily on many other aspects of the system.

The first set of goals concern the attendants to be eliminated. In order of increasing difficulty, the goals may be the elimination from the machine site of 1 maintenance personnel, of 2 programmers and users, of 3 operators, and of 4 watchmen. These goals each have problems of their own which will be treated below.

A second set of goals concern the lengths of time for which the machine shall be expected to operate without the services of any of the four classes of attendants. There appear to be three goals here of increasing difficulty: overnight operation (16 hours), weekend operation (64 hours), and unattended operation for longer periods. Clearly, these goals will be mixed; we may attempt to permit weekend operation without maintenance while demanding freedom from operator attendance only for overnight periods.

It is clear that for a complex of equipment embodying much new technology, even the simplest of these goals will not be realized on the day of delivery of the first machine. The goals of unattended operation will be realized as the machine is field tested and used. At present, it is important to anticipate the problems and to plan the development of machine features and techniques of use that will facilitate their solution.

II Elimination of Engineers

The major effort in an unattended operation program must clearly be directed toward machine operation without maintenance for fairly long periods, since the cost and staffing problems of continuous maintenance are severe. It must be noted, however, that much of the pressure for constant maintenance is generated by customer reaction to the company policy of charging for down time at the standard price. This customer pressure may remain regardless of the measures taken to improve performance of the hardware and the overall system.

A program for planning a system capable of extended operation without maintenance has three important parts. The first is necessarily a deep-rooted effort to develop and use reliable components in well-designed circuits. Wherever possible, mechanical motion, wear, and parts subject to deterioration must be avoided. This effort is already an integral part of the STRETCH Program.

Implied by the necessity to build reliable operation into the machine, is the effort to design a system that will operate properly with faulty components, through the use of error-correcting codes, etc. Research in this area is being conducted by Dr. Cocke and others.

A second part of an unattended operation program is provision of circuitry and devices for fault detection, rapid fault location, and simple fault emendation. A program of research in these areas has been set forth by Messrs. Stephens, Stringfellow and Winkler in another memorandum.

The third part of system design for unmaintained operation is the planning of programming and usage methods for fault location, dumps and restarts, and handicapped operation. These efforts can be facilitated by provision of a few special features in the logical design. These programming and usage methods can be considered in five categories:

1) Fault detection programs. While much less reliance will be placed on programmed fault detection and location than in previous machines, there will be parts of the machine for which fully automatic fault detection apparatus will be impractical. Programmed tests will still be important for these. This approach implies a facility for multi-programming with automatic break-in or transfer from one program to another, as well as the circuitry and devices discussed by Messrs. Stephens, Stringfellow and Winkler.

2) Fault location programs. Special devices, such as programmed voltage level controls, can facilitate programmed diagnosis of those faults whose frequency does not merit full automatic fault location. Alternative programs, each of which uses only part of the unchecked circuitry, may be needed.

3) Fault recording programs. It will be necessary to plan fairly sophisticated programs that will permit the recording of fault information by whatever non-faulty means are available. For fault logging, fault testing, program debugging, and many other applications, it appears desirable to have the machine contain a real-time register which at any instant shows the real clock time in some small fractions of a second.

4) Restart and data protection procedures. Not only must high-speed memory dump techniques be possible, but provision must be made for facile supervisory programs to effect these at suitable time intervals. Some facility must be provided to protect blocks of memory, including those containing supervisory routines, from damage due to programming error. Programmable memory-write-locks on individual memory units appear to offer many advantages for this purpose.

5) Handicapped operation procedures. It appears possible and desirable to devise programming techniques by which the STRETCH system, after recognizing and identifying a fault in its own operation, can rearrange itself and/or its workload so that it can continue performing useful work. These techniques might include the identification and prefacing of each program with a table of components used, the selection among waiting programs of those that do not need a component that has been found faulty, and physical facilities for the reassignment of logical address (superindexing) of input-output units, memory boxes, or any duplicated unit.

III Removal of Programmers and Users

It is desirable to remove much if not all of the necessity for programmers and computer users to be in personal attendance upon the main machine. With present machines, the programmer goes to the machine to deliver the input data, to watch the processing, to prescribe emergency procedures when the debugging or other output does not function as expected, and to carry away the results.

Data delivery and result removal could at present presumably be effected by means other than personal transportation by the user. Indeed, much consideration is being given to such methods for real-time applications. The only essential function now being performed by the user at the machine is supervision over trial runs during the debugging process. At most installations of very fast machines, this supervision is mostly vigilant - the programmer does nothing except when the very unexpected occurs. The general problem to be solved is the development of machine features and of use techniques which will so simplify the program debugging process that the programmer can be spared the pressures of the machine room and that the vast amount of machine time now devoted to debugging can be reduced. These two goals appear to be closely related.

There appear to be four concrete steps by which debugging can be facilitated. These are:

1) Development of automatic coding techniques so that program bugs invariably reflect faulty mathematical logic, rather than transcription or coding errors. The Programming Research Department at World Headquarters, is devoting a great deal of effort to this.

2) Provision in the machine of improved facilities and techniques for using supervisory programs, so that debugging aids such as tracing can be used with a greatly reduced cost in machine operations.

3) Development of programs that will perform fairly sophisticated logical tests on subject programs to ferret out the common logical faults. Present-day assembly programs are first steps in this direction.

4) Provision of machine facilities for program debugging using the machine as an aid. Such on-machine debugging saves time for the programmer. Provision of facilities for simultaneous operation of several programs, effective supervisory programs for protection of other program data, and suitable consoles should permit this form of debugging to be used with great convenience.

IV Elimination of Operators

Observation of the actions of the operator of a modern computing system reveals that he performs several distinct functions. In general, the operator (or a dispatcher) is responsible for logging the time the machine is used on each problem for accounting purposes. The operator loads input equipment with tapes, cards, and other data carriers, loads output equipment with blank data carriers, and unloads both at proper times. He is charged with pushing a fairly large number of buttons that ready input-output units, set or reset indicators, start self-loading processes, and start the machine. He commonly is charged with determining when a program improperly fails to terminate, and stopping the machine in that event. Finally, he watches the machine for catastrophic conditions such as electronic failure, fire, mechanical failure, cooling system failure, and power interruption. In the event of any of these unexpected circumstances, he performs the complex sequence of acts dictated by rule and judgment.

If the STRETCH system is to be able to operate for reasonable periods without human operators, each of these operator functions must be performed by some other means. In general, each will require separate planning.

There appears to be no difficulty in providing supervisory programs and a real-time clock register for automatic self-logging of programs for accounting purposes. When the machine is being used in the multi-programmed fashion, logging becomes much more difficult because of the time-sharing; but it appears possible to provide instruction execution counters that reset only under control of the supervisory program. The problems of accounting for the services of a time-shared machine will need considerable attention.

Loading and unloading of input-output equipment is a major problem. Dr. Buchholz has treated automatic loading for several reels of tape in a separate memorandum. The capacity of such devices required for full system utilization overnight is not yet clear. While it is true that remote keyboard input of data can somewhat ameliorate loading problems, special facilities must still be provided. It appears quite uneconomic to attempt to provide facilities for automatic loading and unloading of sufficient cards to provide long runs of operations that read cards at full speed. For both electronic and electro-mechanical printers, loading and unloading of film and paper for long-run operation also present problems.

The button-pushing functions can be performed by the input-output loading apparatus, by programs, and by signals from remote apparatus, such as the programmer's debugging console. There appear to be no serious difficulties in achieving freedom from the need for human operation in this respect.

Provision of special and separate facilities for debugging should in large measure remove the necessity for an operator to stop programs that have looped. In the rare cases when "completely debugged" programs loop, it will perhaps be possible to cause machine stop with the supervisory program under control of the real-time clock register after some preset running time has expired.

Special apparatus will have to be constructed to replace the operator in his function as watchman. This will include detection of fire, mechanical failure or runaway, cooling system failure, and power interruption, in addition to the built-in checks on accurate machine operation. These detectors will have to be combined with suitable apparatus to protect the machine from the results of the several trouble conditions.

V A Proposed Program

As has been indicated, much work is at present underway in the STRETCH project on various phases of the several goals of unattended operation. Groups are considering automatic fault location and detection devices and error-correcting coding systems. Other efforts which will be needed in the pursuit of the goals of unattended operations can be roughly classified into programming research, education technique development, machine feature design and machine planning.

Programming research in many of the problems associated with simplified program debugging and program arrangement for automatic succession of programs on a machine is underway in the Programming Research Department. Specialized programming techniques such as those set forth in Part II and the self-logging techniques proposed in Part IV will need much work.

Since most of this will be of general applicability to all computing systems, it would appear reasonable to expect that the Programming Research and Information Research Departments will be interested in developing these techniques. If this interest materializes, it would appear that the Stretch Program can assist them primarily by furnishing a full, clear description of the materializing system. This will enable the new programming techniques to be developed and sent to the field together with the new machine.

Education techniques will need to be developed to facilitate the instruction of programmers and servicemen. New techniques will be needed for instruction because the radically new servicing and programming techniques and the increased power of the system will inevitably mean that much must be learned. In writing preliminary manuals, the personnel of the Stretch project will need to hold these new needs in mind; and as the project moves to more advanced stages, it may be possible to interest the Department of Education in devoting effort to further development of these, in order to simplify their tasks when the system goes into the field.

From the point of view of the system planning effort, it appears that many of the goals of unattended operation will be facilitated by the devotion of considerable effort to three projects:

1) Planning a system - hardware and techniques of use - for the interlaced performance of several programs at one time without undue burden on the programmer of any program.

2) Planning a system for the efficient performance of supervisory or executive programs which will not place any requirements on the coder of programs that are operated subject to the control of a supervisory program.

3) Planning a system for on-machine debugging of programs, using the facilities for multiprogramming and supervisory program control in order that this mode of debugging may be effected with nominal cost of machine time and with ease to the programmer.

Since these three projects appear most crucial to the unattended operation program, present work in system planning will be devoted to these. Memoranda describing preliminary results of each effort will be prepared shortly.