N O T I C E

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In reply refer to:

200-79-012

February 8, 1979

National Aeronautics & Space Admin.
Goddard Space Flight Center
Greenbelt, MD 20771

Attention: Publication Branch, Code 251

Reference: Contract NAS5-24304

Subject: Submittal of Final Project Report No. 603706.

Dear Sirs:

Enclosed herewith is one copy of the Final Project Report in accordance with Article XIII of the above referenced contract.

Very truly yours,

CYCLOMATIC INDUSTRIES INC.

Lloyd Nissley
Program Manager

LN;jam

Enc.

(NASA-CR-166633) AEROSPACE GROUND EQUIPMENT FOR MODEL 4080 SEQUENCE PROGRAMMER. A STANDARD COMPUTER TERMINAL IS ADAPTED TO PROVIDE CONVENIENT OPERATOR TO DEVICE INTERFACE Final (Cyclomatic Industries,

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cyclomatic Industries Inc.

NASA CR-166633 603706

AEROSPACE GROUND EQUIPMENT FOR MODEL 4080 SEQUENCE PROGRAMMER

A standard computer terminal is adapted to provide convenient operator to device interface

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January 1979
FINAL PROJECT REPORT - 9/77 thru 1/79

Prepared for
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

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16. Abstract
The Aerospace Ground Equipment (AGE) provides an interface between a human operator and a complex spaceborne sequence timing device which has its program stored in a memory. In addition to serving as a control panel for operating the timing device, the AGE provides a convenient means for composing, editing, syntax checking and storing timing device programs. It also transmits programs to the remotely located timing device and performs a readback operation for verification.

The AGE is implemented with a standard Hewlett-Packard 2649A terminal system and a minimum of special hardware. The terminal's dual tape interface is used to store timing device programs and to read in special AGE operating system software which works with the standard firmware resident in the terminal.

To compose a new program for the timing device, the operator uses the keyboard to fill in a form displayed on the screen. The AGE automatically identifies illogical entries. After the form is filled in, the AGE compiles it into machine language for the timing device.

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1.0 INTRODUCTION

The scope of this contract was to design and fabricate two units of Aerospace Ground Equipment (AGE) for the Model 4080 Memory Controlled Sequence Programmer (4080). The AGE specification specifically requires the AGE to use a microcomputer terminal with keyboard, cathode ray tube display and printer.

The 4080 Programmer that the AGE serves is produced to NASA/GSFC specification S-745-P-3, Rev. E. The 4080 is a small, rugged space qualified sequence timer having 48 programmable outputs. The 4080 timing sequence can have up to 57 different "events".

At each event the user can program one of eight different types of "operations" to occur. The basic and most used operations are to set the state of outputs. The outputs are classified into two identical groups of 24 each. A single event can be programmed to set the state of any combination of one group of 24 outputs. This allows the 4080 to be used for outputting parallel digital words as well as generating complex sequencing. Other types of event operations set up the 4080 for interaction with external control signals and for housekeeping functions associated with starting and ending a sequence.

4080 events are normally executed sequentially but it is possible to use event operations to program a "jump" to any other event in the program. Thus, it is possible to program sequencing "loops" of repeating events and/or include decision making branches where the sequence is modified according to the status of external signals.

The user programs each time interval between events as a "count" between 1 and 2,046 and a "clock period" by which the count is multiplied to determine the associated interval. A clock period of 0.0001, 0.005 or 0.05 seconds can be selected. Thus an interval can be as short as 0.0001 seconds or as long as 102.3 seconds (0.05 x 2,046). Longer intervals can be attained by combining intervals. The total sequence time is the sum of all intervals programmed. Basic timing accuracy is conservatively specified at ± 0.01 % under any combination of environments. It is also possible to program "infinite" intervals where the sequence waits for an external command before proceeding, or to have the programmed interval serve as a backup to an external signal in case it fails to occur.

The reason for the preceeding digression into 4080 specifications is to explain the complexity involved in programming a 4080 sequence. In order to tell the 4080 how to execute a sequence it is necessary to specify 2,304 digital "bits" of binary data. The 4080 stores the 2,304 bits of data in a recirculating loop shift register memory. The recirculating loop memory organization facilitates entering the data serially thru a single wire, a highly desirable feature since the 4080 is usually located in a rocket vehicle having a minimum of control wires. The memory data can also be circulated to read back serially for verification.

Since the long umbilical lines between the blockhouse and vehicle are notorious for electrical interference problems, sophisticated noise rejection techniques are a paramount consideration in the design of all interfaces between the 4080 and the AGE.

Simply put, the function of the AGE is to interface between the 4080 and its human operator. The AGE display presents human readable information and its keyboard accepts human inputs in a convenient and easily understood manner. At the 4080 end of the interface, the AGE supplies the 2,304 bit strings of "ones" and "zeros" that specify a program in 4080 machine language and also applies appropriate control signals.

2.0 SUMMARY OF AGE FEATURES

The AGE performs the following functions:

1. Provides a fast convenient means for developing and editing 4080 sequences, checking them for syntax errors and compiling them into 4080 machine language.

2. Provides for storage of 4080 programs on magnetic tape cassettes and for printing out programs in both human readable and machine language formats.

3. Provides a "controller" mode capable of not only loading and verifying 4080 programs, but also of completely controlling operation of the 4080 via seven programmable "softkeys" on the terminal. In this mode the AGE display presents the status of all control signals, the status of the "zero time" indicator, the actual measured time of the last interval completed and the number of this interval. Also displayed is information concerning the status of the AGE.

4. Provides a means of quickly changing certain sequence information (six intervals and six associated switch states) that must be adjusted just before launch and provides confirmation by displaying the actual measured results of the change.

3.0 PRE-CONTRACT HISTORICAL BACKGROUND

This project has more pre-history than history. Cyclomatic Industries, or more correctly its predecessor companies, first became involved in the earliest roots of the project in 1964 with an order from Control Research Associates. NASA/GSFC Sounding Rocket Group had Control Research under contract to study development of a sequence timer in which three time intervals could reliably be adjusted remotely at the last minute before launch. This was necessary for rocket research payloads that had to be aligned in reference to inertial space. Since the earth is rotating, the earth's position at the time of launch must be factored in. This is done by torquing the three gyros of the systems inertial platform for time durations controlled by the aforementioned remotely adjusted intervals. Many problems were originally encountered by NASA in reliably adjusting the intervals accurately by remote control because of electrical interference common to long umbilical lines to the rocket.

By 1967 the sequence of events thus started had led to the development of the Cyclomatic Model 4030 Programmer which NASA is still using in highly cost efficient sounding rocket research playing no small part in the world's present knowledge of our astronomical surroundings.

The Model 4030 has a relatively simple sequence that is specified with only 276 binary bits. These bits are "hard wired" by the user installing screws in a program board, except for 33 bits that contain the remotely adjustable information. These 33 bits are entered serially into a magnetic core shift register memory.

The usual pressure for ever increasing complexity led to the development of the 4080 which was qualified in 1974. With the 4080, the entire program, not just the part needing remote adjustment, was stored in a memory because 2,304 bits is too many for an electromechanical program board of practical size.

The problems of the operator dealing with 2,304 bits of data were not anticipated during the 4080's development, but quickly became obvious when Cyclomatic tried to do the programming manually. Techniques so easy for 33 bits were hopelessly burdensome with more than 2,000 bits.

The complexity of the launch control equipment required caused NASA to come back with a contract for one unit of the "original" AGE. This was implemented in the classic random logic manner. Although it was appreciated that this was a good application for a microcomputer, microcomputers were then in a relatively fluid state of development, Cyclomatic had little experience with them, and the contract budget did not allow for a learning experience.

Still not believing how complex the job really was, Cyclomatic greatly underbid the fixed price contract for the original AGE. It grew into something of a complex monster with minimal documentation, a scary situation from the service/maintenance point of view. Never-the-less, it worked after some signal interface buffers were added by NASA field engineers, the later task being a considerable development effort in itself. However, the paper tape readers that the AGE used to read in 4080 programs did not withstand travel well and the cost of building follow-on units promised to be very high.

When the time came to procure additional 4080 AGE, NASA came out with an RFQ for a rigidly specified microcomputer terminal approach. Bids to this specification were all well beyond NASA's budget. NASA was almost resigned to living with a duplicate of the original AGE when Cyclomatic's Software subcontractor, David Ahlgren of Sorrento Valley Associates, avocated a less costly approach that could be used if the specifications were changed to allow more freedom in the approach used. Somewhat oversimplified, Mr. Ahlgren's approach was less costly because it used a terminal having a standard resident firmware operating system with features useful to the AGE. This sharply reduced the amount of special software development required.

NASA responded with a revised RFQ which eventually resulted in the contract that is the subject of this report.

4.0 PROJECT HISTORY

4.1 EVOLUTION OF TECHNICAL APPROACH:

Cyclomatic's revised proposal that actually resulted in the contract was based on using a Hewlett-Packard (HP) Model 2649A terminal with dual tape drives and compatible printer. This terminal has a wide range of optional configurations by plugging cards into a buss in the classic microcomputer terminal manner.

Options of particular interest to this application were firmware for generating, filling in and editing "forms" such as might be used in business for order entry, inventory control, etc.

The approach used for operator entry of the 4080 program is to display a blank programming form on the screen and allow the operator to type in entries much as if he were working with a worksheet and pencil.

After using this approach during the course of this contract, the author believes that this is the optimum possible human interface for entering complex sequence programs. Using any other approach, including the one originally requested by NASA, the operator would probably end up generating and filling in exactly such a worksheet form on paper so he/she could visualize the relationship of the various elements of the sequence to each other. Then it would be necessary to tediously transcribe the information from the worksheet to whatever input the machine requires.

With the word processor-like editing features of the terminal, filling-in and editing the information directly on ther terminal is actually easier than using a pencil and paper worksheet. As an example of the many special conveniences, the form (which is too long to be displayed all at once) can be scrolled up and down under the heading.

Old programs can be called up from tape cassettes to the displayed form and the printer can supply hard copies of filled in forms whenever required.

Although numerous small refinements were made, the form (see Figure 1) ended up being, in principle, exactly what was envisioned during the proposal.

On the other hand, the compiler function that checks form entries for syntax errors and converts them into 4080 machine language went through several stages of evolution into something that is far different (and better) than the proposal concept.

4.1 EVOLUTION OF TECHNICAL APPROACH CON'T.

The proposal concept had the compiled information together with a list of all syntax errors presented on a special display format. It required waiting until the entire program was entered before making syntax checks and them switching the AGE back and forth between modes if all syntax errors were not corrected the first time. The final design permits the operator to make syntax checks line by line if desired and, when an error is detected, he/she can instantly go back to the form to make the required correction. In fact, the cursor is positioned at the offending line automatically! Another advantage of this approach is that the operator has to deal with only one error at a time - it is not necessary to print out and consult an error list.

In summary, the AGE information input/syntax check/edit/compilation system has the kind of straight-forward elegant simplicity that infuriates its creators by looking so easy and obvious that it is impossible to convince anyone of the amount of effort that went into it.

The "controller" mode of the AGE that loads and verifies programs as well as providing the operator with a control/indicator panel for operating the 4080 turned out almost exactly as envisioned in the proposal after considerably more effort than originally envisioned. The Controller function is accomplished without any outward modifications to the terminal thanks to the terminal's user definable "softkeys." (See Figure 2 for the Controller display).

The terminal is all standard HP hardware except for one special circuit card. The special card is of wirewrapped construction and fabricated on a standard HP prototyping board. This card interfaces the terminal with special AGE functions.

The only other non-standard items in the AGE system are a "Junction Box" measuring about 13" x 6" x 8" and three cables.

The special operating system software developed during this contract is stored on a magnetic tape cassette and is loaded into the terminal via its standard tape interface. The special software is supplemented by, and interacts with, the HP operating system firmware resident in the terminal.

The fact that the bulk of the AGE is standard Hewlett-Packard equipment backed up by their service organization and that the few special portions of the AGE are well documented assures that the AGE can always be maintained. It also allows follow-on units to be fabricated at a reasonable cost.

4.2 PROJECT BUSINESS HISTORY:

Cyclomatic entered subject contract under financial terms less favorable than better judgement dictated because of the following factors:

1) Cyclomatic had a substantial unfunded investment in the 4080 design and it was obvious that the 4080 would never achieve market acceptance without a good AGE to back it up.

2) Cyclomatic engineers were anxious for more experience with computer terminals.

3) Cyclomatic was less than enthusiastic at the prospect of fabricating more units of the original AGE.

The unfavorable initial position was compounded by the following additional factors:

a) Although at no time was the success of the project in doubt, everything about it took longer than estimated.

b) A key engineer who, as the designer of the original AGE, had specialized in knowledge important to the project left Cyclomatic.

c) Professional integrity did not allow the designers to compromise quality in the interest of maintaining time estimates.

In the end the project was finished by the author donating time.

4.3 SOFTWARE SUBCONTRACTOR:

More than half of the work was subcontracted on a fixed price basis to the Sorrento Valley Associates (SVA), a software specialist. After the key engineer left Cyclomatic, design, fabrication and documentation of the special terminal cards was also subcontracted to SVA.

Cyclomatic rates SVA's performance as outstanding in all matters except adherance to schedule. Although they were probably also exceeding their time estimates, SVA provided innumerable extra touches in the interest of providing a better product, and this without making petty claims for out of scope work. The aforementioned extra features are too detailed to explain here, but will be much appreciated by AGE users.

The schedule delays were partly caused by underestimating the time required and partly by pressure of competing projects due to the boom level of business that the San Diego area electronics industry enjoyed during the period of this project.

4.4 HEWLETT-PACKARD HARDWARE

As previously mentioned, the bulk of the AGE hardware is a standard HP display terminal system.

The hardware was found to be of excellent quality and appears to be well designed.

The only hardware failure experienced during the contract was one unreliable 8K RAM card. This had to be replaced twice before getting satisfactory operation.

However, Cyclomatic's local customer service interface with H.P. was poor, wasting untold amounts of time. It took a long time to get answers to the simplest questions and the answers were frequently wrong.

Cyclomatic's quote on this contract had to be revised because H.P. revised their price. Insufficient information caused Cyclomatic to order options that could not be used. Manuals had to be purchased separately even though a $500 Technical Information Package was purchased. The terminals were not delivered with an operable top plane connector configuration.

More serious was a screw up over the "line drawing set" used to generate forms on the display. It turned out that the HP printers, although specifically designed for the terminal, could not print the lines. In the end, this problem was solved by using dashes, etc. in the standard character set to draw the forms in a manner that can be printed. This turned out to have advantages in the software, so the dashed forms will probably be retained in future production. The software advantage is that the special character set does not have to be turned on and off each time you cross a vertical line on the form.

The Sorrento Valley Associates people had a very hard time learning enough about the terminal to be able to communicate between it and their software development system. The terminal has a complex operating system as may be deduced from the 3 inch thick stack of program listings in the data package. Unfortunately, however, the operating system does not include floating point arithmetic. This caused difficulty in programming the part of the controller display that deals with entering remote adjust intervals in seconds.

```
|PROGRAM: 603791  AGE EXERCISE #1      |DATE: 12/14/78        T4080 SOURCE CODE|
|PROGRAMMER: L.E.N.   |CLOCK & OUTPUT FIELDS, MEMORY ADD DECODE, RMT ADJ SIGN   |
| W | C  |C | C  |JMP|   PRIMARY OUTPUT STATES    |  SECONDARY OUTPUT STATES   |
| O | O  |L | O  |ADR| AT END OF LISTED INTERVAL  | AT END OF LISTED INTERVAL  |
| R | D  |O | U  |   |                            |                            |
| D | E  |C | N  |OR |   0     1     1     2      |   0     1     1     2      |
|   |    |K | T  |RMT|12345 67890 12345 67890 1234|12345 67890 12345 67890 1234|
|===|====|==|====|===|============================|============================|
|0  |ZTC |50|0004|   |     .     .     .     .    |     .     .     .     .    |
|1  |PRI |05|0040|   |X    .     .     .     .    |     .     .     .     .    |
|2  |PRI |.1|2000|   | X   .     .     .     .    |     .     .     .     .    |
|3  |PRI |50|0004|   |  X  .     .     .     .    |     .     .     .     .    |
|4  |PRI |50|0004|   |   X .     .     .     .    |     .     .     .     .    |
|5  |PRI |05|0040|   |    X.     .     .     .    |     .     .     .     .    |
|6  |PRI |.1|2000|   |     .X    .     .     .    |     .     .     .     .    |
|7  |PRI |.1|2000|   |     . X   .     .     .    |     .     .     .     .    |
|8  |PRI |.1|2000|   |     .  X  .     .     .    |     .     .     .     .    |
|9  |PRI |05|0040|   |     .   X .     .     .    |     .     .     .     .    |
|10 |PRI |05|0040|   |     .    X.     .     .    |     .     .     .     .    |
|11 |PRI |50|0004|   |     .     .X    .     .    |     .     .     .     .    |
|12 |PRI |50|0004|   |     .     . X   .     .    |     .     .     .     .    |
|13 |PRI |05|0040|   |     .     .  X  .     .    |     .     .     .     .    |
|14 |PRI |50|0004|   |     .     .   X .     .    |     .     .     .     .    |
|15 |PRI |50|0004|   |     .     .    X.     .    |     .     .     .     .    |
|16 |PRI |50|0004|   |     .     .     .X    .    |     .     .     .     .    |
|17 |PRI |05|0040|   |     .     .     . X   .    |     .     .     .     .    |
|18 |PRI |.1|2000|RMT|     .     .     .  X  .    |     .     .     .     .    |
|19 |PRI |05|0040|RMT|     .     .     .   X .    |     .     .     .     .    |
|20 |PRI |50|0004|RMT|     .     .     .    X.    |     .     .     .     .    |
|21 |PRI |.1|2000|RMT|     .     .     .     .X   |     .     .     .     .    |
|22 |PRI |05|0040|RMT|     .     .     .     . X  |     .     .     .     .    |
|23 |PRI |50|0004|RMT|     .     .     .     .  X |     .     .     .     .    |
|24 |PRI |05|0040|   |     .     .     .     .   X|     .     .     .     .    |
|25 |PRI |50|0004|   |0    .     .     .     .    |     .     .     .     .    |
|26 |SEC |05|0040|   |0    .     .     .     .    |X    .     .     .     .    |
|27 |SEC |50|0004|   |0    .     .     .     .    | X   .     .     .     .    |
|28 |SEC |.1|2000|   |0    .     .     .     .    |  X  .     .     .     .    |
|29 |SEC |05|0040|   |0    .     .     .     .    |   X .     .     .     .    |
|30 |SEC |.1|2000|   |0    .     .     .     .    |    X.     .     .     .    |
|31 |SEC |50|0004|   |0    .     .     .     .    |     .X    .     .     .    |
|32 |SEC |.1|2000|   |0    .     .     .     .    |     . X   .     .     .    |
|33 |SEC |05|0040|   |0    .     .     .     .    |     .  X  .     .     .    |
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FOLDOUT FRAME

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|17 |PRI |05|0040|   |    .    .    .    X    .    |    .    .    .    .    |
|18 |PRI |.1|2000|RMT|    .    .    .    .X   .    |    .    .    .    .    |
|19 |PRI |05|0040|RMT|    .    .    .    .  X .    |    .    .    .    .    |
|20 |PRI |50|0004|RMT|    .    .    .    .   X.    |    .    .    .    .    |
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|22 |PRI |05|0040|RMT|    .    .    .    .    . X  |    .    .    .    .    |
|23 |PRI |50|0004|RMT|    .    .    .    .    .  X |    .    .    .    .    |
|24 |PRI |05|0040|   |    .    .    .    .    .   X|    .    .    .    .    |
|25 |PRI |50|0004|   |0   .    .    .    .    .    |    .    .    .    .    |
|26 |SEC |05|0040|   |0   .    .    .    .    .    |X   .    .    .    .    |
|27 |SEC |50|0004|   |0   .    .    .    .    .    | X  .    .    .    .    |
|28 |SEC |.1|2000|   |0   .    .    .    .    .    |  X .    .    .    .    |
|29 |SEC |05|0040|   |0   .    .    .    .    .    |   X.    .    .    .    |
|30 |SEC |.1|2000|   |0   .    .    .    .    .    |    X.   .    .    .    |
|31 |SEC |50|0004|   |0   .    .    .    .    .    |    .X   .    .    .    |
|32 |SEC |.1|2000|   |0   .    .    .    .    .    |    . X  .    .    .    |
|33 |SEC |05|0040|   |0   .    .    .    .    .    |    .  X .    .    .    |
|34 |SEC |50|0004|   |0   .    .    .    .    .    |    .   X.    .    .    |
|35 |SEC |05|0040|   |0   .    .    .    .    .    |    .    X.   .    .    |
|36 |SEC |05|0040|   |0   .    .    .    .    .    |    .    .X   .    .    |
|37 |SEC |50|0004|   |0   .    .    .    .    .    |    .    . X  .    .    |
|38 |SEC |50|0004|   |0   .    .    .    .    .    |    .    .  X .    .    |
|39 |SEC |05|0040|   |0   .    .    .    .    .    |    .    .   X.    .    |
|40 |SEC |.1|2000|   |0   .    .    .    .    .    |    .    .    X.   .    |
|41 |SEC |.1|2000|   |0   .    .    .    .    .    |    .    .    .X   .    |
|42 |SEC |50|0004|   |0   .    .    .    .    .    |    .    .    . X  .    |
|43 |SEC |50|0004|   |0   .    .    .    .    .    |    .    .    .  X .    |
|44 |SEC |05|0040|   |0   .    .    .    .    .    |    .    .    .   X.    |
|45 |SEC |05|0040|   |0   .    .    .    .    .    |    .    .    .    X.   |
|46 |SEC |05|0040|   |0   .    .    .    .    .    |    .    .    .    .X   |
|47 |SEC |.1|2000|   |0   .    .    .    .    .    |    .    .    .    . X  |
|48 |SEC |50|0004|   |0   .    .    .    .    .    |    .    .    .    .  X |
|49 |SEC | 1|2000|   |0   .    .    .    .    .    |    .    .    .    .   X|
|50 |SEC |50|0004|   |0   .    .    .    .    .    |0   .    .    .    .    |
|51 |PRI |05|0040|   |X X X. X X .X X X. X X .X X |0   .    .    .    .    |
|52 |SEC |05|0040|   |X X X. X X .X X X. X X .X X | X X .X X X. X X .X X X. X X|
|53 |PRI |05|0040|   | X X .X X X. X X .X X X. X X| X X .X X X. X X .X X X. X X|
|54 |SEC |50|0004|   | X X .X X X. X X .X X X. X X|X X X. X X .X X X. X X .X X |
|55 |PRI |50|0004|   |XXXXX.XXXXX.XXXXX.XXXXX.XXXX|X X X. X X .X X X. X X .X X |
|56 |SEC |50|0004|   |XXXXX.XXXXX.XXXXX.XXXXX.XXXX|XXXXX.XXXXX.XXXXX.XXXXX.XXXX|
|57 |RUJ |05|0038|001|    .    .    .    .    .    |    .    .    .    .    |
|___|____|__|____|___|____________________________|____________________________|
```

FIGURE 1.

SOURCE FORM WITH PROGRAM FILLED IN

FIGURE I

FOLDOUT FRAME

PROGRAM: 603791 AGE EXERCISE #1		DATE: 12/14/78	4000 CONTROLLER
CONTROL MODE: RUN		EVENT WORD: 15 -	EVENT INTRVAL: .2
PROGRAM STATUS:			
f1 RESET:	f2 START:	f3 HOLD:	f4 CON JMP:
f5 GT TRIG EN:	f6 GATED TRIG:	f7 UNGATED TRIG:	ZERO TIME:
LOAD:			
REMOTE ADJUST: LOADED IN 4080			

NUMBER	WORD	PRG INTERVAL	P SIGN	ADJ INTERVAL	A SIGN	MEA INTERVAL	M SIGN
1	18	.2	-	.0005	+	.0005	+
2	19	.2	-	1.245	+	1.2449	+
3	20	.2	-	2.	+	1.9999	+
4	21	.2	+	.2041	+	.2041	+
5	22	.2	-	.345	+	.345	+
6	23	.2	-	10.05	+	10.0496	+

FIGURE 2

CONTROLLER FORM

Figure 2

5.0 ACCEPTANCE TEST RESULTS

The following are frank comments giving impressions of how well the AGE design works, based on experience during debugging and extensive acceptance tests. Actual acceptance test data is supplied separately as it is too voluminous for this report.

1. No problems were encountered with the tape cassette system. It appears to have a remarkably secure error checking system. The tape cartridges should prove a convenient program storage medium.

2. The load and verify system has always performed impeccably.

3. The syntax check system took lots of debugging but now works very well. It is virtually impossible to compile a program that the 4080 cannot execute. One thing that the compiler cannot catch is making a jump to an unused address.

   Special comment with regard to the compiler system:

   In a few situations where the correct entry is mandated by the content of the rest of the program, the compiler does not give an error message in response to an incorrect entry, it simply corrects the entry. The moral is to check the display after compiling - what you see then is what you get.

   The automatic carry-down of Xs indicating switch "on" states is a great convenience and assures that the form, after compilation, is always in exact agreement with what the 4080 will actually execute.

4. The compiler will not compile a program with "RMT" (remote adjust) flags on words not preceded by a "PRI" (primary) word because the "sign" associated with the remote adjust interval must be programmed by a preceding primary word.

   RMT is the one source form entry that doesn't translate to the actual 4080 program. The RMT entry is only to tell the AGE Controller Mode which words, if any, it should treat as remote adjusts.

   The remote adjust feature can only change the count of the interval, not the clock period. The clock period remains as entered on the source form.

   Should it become desirable to defeat this for test purposes, it is possible to run one program in the 4080 and have another, with remote adjust words flagged wherever you desire, in the terminal. There will be confusing interval readouts if the clock periods don't agree however.

5. The Controller-Adjust Mode accepts interval times in real seconds so that the intervals entered can be compared directly to the display of actual measured intervals.

   Since the count, not the interval, is what is actually changed, the clock period specified on the source form for each remote adjust interval must be taken into account by the AGE. This caused a lot of software complications.

   The Controller display should have listed the clock periods for reference. As it is the operator who must remember what the clock period was for each interval so he/she can enter times that are a multiple of that clock period. (Not a big deal in practical use because the clock periods are normally all the same anyway).

   The AGE remote adjust entry system, of course, has a syntax check that rejects illegal entries. However, certain entries that are not a multiple of the specified clock period do not cause an error message. Instead, when they are entered they automatically change to the nearest lower multiple of the clock period. According to SVA, this approach was required by software restrictions. Once it was understood, it was found not hard to live with because the display always correctly shows what the value is. Here again, the operator must check the display after the AGE accepts the remote adjust intervals. What you see then is what you get.

6. The remote adjust measured interval display gets into a subtle problem when the remote adjust intervals are in a fast 4080 program loop. The problem can be avoided if the intervals in the loop average 0.1 seconds or more. This restriction is not a problem in practical use because the remote adjust intervals are not used that way. It can cause confusion during testing however, because it is so convenient to program a loop to get repeating results.

7. One of the terminals gave a lot of trouble by intermittently dropping the program at random times. The cause was traced by substitution to the 8K RAM card next to the processor card. One replacement card had the same problem. Should this problem reoccur in the future, the 8K RAM card is a good place to start checking.

8. As mentioned earlier in this report, NASA's field experience with the 4080 determined that buffer/drivers were required at the 4080 end on three signal lines, namely the Memory Verify, Event Monitor and Memory Address. These buffers, then, become an integral part of the 4080/AGE system that must be included to have a valid test results.

Unfortunately, testing revealed problems with the present buffer circuits which Cyclomatic cannot resolve along since the buffers are supplied by NASA. The problems are:

a) The slew rate of the Memory Address Buffer is not fast enough in some circumstances for the AGE to reliably capture the remote adjust intervals.

b) Both the Memory Verify and Event Monitor Buffers tended to oscillate in the test configuration.

c) The Event Monitor Buffer can overheat when a fast loop is programmed.

Very possibly problems b) and c) are not present in the actual hardware configuration.

Pending final resolution of these problems, Cyclomatic tested using the hastily devised configuration of Sketch 927 to give a basis of comparison.

9. Since the Memory Address Signal system used to identify remote adjust intervals for display is known to be inherent problem area, tests of this system were watched closely with the following conclusions:

   a) Jumps from one address to another don't present the anticipated problems.

   b) Reference Table I of Cycloamtic Manual 603705, most transitions between sequential memory address involve a 2.5 volt shift in memory address indicator voltage. However, several addresses involve a 17.19 volt shift. These addresses proved to be harder to capture.

   c) The AGE seems to have the most trouble capturing remote adjust intervals when they are sandwiched between minimum (0.0001 second) intervals as they are in the first loop of ATP Exercise #5 (Tape 603795). Once in awhile we noted a 0.0001 interval being picked up instead of the correct interval.

6.0 RECOMMENDATIONS

1. The fol'owing is a list of improvements that are relatively easy to accomplish. These improvements are not recommended unless they meet a serious need since the AGE is probably already at the point of diminishing returns on refinements with respect to benefits gained vs. effort required.

   a). If the three 4K memory cards were replaced with one of the new 12K cards, two card slots become available.

   b). The wait for the tape to read each time you switch between Editor/Compiler mode and Controller mode could be eliminated by having an additional 8K RAM card to store both programs for instant recall.

   c). The software now contains a list of every measured interval in the sequence (so the remote adjust intervals can be picked out). It may be easy to get them all displayed, though dealing with a loop sequence may present problems of knowing where to start.

   d). A telephone interface could be added.

2. Retest the memory address related performance in the actual launch environment with the final memory address buffer circuit.

3. Set up the printers for narrower paper, since the AGE printouts are limited to 80 columns.

4. Now that the design is working someone should step back from the details and analyze the overall software/hardware system for single point failure modes that can affect both the load and verify modes such that an error is not caught. Possibly some king of checksum system would help. One weak point already noted is that each object code bit effecitvely depends on one bit in memory (the same bit for both load and verify). Since the object code is stored in ASCII characters, all seven bits could be monitored to give better data security.

5. With regard to service of the Hewlett-Packard equipment, it is so complex and HP has so many models to deal with that you will probably not find it practical to repair it yourself or even have it repaired at the local HP office. The most practical thing to do is to isolate the failure to one assembly by substitution, then send it back to the factory under HP's exchange system where they send you a repaired assembly from stock (at a substantial percentage of a new assembly cost). They can get you a replacement assembly virtually overnight if you convince them that you have a bonafide emergency. You may find it wise to get the proper procedures lined up with your purchasing department and the local HP office so there will be no unnecessary delays when you need a quick exchange.

7.0 OPERATION & MAINTENANCE INSTRUCTIONS

The contract specifies that this report include complete Operation and Maintenance Instructions. Since the operation and maintenance data delivered under this contract is a stack of 8½ x 11 documents more than 19" high, this data is incorporated herein by reference.