

PROGRAM TITLE: SIGPERT - An improved program package for the Scheduling of Critical Paths

PROGRAM CLASSIFICATION: General Topics

CONTRIBUTORS: Based on RUG Programs:
No. 58 - SCHEDULE CRITICAL PATH
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No. 61 - CRITICAL PATH SPECIAL OUTPUT PROGRAM
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No. 1095 - CRITICAL PATH DATA CHECK
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PURPOSE: Provides an automatic check for possible violations of data format restrictions and streamlined methods for correcting such violations in information describing the network of tasks that must be followed to complete some total job. The program finds the Critical Path: the sequence of tasks which determine the time necessary to complete the total job.

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FOREWORD

General Description of the Problem

When any job is undertaken one of the most important considerations is how long it will take from beginning to end. For example, this time determines the delivery date in bidding on contracts. Since price and delivery are the two essentials of any bid this time is an important consideration.

The scheduling function has been an important part of military and industrial planning for many years. The length of time to perform each task is estimated and the relation of the tasks worked out so that the total amount of time for the job is easily computed.

This type of schedule, however, leaves several unanswered questions. For example:

What tasks should be shortened in order to decrease the total time necessary for the total job?

or

When a task takes longer than scheduled, what effect does it have on the total schedule?

In order to answer these questions and to provide a method of dealing with the massive schedules supporting modern projects, a method of computer use has evolved called Schedule Critical Path Calculation. In simplest terms, the computer is fed a schedule and the relationship of each task (i.e., what tasks must be completed before work can be completed on a subsequent task) and the computer will determine the Critical Path (the tasks which determine how long it will take for the total job) and the amount of leeway (slack) for all other tasks.

Credit for the development of this work must be given to the Navy which has done much research on its application and has it in operation under the name of PERT, and to the Air Force under the name of PEP. Two papers are available describing these systems:

PEP (Program Evaluation Procedure)

Program Evaluation Procedure

Program Control Office

Directorate of Systems Management WADD

September, 1960

PERT (Program Evaluation and Review Technique)
Application of a Technique for Research
and Development Program Evaluation
W. Fazar - Special Projects Office
U. S. Navy, Washington D. C.
April, 1959

Development of this Package

In July, 1962, U. S. Army Satellite Communications Agency (formerly ADVENT Management Agency) required a method for Schedule Critical Path calculation that could be used to demonstrate computer applications in the field of satellite program planning. They approached the U. S. Army Signal Center and School for RECOMP II Computer support.

Signal School personnel found that RUG Programs No. 58, 61, and 1095 were basically suitable for this use. Personnel who were to operate them as a unified system, however, had to be extensively trained in RECOMP computer and console operation. SATCOM requested a Schedule Critical Path Calculation program package that could be used by management personnel after a minimum orientation in its operation.

The Signal School added programming of its own to the best features of the RUG programs cited above, and combined them into one system tape. The system provides:

- Programs called and controlled mainly from the computer typewriter.
- The added capability of naming all events in the total job. These 24-character alphanumeric identifications may appear on Schedule Critical Path output listings to directly provide easily understood reports for management executives.

1. INTRODUCTION

This program provides an automatic data check for possible violations of data format restrictions and streamlined methods for correcting such violations in information describing the network of tasks that must be followed to complete some total job. The program finds the Critical Path: the sequence of tasks which determine the time necessary to complete the total job, and then provides a choice of output formats for typewriter report of this information.

1.1 Definitions

- 1.1.1 Event - The point in time that a task is completed. These check points in the schedule are places where it is convenient to assign a deadline.
- 1.1.2 Event Number - The identification number assigned to each Event.
- 1.1.3 Activity - The task necessary from the end of one Event to the end of a connecting Event. (Identification of an Activity consists of a 'From' Event Number and a 'To' Event Number).
- 1.1.4 Activity Time (Te) - The estimated time necessary to perform an Activity.
- 1.1.5 Expected Activity Time (ATE) - The necessary elapsed time from the beginning of the project to the completion of an Activity.
- 1.1.6 Latest Activity Time (ATL) - The latest time after the beginning of a project that an Activity may be completed without affecting the schedule.
- 1.1.7 Expected Event Time (ETE) - The necessary elapsed time from the beginning of the project to the completion of the Event.
- 1.1.8 Latest Event Time (ETL) - The latest time after the beginning of the project that an Event may be completed without affecting the schedule.

2. METHOD

- 2.1 Computation of Expected Activity Times and Expected Event Times
 - 2.1.1 Find 'From' Event in Event file.

-
- 2.1.2 Find Expected Time, ETE', for that Event.
- 2.1.3 Add Activity Time, Te, for the current Activity to the ETE found in 2.1.2. This is the Expected Activity Time, ATE, for the Activity under consideration.
- $$Te + ETE' = ATE$$
- 2.1.4 Find the 'To' Event of the same Activity in the Event File.
- 2.1.5 Find the Expected Time, ETE'', for this 'To' Event.
- 2.1.6 If ATE is larger than ETE'', replace ETE'' with ATE. If ATE is less than or equal to ETE'', then ETE'' remains unchanged.
- 2.1.7 Steps outlined in 2.1.1 through 2.1.6 are repeated until all entries in the Activity Table have been considered. These entries are considered consecutively.
- 2.2 Computation of Latest Activity Times and Latest Event Times
- 2.2.1 The Latest Activity Time, ATL, corresponding to the final entry in the Activity table is set equal to the corresponding Expected Activity Time.
- 2.2.2 Find 'To' Event in the Event file.
- 2.2.3 Find the corresponding Latest Event time, ETL'', for that Event. This is ATL for the Activity under consideration.
- 2.2.4 Subtract the corresponding Activity Time, Te, from ATL.
- 2.2.5 Find the 'From' Event corresponding to the Activity under consideration in the Event file.
- 2.2.6 Find the corresponding Latest Event Time, ETL', for that Event.
- 2.2.7 If $(ATL - Te)$ is less than ETL', replace ETL' with $(ATL - Te)$. Otherwise, ETL' remains unchanged.
- 2.2.8 Repeat steps outlined in 2.2.2 through 2.2.7 until all entries in the Activity table have been considered. These entries are considered consecutively, beginning with the final entry in the Activity Table.

3. RESTRICTIONS

- 3.1 Each Event Number must be greater than zero and less than or equal to 9,999. These numbers must be integers.
- 3.2 Each Event Name is an optional alphanumeric entry which may contain no more than 24 characters, including case shifts and spaces.
- 3.3 Activity Times may be no less than zero and no greater than 999.9.
- 3.4 If Event Names are included as input data, there may be no more than 255 Event Names, and no more than 340 Activities. If Critical Path output listings are to be completely numeric, with no Event Names shown, as many as 704 Activities may be entered.
- 3.5 No Event Number may appear in the 'To' side of the Activity Table after it has appeared in the 'From' side of the Activity table. For example, the following situation cannot occur:

ACTIVITY TABLE

| FROM | TO |
|------|--------------------------|
| 450 | 142 |
| 450 | 163 |
| 118 | <u>450</u> (Not allowed) |

- 3.6 All Activities with a given 'From' Event Number must occur consecutively in the Activity table.
- 3.7 The first Activity in the Activity Table must be a 'dummy' Activity that leads 'From' mythical Event 0. 'To' the first actual Event in the job network with a Te of 0. This dummy Activity is required by the Data Checking portions of the package, and will be automatically removed before Schedule Critical Path calculation begins.
4. USAGE
- 4.1 Input Data
- 4.1.1 Input data must consist of 'From' and 'To' Event numbers for each Activity and the corresponding Activity times for each Activity.

- 4.1.2 Input data may also consist of Event Numbers for each Event and a corresponding line of 24 alphanumeric characters which comprise the Event Name.
- 4.1.3 Data is normally input from tapes prepared off-line. Activity Table data may also be input from the computer console keyboard. After the main body of data has been read in and typed back for proof-reading, corrections may be made under program control through the computer typewriter.
- 4.2 Operating Procedures
- 4.2.1 Activity Table Tape Input Procedure
- 4.2.1.1 Data must be preceded by a location setting of 1000 (octal) and an N code for decimal number entry. Data entries must include at least 12 blank spaces between each decimal point and enter code on the tape. Note restriction that if an Event Name Table is also to be entered, Activity tape may contain no more than 340 activity entries.
- 4.2.1.2 The first activity entered on tape must be a 'dummy'. Punch + 0 ., twelve blanks, and an enter code (carriage return). If a teletypewriter is used for tape preparation, a quotation mark (figures Z) is equivalent to a + sign. Then punch the 'From' event number of the first activity in the network as a positive integer. Terminate this with a decimal point, twelve blanks, and an enter code. Next, punch + 0 ., twelve blanks and an enter code.
- 4.2.1.3 Each activity in the network may now be entered as sequences of three positive numbers. Enter the 'From' event number as a positive integer. Terminate it with a decimal point, twelve blanks, and an enter code. Then enter the 'To' event number as a positive integer. Terminate it with a decimal point, twelve blanks, and an enter code. Now enter the Activity time (Te) as a positive integer and terminate with a decimal point, twelve blanks, and an enter code. The time will be treated by the program as a mixed number, with an implied decimal point between the two low-order digits.
- 4.2.1.4 After the final Activity Time entry, punch any negative integer on the tape. This number is used by the program as an end-of-file indicator. Terminate it with a decimal point, twelve blanks, an enter code, and a stop code (figures H).

- 4.2.1.5 Page copy from a teletypewriter printout of a properly prepared Activity Table tape would appear as follows:

```
L10000
N+0.
+450.
+0.
+450.
+526.
+10.
+450.
+210.
+50.
```

etc...etc...

```
+189.
+100.
+0.
-9999.
```

- 4.2.1.6 If yellow teletypewriter tape is used for off-line tape preparation, it must be reproduced on 11/16-inch black chad (completely perforated holes) tape before it is loaded in the computer.

4.2.2 Event Name Table Tape Input Procedure

- 4.2.2.1 Data must be preceded by a location setting of 3000 (octal). Each Name Table entry consists of an event number and 24 alphanumeric characters which comprise the event name. Note restriction that the Table may contain no more than 255 entries.

- 4.2.2.2 To enter an event number, punch N + , the event number, a decimal point, twelve blanks and an enter code (carriage return). Then enter the event name by punching F immediately followed by the first eight characters of the 24-character name. Terminate these first eight characters with an enter code and enter eight more characters of the name. Terminate this second group of eight characters with an enter code. Punch the final eight characters of the name, an enter code, and 12 blanks. If the name is short, use spaces to fill it out to 24 characters. 24 alphanumeric characters must be punched in three groups of eight.

- 4.2.2.3 Repeat the entire procedure of 4.2.2.2 for each Name Table entry. After the final entry, punch N and any negative integer. This number is used

by the program as an end-of-file indicator. Terminate it with a decimal point, twelve blanks, an enter code, and a stop code (figures H).

- 4.2.2.4 Page copy from a teletypewriter printout of a properly prepared Name Table tape would appear as follows:

```
L30000
N+450.
FCONTRACT
  AWARD D
ATE
N+526.
FSPARE PA
RTS REQU
ISITION
N+915.
FSUBM INS
TR CONSO
LE DESGN
```

etc...etc...

```
N+189.
FCOMPLETE
  SYSTEMS
  TESTS
N-9999.
```

When these names appear in output listings, all 24 characters will be printed on one line. The F preceding each name entry is a computer code that will not appear in output listings. Any 'F' used as an integral part of the Event Name will appear normally.

- 4.2.2.5 If yellow teletypewriter tape is used for off-line tape preparation, it must be reproduced on 11/16-inch black chad (completely perforated holes) tape before it is loaded in the computer.
- 4.2.3 Computer Console Keyboard Activity Table Input Procedure
- 4.2.3.1 Set the Location Counter to 1000.0. Depress the 'N' mode key.
- 4.2.3.2 Enter on the console + 0 Terminate with the decimal point key and the clear key. Then enter the 'From' event number of the first activity in the network as a positive integer. Terminate with

the decimal point key and the clear key. Again, enter + 0 , decimal point, clear.

- 4.2.3.3 Starting again with the first Activity in the network, enter each activity as follows:
 - 4.2.3.3.1 Enter on the console the 'From' event number as a positive integer and terminate with the decimal point and clear keys.
 - 4.2.3.3.2 Enter on the console the 'To' Event number as a positive integer and terminate with the decimal point and clear keys.
 - 4.2.3.3.3 Enter on the console the Activity Time as a positive integer and terminate with the decimal point key and the clear key. The number entered will be treated by the program as a mixed number, with an implied decimal point between the two low order digits.
- 4.2.3.4 Immediately following the final Activity time entry, enter any negative number. This number is used by the program as an end-of-file indicator.
- 4.3 Program package operation procedures
 - 4.3.1 Set computer typewriter margin at 10. Set tabs at 20, 28, 38, 53, 63, and 73.
 - 4.3.2 Before loading program tapes, computer memory should be cleared to minus zeros with a memory zero program such as RUG No. 21. This is not absolutely necessary, however.
 - 4.3.3 Load Activity Table and Event Name tapes. If the Event Name option is not used, turn Sense Switch 'C' on.
 - 4.3.4 Load SIGPERT tape and press 'fill'. Approximately two-thirds of the tape will read into memory. The computer will automatically begin computing a hash sum to verify the accuracy of the reading operation. If any reading error occurred, the statement

READING ERROR!! RELOAD TAPE

will be printed on the typewriter. Otherwise, the program will interrogate Sense Switch 'C'. If an Event Name Table is in memory, the Table will be sorted into ascending Event Number order.

4.3.5 A heading will be printed on the typewriter to identify the package and remind the operator that Activity and Name data should be in memory. A reminder of the typewriter margin and tab settings will also be printed. If the operator wishes to adjust tab settings after this timeout has begun, press 'Error Reset' button on the console and switch the 'Computer-Manual Punch' switch to the 'Manual Punch' position. Turn the tape punch off. Then make the necessary changes. Restart the program by restoring the 'Computer-Manual Punch' switch to the 'Computer' position, turning the punch on, and pressing the 'Start-2' button on the computer console.

4.3.6 Selection of the operations to be performed by the package can be made through a format distributor. The typewriter will print

SELECT YOUR PROGRAM:

and the computer will halt in the alpha read mode. Depending on the letter key depressed, program control can be sent to any of the following routines:

- E - PRINT LISTING OF ACTIVITY TABLE
- F - CHECK VALIDITY OF ACTIVITY TABLE
- G - ACTIVITY TABLE INSERTION
- H - ACTIVITY TABLE DELETION
- J - ACTIVITY TABLE CORRECTION
- K - DUMP ACTIVITY TABLE TAPE
- L - PRINT LISTING OF EVENT NAME TABLE
- M - NAME TABLE INSERTION
- N - NAME TABLE DELETION
- P - DUMP NAME TABLE TAPE
- Q - COMPUTE CRITICAL PATH

If keys other than those shown are struck, no damage will be done. The computer will type ?? , and stop again in the alpha read mode. Carriage return or tab keys will cause the computer to carriage return and ask again for a program selection.

4.3.6.1 E - PRINT LISTING OF ACTIVITY TABLE routine.
A sequential listing of the Activity Table will be printed. Each line will show an Activity Code Number which is a reference number used by the CHECK VALIDITY OF ACTIVITY TABLE routine, the memory address of the 'From' Event for that Activity,

the 'From' Event for the Activity, the 'To' Event, and the Activity Time. After listing the Activity Table, the computer will ask for another program selection.

- 4.3.6.2 F - CHECK VALIDITY OF ACTIVITY TABLE routine. The Activity Table will be automatically checked for data format restriction violations and for continuity of each path in the network. When the 'F' key is depressed on the typewriter, the computer will print

CHECKING VALIDITY OF CRITICAL PATH
ACTIVITY TABLE:

and enter the checking routine. Four error tests are made. If mistakes are discovered, one of the following typeouts will occur:

- 4.3.6.2.1 ACTIVITY N IS NOT LISTED CONSECUTIVELY WITH THE BALANCE OF ACTIVITIES FOR THIS EVENT.
- 4.3.6.2.2 ACTIVITY N HAS A TO EVENT NOT CONNECTED TO THE BALANCE OF THE NETWORK.
- 4.3.6.2.3 ACTIVITY N HAS A FROM EVENT NOT APPEARING ON THE TO SIDE OF THE ACTIVITY TABLE FIRST.
- 4.3.6.2.4 ACTIVITY N HAS AN EVENT APPEARING ON THE TO SIDE OF THE ACTIVITY TABLE AFTER IT HAS APPEARED ON THE FROM SIDE.

N in each case will be an Activity Code Number which refers to the Activity Table Listing produced by routine E. After such an error typeout, the computer will halt. It may be restarted by pressing either the 'START - 1' button, or the 'START' key on the computer console. If no errors are discovered by the routine, the following statement will be printed:

ACTIVITY TABLE CHECKS OUT AS LOGICALLY
VALID.

and a new program selection will be requested.

- 4.3.6.3 G - ACTIVITY TABLE INSERTION routine. One of three routines that provide for the correction of errors found in the Activity Table. After identifying

itself, the routine will query:

INSERT AT LOCATION:

and halt in the alpha read mode. The typewriter will now be ready to accept the four-digit octal location at which the new Activity is to be inserted. Consult an Activity Table listing produced by routine E to determine the proper location. This routine will analyze each digit as it is entered. The typewriter will execute an audible figures shift to indicate when it is ready for the next digit. If keys other than the numbers 0 - 7 are struck, the computer will type ?? and stop again in the alpha read mode. After accepting a location, the routine will ask for a description of the Activity:

ACTIVITY - FROM:

and halt in the alpha read mode. Enter the 'From' Event Number as a decimal integer and terminate it with a period. The routine will then request the 'To' Event Number. Enter it as a decimal integer terminated with a period. If, at this time, the routine determines that the Activity being entered is new, and not a correction of the Activity already in the list, the list will be automatically opened. A running display of the opening will appear on the console nixies. The routine will then request 'TE:'. Enter the Activity Time as a mixed number with an implied decimal point between the two low-order digits. Terminate with a period. A typical insertion would appear as follows:

ACTIVITY TABLE INSERTION

INSERT AT LOCATION: 1052
ACTIVITY - FROM: 180. TO: 189. TE: 70.

After the insertion is accomplished, the typewriter will ask again for a program selection.

4.3.6.4 H - ACTIVITY TABLE DELETION routine. After identifying itself, the routine will query:

DELETE AT LOCATION:

and halt in the alpha read mode. The location of the Activity to be deleted can then be entered in the same manner as indicated in 4.3.6.3. During the

closing of the list, a running display of the operation will appear on the console nixies. The computer will then ask again for a program selection.

- 4.3.6.5 J - ACTIVITY TABLE CORRECTION routine. Queries and responses for this routine are identical to routine G. This routine allows the changing of an Activity without opening the Activity Table.
- 4.3.6.6 K - DUMP ACTIVITY TABLE TAPE routine. A permanent copy of the Activity Table is punched for use in future Critical Path calculations. The paper tape produced by this routine will be in RECOMP alpha-numeric format and will not produce an intelligible printout on an off-line teletypewriter. After punching the tape, the computer will carriage return the typewriter and ask again for a program selection.
- 4.3.6.7 L - PRINT LISTING OF EVENT NAME TABLE routine. A listing of the Event Name table will be produced showing the Events in numerical order. Each line in the listing will show the starting location of the Event Name in memory, the Event Number, and the Event Name itself. After listing the Event Name Table, the computer will ask for another program selection.
- 4.3.6.8 M - NAME TABLE INSERTION routine. Provides for the insertion of new Event Names in the Event Name Table or the correction of entries already in the Table. After identifying itself, the routine will query:

INSERT EVENT NUMBER:

and the computer will halt in the alpha read mode. Enter the Event Number as a decimal integer terminated with a period. This routine will analyze each digit as it is entered. The typewriter will execute an audible figures shift to indicate when it is ready for the next digit. After accepting the Event Number, the routine will request:

EVENT NAME (24 CHARACTERS):

and halt in the alpha read mode. Type in the new Event Name. If the Name is shorter than 24 characters (including case shifts, etc.), fill it out with spaces. The routine will count the characters being entered and go into a request for a new

program selection when the 24th character is entered.

- 4.3.6.9 N - NAME TABLE DELETION routine. After identifying itself, the routine will query:

DELETE EVENT NUMBER:

and halt in the alpha read mode. The Event Number to be deleted can then be indicated in the same way an Event Number was indicated in routine M. If the routine is unable to find the Event Number to be deleted in the Event Name list, the statement

EVENT IS NOT IN LIST

will be typed. Otherwise the indicated Event Name entry will be found and deleted. A running display of this operation will appear on the RECOMP nixies. The computer will then ask again for a program selection.

- 4.3.6.10 P - DUMP NAME TABLE TAPE routine. A permanent copy of the Event Name table is punched for use in future Critical Path calculations. The paper tape produced by this routine will be in RECOMP alphanumeric format and will not produce an intelligible printout on an off-line teletypewriter. After punching the tape, the computer will carriage return the typewriter and ask again for a program selection.

- 4.3.6.11 Q - COMPUTE CRITICAL PATH routine. Provides an entry to the second major portion of the SIGPERT program package tape. Before calling this routine, listings of the Activity and Event Name Tables should be made and corrected, validity of the Activity table should be checked, and tape dumps of the Tables should be made. Once this routine is entered, Critical Path calculation will proceed to completion and the contents of the Activity Table will be altered in memory. When this routine is called, the Activity Table will first be truncated to remove the dummy Activity at its head. A running display of this operation will appear on the RECOMP nixies. Then the statement:

COMPUTING CRITICAL PATH

will be typed on the typewriter and another portion of the SIGPERT program tape will automatically be read in. When this reading operation is completed a hash sum computation will be made to verify the

accuracy of the reading operation. If a reading error occurred, the statement

READING ERROR

will be printed on the typewriter. In this event, the SIGPERT program package should be loaded back into memory following the procedure in 4.3.4 and the COMPUTE CRITICAL PATH routine called again through the program selector. If no reading error occurred, Critical Path calculation will automatically begin.

- 4.3.7 Restart procedures for first and second parts of SIGPERT package.
- 4.3.7.1 If reading errors occur during the loading of the first data checking and editing part of SIGPERT or the second Schedule Critical Path calculation part, reload the SIGPERT tape at its beginning and proceed as outlined in 4.3.4 et seq.
- 4.3.7.2 When the first data checking and editing part of SIGPERT is in memory, the program selector can be entered at any time by pressing the 'Error Reset' button on the computer console and then pressing 'Start-1'. 'Start-2' can also be used for this purpose, but it will initiate a printout of the package name and the reminders to set tabs and have data in memory before it requests a program selection.
- 4.3.8 Event Name option. Schedule Critical Path output listings may be made with no alphanumeric Event Name accompanying each Event Number. While this impairs the readability of the final output, it does permit increasing the number of allowed Activity Table entries to 704. (See 3.4) Sense switch 'C' should be kept in the 'on' position at any time an Event Name table is not in memory. This sense switch disables all routines in the first part of SIGPERT that pertain to the Event Name Table and corrects output listings for the absence of Event Names. If, in the first part of SIGPERT, an attempt is made to call routines L, M, N, or P, the statement:

SENSE SWITCH 'C' IS ON. YOU CLAIM NO
NAME TABLE IS IN MEMORY.

will be typed and the computer will ask for another program selection.

4.3.9 Final Expected Activity Time option. If Sense switch 'B' is 'on' (down) during computation of the Schedule Critical Path, all Expected Activity Times and Expected Event Times will be computed, the FINAL Expected Activity Time (which is the target time for the completion of the entire project) will be typed out, and the computer will halt with the location counter at 0762.0. On the console keyboard, depress N, enter the desired value of Expected Activity Time, terminate with the decimal point key and depress 'Start'. Computation will proceed to the end and the Latest Activity and Event Times will be adjusted by the difference between the computed final Expected Activity Time and the Expected Activity Time entered on the keyboard.

4.3.10 Output options for computed Schedule Critical Path.

4.3.10.1 If Sense switch 'D' is 'on' (down) at the completion of Critical Path calculation, an all-numeric 'CRITICAL PATH' output listing will be produced on the typewriter. It outputs each Activity in the order it was received and gives Activity Time, Expected Activity Time, and Latest Activity Time for that Activity. Each Event in the job network is also listed with its Expected Event Time and its Latest Event Time. This output format is not normally desired since the entire job network must be printed out before the Critical Path becomes apparent. During normal SIGPERT runs, Sense switch 'D' will be left 'off' (up). In this condition the computer will automatically read in the last part of the SIGPERT package when Critical Path calculation is finished. After this reading operation, a hash sum calculation will automatically check the accuracy of the reading operation. If a reading error occurred, the computer will type:

READING ERROR. RELOAD TAPE AT WHITE MARK
AND PRESS 'FILL'.

This permits the reading of the last part of the SIGPERT package without calculating the Schedule Critical Path.

4.3.10.2 The last part of the SIGPERT package contains two special output routines that may be entered through a program selector. If the read-in operation was accomplished properly, the computer will type:

SELECT YOUR PROGRAM:

and halt in the alpha read mode. One of two responses may be made on the typewriter:

- 4.3.10.2.1 EVT - This response will direct the computer to print the output heading:

EVENTS IN ORDER OF SLACK

and then type Events in groups. The first group will consist of Events with slack of zero. These Events are on the Critical Path. The next group will consist of events with the smallest non-zero slack, the next group with the second smallest slack, etc. until all events have been typed. Then a request will again be made for a program selection.

- 4.3.10.2.2 ACT - This response will direct the computer to print the output heading:

ACTIVITIES IN ORDER OF SLACK

and then type Activities in groups. The first group will consist of Activities with slack of zero. These Activities are on the Critical Path. The next group will consist of Activities with the smallest non-zero slack, the next group with the second smallest slack, etc. until all Activities have been typed. Then a request will again be made for a program selection.

- 4.3.10.2.3 Striking other combinations of keys will cause the typewriter to type ?? and halt again in the alpha read mode awaiting a new response.

- 4.3.11 Restarts may be made in the third part of the SIGPERT package by pressing the 'Error Reset' button on the computer console and then pressing 'Start - 3'. The computer will carriage return and ask for a program selection. The Event output routine may be entered directly with 'Start - 1', and the Activity output routine may be entered directly with 'Start - 2'.

- 4.3.12 If Sense switch 'C' is on (down) the output routines in the third part of the SIGPERT package will produce output listings with no Event Names accompanying Event Numbers. See 3.4 and 4.3.8.

5. CODING INFORMATION.

5.1 Memory filled by first read-in operation on SIGPERT package:

| Locations | Contents |
|-----------|---|
| 0000-0777 | Data Validity Check; Fixed Point Output Utility Routines |
| 6000-6767 | Data Check Routines Program Selector; Data Editing and Correction Routines; Listers |
| 7400-7750 | Sorts, Table Lookup Routines. |

5.2 Memory affected by second (Critical Path calculation) part of SIGPERT package.

5.2.1 Second read-in operation fills the following areas in memory:

| Locations | Contents |
|-----------|-------------------------|
| 0000-0037 | Main Program |
| 0040-0077 | Search Routine |
| 0100-0267 | Main Program |
| 0270-0277 | Temp Storage |
| 0300-0347 | Sort Routine |
| 0350-0357 | Temp Storage |
| 0360-0377 | Event File Selector |
| 0400-0477 | Output Format |
| 0500-0677 | Decimal Output - AN-016 |
| 0700-0741 | Output Format |
| 0742-0765 | Main Program |
| 0766-0771 | Not Used |
| 0772-0776 | End of File Set |

| Locations | Contents |
|-----------|--------------|
| 5000-5031 | Hash sum |
| 7700-7747 | Main Program |

- 5.2.2 The Schedule Critical Path calculation will modify and extend the Activity Table as follows:
- 5.2.2.1 The Activity Identification will be packed into one word with the 'From' Event number at B19 and the 'To' Event Number at B39.
- 5.2.2.2 The Activity Times will each occupy one word, and must be divided by 10 (decimal) before output.
- 5.2.2.3 The Latest Activity Time (ATL) and the Expected Activity Time (ATE) for each Activity will be packed in one word, with ATL at B19 and ATE at B39. Each must be divided by 10 (decimal) before output.
- 5.2.2.4 Activity Table Format:
- 5.2.2.4.1 'From' Event Number at B19, 'To' Event Number at B39, Activity at W.
- 5.2.2.4.2 Activity Time for a given Activity at W+1.
- 5.2.2.4.3 Latest Activity Time at B19, Expected Activity Time at B39 for a given Activity at W+2.
- 5.2.2.4.4 Initial value of W = 1000 (octal).
- 5.2.2.4.5 A negative number marks the end of the file.
- 5.2.2.5 Event Table Format:
- 5.2.2.5.1 Event identification numbers will be stored in ascending order in consecutive locations as integers at B19. The Event Identification file will extend from 5100 through 5100 + m, where m is the number of distinct events in the schedule. A negative number at 5100 + (m+1) marks the end of the file.
- 5.2.2.5.2 The Latest Event Time (ETL) and the Expected Event Time (ETE) for each event will be packed into one word starting at 6400. ETL in each word will be at B19 and ETE at B39. Each must be divided by 10 (decimal) before output. Location of an Event

plus 1300 = Location of the Event Times corresponding to that Event.

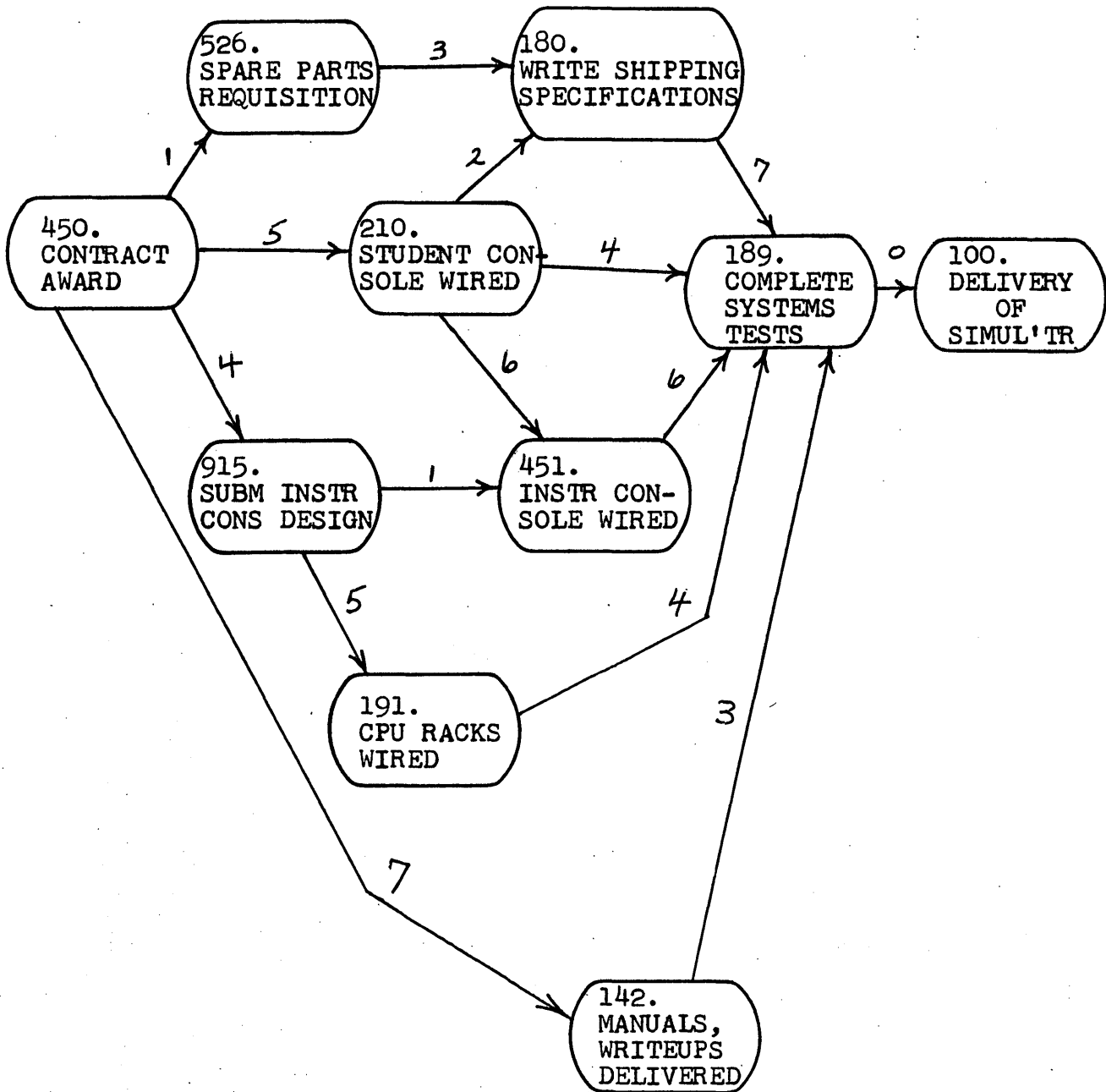
5.2.2.5.3 Slack Times (Latest Time minus Expected Time) are not computed in part two of the SIGPERT package. These are computed by the output routines in part three during printout.

5.3 Memory filled by the third read-in operation on SIGPERT package:

| Locations | Contents |
|-----------|------------------------|
| 0001-0477 | Main Program |
| 0500-0677 | Decimal Output AN-016 |
| 0700-0707 | Main Program |
| 0712-0777 | Additional Programming |
| 7600-7707 | Additional Programming |
| 7710-7751 | Hash sum |

6. SAMPLE PROBLEM

A typical Schedule network that can be evaluated by the SIGPERT package.



7. Computer typewriter printout during the running of this network might appear as follows:

SIGPERT - DATA CHECK ROUTINE

ACTIVITY AND NAME TABLES SHOULD ALREADY BE IN MEMORY
 SET MARGIN: 10 SET TABS: 20, 28, 38, 53, 63, 73.

SELECT YOUR PROGRAM: E

| ACTIVITY CODE NO. | FROM EVENT LOC. | FROM EVENT | TO EVENT | ACTIVITY TIMES | | |
|----------------------|-----------------------|---------------|-------------|----------------|---|---|
| | | | | A | B | C |
| | 1000 | | 450 | | | |
| 1 | 1003 | 450 | 526 | 10 | | |
| 2 | 1006 | 450 | 210 | 50 | | |
| 3 | 1011 | 450 | 915 | 400 | | |
| 4 | 1014 | 450 | 142 | 70 | | |
| 5 | 1017 | 526 | 180 | 30 | | |
| 6 | 1022 | 210 | 180 | 20 | | |
| 7 | 1025 | 210 | 189 | 40 | | |
| 8 | 1030 | 210 | 451 | 60 | | |
| 9 | 1033 | 915 | 451 | 10 | | |
| 10 | 1036 | 915 | 191 | 50 | | |
| 11 | 1041 | 191 | 189 | 40 | | |
| 12 | 1044 | 142 | 189 | 30 | | |
| 13 | 1047 | 180 | 189 | 70 | | |
| 14 | 1052 | 189 | 100 | | | |
| 15 | 1055 | | | | | |

SELECT YOUR PROGRAM:

SELECT YOUR PROGRAM: F

CHECKING VALIDITY OF CRITICAL PATH ACTIVITY TABLE:

ACTIVITY 8 HAS A TO EVENT NOT CONNECTED TO THE BALANCE OF THE NETWORK

SELECT YOUR PROGRAM: G

ACTIVITY TABLE INSERTION

INSERT AT LOCATION: 1041
ACTIVITY - FROM: 451. TO: 189. TE: 60.

SELECT YOUR PROGRAM: J

CORRECT ACTIVITY TABLE

CORRECT AT LOCATION: 1011
ACTIVITY - FROM: 450. TO: 915. TE: 40.

SELECT YOUR PROGRAM: F

CHECKING VALIDITY OF CRITICAL PATH ACTIVITY TABLE:

ACTIVITY TABLE CHECKS OUT AS LOGICALLY VALID.

SELECT YOUR PROGRAM:

SELECT YOUR PROGRAM: E

| ACTIVITY CODE NO. | FROM EVENT LOC. | FROM EVENT | TO EVENT | ACTIVITY TIMES | | |
|----------------------|-----------------------|---------------|-------------|----------------|---|---|
| | | | | A | B | C |
| | 1000 | | 450 | | | |
| 1 | 1003 | 450 | 526 | 10 | | |
| 2 | 1006 | 450 | 210 | 50 | | |
| 3 | 1011 | 450 | 915 | 40 | | |
| 4 | 1014 | 450 | 142 | 70 | | |
| 5 | 1017 | 526 | 180 | 30 | | |
| 6 | 1022 | 210 | 180 | 20 | | |
| 7 | 1025 | 210 | 189 | 40 | | |
| 8 | 1030 | 210 | 451 | 60 | | |
| 9 | 1033 | 915 | 451 | 10 | | |
| 10 | 1036 | 915 | 191 | 50 | | |
| 11 | 1041 | 451 | 189 | 60 | | |
| 12 | 1044 | 191 | 189 | 40 | | |
| 13 | 1047 | 142 | 189 | 30 | | |
| 14 | 1052 | 180 | 189 | 70 | | |
| 15 | 1055 | 189 | 100 | | | |
| 16 | 1060 | | | | | |

SELECT YOUR PROGRAM: K
DUMPING ACTIVITY TABLE.

SELECT YOUR PROGRAM: L

CRITICAL PATH EVENT NAME LIST

| LOCATION | EVENT | NAME |
|----------|-------|--------------------------|
| 3000 | 0100. | DELIVERY OF SIMULATOR |
| 3004 | 0142. | MANUALS, WRITEUPS DEL |
| 3010 | 0180. | WRITE SHIPPING SPECS |
| 3014 | 0189. | COMPLETE SYSTEMS TESTS |
| 3020 | 0191. | CPU RACKS WIRED |
| 3024 | 0210. | STUDENT CONSOLE WIRED |
| 3030 | 0450. | CONTRACT AWARD |
| 3034 | 0451. | INSTR CONSOLE WIRED |
| 3040 | 0526. | SPARE PARTS REQUISITION |
| 3044 | 0915. | SUBM INSTR CONSOLE DESGN |
| 3050 | | |

SELECT YOUR PROGRAM: M

NAME TABLE INSERTION

INSERT EVENT NUMBER: 189.

EVENT NAME (24 CHARACTERS): COMPLETE SYSTEMS TESTS

SELECT YOUR PROGRAM: P
DUMPING EVENT NAME TABLE.

SELECT YOUR PROGRAM: Q

COMPUTING CRITICAL PATH

CRITICAL PATH

| ACTIVITY | | TE | ATE | ATL | EVENT | ETE | ETL |
|----------|------|-----|------|------|-------|------|------|
| FROM | TO | | | | | | |
| 450. | 526. | 1.0 | 1.0 | 7.0 | 142. | 7.0 | 14.0 |
| 450. | 210. | 5.0 | 5.0 | 5.0 | 180. | 7.0 | 10.0 |
| 450. | 915. | 4.0 | 4.0 | 8.0 | 189. | 17.0 | 17.0 |
| 450. | 142. | 7.0 | 7.0 | 14.0 | 191. | 9.0 | 13.0 |
| 526. | 180. | 3.0 | 4.0 | 10.0 | 210. | 5.0 | 5.0 |
| 210. | 180. | 2.0 | 7.0 | 10.0 | 450. | .0 | .0 |
| 210. | 189. | 4.0 | 9.0 | 17.0 | 451. | 11.0 | 11.0 |
| 210. | 451. | 6.0 | 11.0 | 11.0 | 526. | 1.0 | 7.0 |
| 915. | 451. | 1.0 | 5.0 | 11.0 | 915. | 4.0 | 8.0 |
| 915. | 191. | 5.0 | 9.0 | 13.0 | | | |
| 451. | 189. | 6.0 | 17.0 | 17.0 | | | |
| 191. | 189. | 4.0 | 13.0 | 17.0 | | | |
| 142. | 189. | 3.0 | 10.0 | 17.0 | | | |
| 180. | 189. | 7.0 | 14.0 | 17.0 | | | |
| 189. | 100. | .0 | 17.0 | 17.0 | | | |

SET TABS AT 22, 33, 46, 62, 82, AND PRESS 'START'.
SELECT YOUR PROGRAM: EVT

EVENTS IN ORDER OF SLACK

EVENTS WITH SLACK OF 0

| EVENT NO. | EVENT NAME | EXPECTED TIME |
|-----------|------------------------|---------------|
| 189. | COMPLETE SYSTEMS TESTS | 17.0 |
| 210. | STUDENT CONSOLE WIRED | 5.0 |
| 450. | CONTRACT AWARD | .0 |
| 451. | INSTR CONSOLE WIRED | 11.0 |

EVENTS WITH SLACK OF 3.0

| EVENT NO. | EVENT NAME | EXPECTED TIME |
|-----------|----------------------|---------------|
| 180. | WRITE SHIPPING SPECS | 7.0 |

EVENTS WITH SLACK OF 4.0

| EVENT NO. | EVENT NAME | EXPECTED TIME |
|-----------|--------------------------|---------------|
| 191. | CPU RACKS WIRED | 9.0 |
| 915. | SUBM INSTR CONSOLE DESGN | 4.0 |

EVENTS WITH SLACK OF 6.0

| EVENT NO. | EVENT NAME | EXPECTED TIME |
|-----------|-------------------------|---------------|
| 526. | SPARE PARTS REQUISITION | 1.0 |

| EVENTS WITH SLACK OF | 7.0 | EXPECTED TIME |
|----------------------|--|---------------|
| EVENT NO. | EVENT NAME | |
| 142. | MANUALS, WRITEUPS DEL SELECT YOUR PROGRAM:ACT | 7.0 |

ACTIVITIES IN ORDER OF SLACK

| ACTIVITIES WITH SLACK OF | .0 | EXPECTED TIME |
|--------------------------|-------------------------|----------------------------------|
| FROM | ACTIVITY IDENTIFICATION | TO |
| 450. | CONTRACT AWARD | 210. STUDENT CONSOLE WIRED 5.0 |
| 210. | STUDENT CONSOLE WIRED | 451. INSTR CONSOLE WIRED 11.0 |
| 451. | INSTR CONSOLE WIRED | 189. COMPLETE SYSTEMS TESTS 17.0 |
| 189. | COMPLETE SYSTEMS TESTS | 100. DELIVERY OF SIMULATOR 17.0 |

| ACTIVITIES WITH SLACK OF | 3.0 | EXPECTED TIME |
|--------------------------|-------------------------|----------------------------------|
| FROM | ACTIVITY IDENTIFICATION | TO |
| 210. | STUDENT CONSOLE WIRED | 180. WRITE SHIPPING SPECS 7.0 |
| 180. | WRITE SHIPPING SPECS | 189. COMPLETE SYSTEMS TESTS 14.0 |

| ACTIVITIES WITH SLACK OF 4.0 | | ACTIVITY IDENTIFICATION | | EXPECTED TIME |
|------------------------------|--------------------------|-------------------------|--------------------------|---------------|
| FROM | | TO | | |
| 450. | CONTRACT AWARD | 915. | SUBM INSTR CONSOLE DESGN | 4.0 |
| 915. | SUBM INSTR CONSOLE DESGN | 191. | CPU RACKS WIRED | 9.0 |
| 191. | CPU RACKS WIRED | 189. | COMPLETE SYSTEMS TESTS | 13.0 |

| ACTIVITIES WITH SLACK OF 6.0 | | ACTIVITY IDENTIFICATION | | EXPECTED TIME |
|------------------------------|--------------------------|-------------------------|-------------------------|---------------|
| FROM | | TO | | |
| 450. | CONTRACT AWARD | 526. | SPARE PARTS REQUISITION | 1.0 |
| 526. | SPARE PARTS REQUISITION | 180. | WRITE SHIPPING SPECS | 4.0 |
| 915. | SUBM INSTR CONSOLE DESGN | 451. | INSTR CONSOLE WIRED | 5.0 |

| ACTIVITIES WITH SLACK OF 7.0 | | ACTIVITY IDENTIFICATION | | EXPECTED TIME |
|------------------------------|-----------------------|-------------------------|------------------------|---------------|
| FROM | | TO | | |
| 450. | CONTRACT AWARD | 142. | MANUALS, WRITEUPS DEL | 7.0 |
| 142. | MANUALS, WRITEUPS DEL | 189. | COMPLETE SYSTEMS TESTS | 10.0 |

| ACTIVITIES WITH SLACK OF 8.0 | | ACTIVITY IDENTIFICATION | | EXPECTED TIME |
|------------------------------|-----------------------|-------------------------|------------------------|---------------|
| FROM | | TO | | |
| 210. | STUDENT CONSOLE WIRED | 189. | COMPLETE SYSTEMS TESTS | 9.0 |
| END OF ACTIVITY FILE | | | | |

SELECT YOUR PROGRAM:END???

SELECT YOUR PROGRAM: