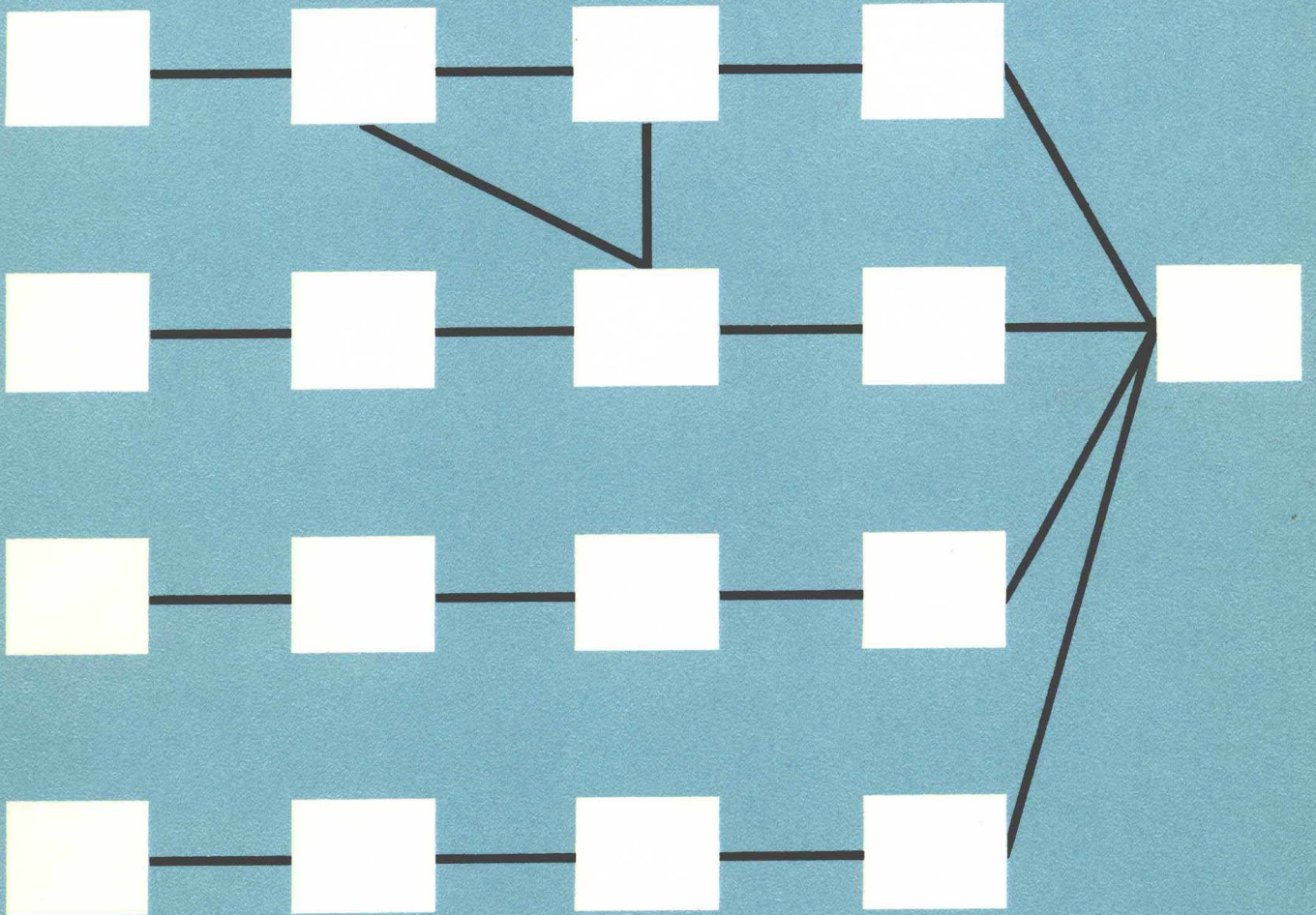


CONTROL DATA

C O R P O R A T I O N



PROGRAM EVALUATION REVIEW TECHNIQUE

PERT

PROGRAM EVALUATION REVIEW TECHNIQUE

CONTROL DATA

C O R P O R A T I O N

COMPUTER DIVISION

501 PARK AVENUE, MINNEAPOLIS 15, MINNESOTA

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GENERAL DESCRIPTION

INTRODUCTION

The use of computer techniques to determine the status of large, multi-phase projects at any time during the project cycle has become an increasingly valuable tool to industry. Determination of present project status with computer speed and accuracy improves the evaluation of present progress and also aids in the planning of major research and development projects. As an aid to management control a computer based progress report can provide:

1. Fast progress evaluation.
2. Orderly and consistent evaluation of plans.
3. Dynamic project representation.
4. Early identification of critical scheduling problems.

This concept of project evaluation is known as the PERT¹ system.

THE PERT NETWORK

The evaluation technique is based on a pictorial representation of the project. This pictorial representation or PERT network is formed by defining a unit of work in terms of the activities required to complete the unit of work and the relationships among these activities.

An activity is a sub-task of the project. An activity is selected such that it cannot begin until all activities preceding it are complete. An event is a relationship between activities. Events are defined as predecessor or successor events when they precede or succeed an activity. A starting event has no predecessors and a terminal event has no successors.

1. PERT, for Program Evaluation and Review Technique, was conceived by the U. S. Navy and is described in the report of Booz, Allen and Hamilton, management consultants to the Special Projects Office, Bureau of Ordnance, Department of the Navy.

Using these definitions, Figure 1 can be read.

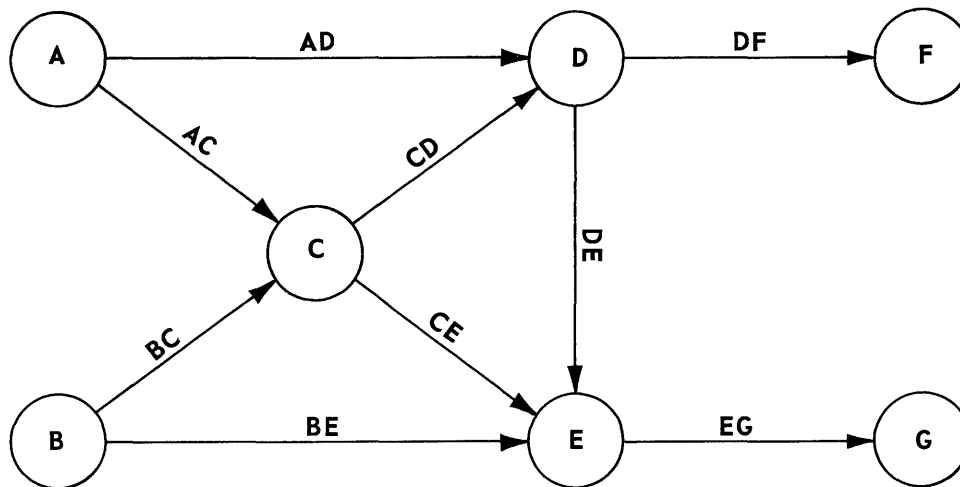


Figure 1. PERT Network

A and B are starting events, F and G are terminal events. Activities CD and CE may not start until both activity AC and activity BC are complete. Similarly, activities DF and DE may not start until both activity AD and activity CD are complete. Activity EG may not start until activities BE, CE and DE are all complete.

ESTIMATES AND CONFIDENCE

The scheduling information used to construct a project network must be estimates of the length of time required to complete an activity. Since estimates cannot be the exact time required, a range of possible times is used to determine an average completion time.

The range of estimated times for an activity are chosen as three possibilities.

1. The optimistic, denoted a . This estimate is the time required for completion of the activity if all factors are favorable to early completion.
2. The most likely, denoted m . This estimate is the time required for completion of the activity when all factors are considered to have their most likely effect on the completion date.
3. The pessimistic, denoted b . This estimate is the time required for completion of the activity if all factors are unfavorable to early completion.

From these three estimates a weighted average of the completion time for an activity is calculated using the formula:

$$t_E = \frac{a + 4m + b}{6}$$

The probability of completing an activity in time t_E is assumed to be .5 by the program.

If a greater certainty of completion within the estimated time is desired, the program will calculate a new estimate for each activity, t_e , which replaces t_E for the activity and will have the desired certainty of completion.

THE BASIC ALGORITHM

When a PERT network representing a project has been constructed and the scheduling information supplied, evaluation of the events can proceed.

To aid in the discussion of the evaluation technique, the following terms are defined:

T_E is the time at which an event occurs.

T_S is the time at which an activity starts.

T_C is the time at which an activity is complete.

Given T_E for a set of starting events and the information for determining t_E for all the project activities, the basic algorithm determines T_E for a set of terminal events of the project. As a result of the basic algorithm T_E for all events is determined.

To illustrate the algorithm, refer to Figure 2, and Table 1.

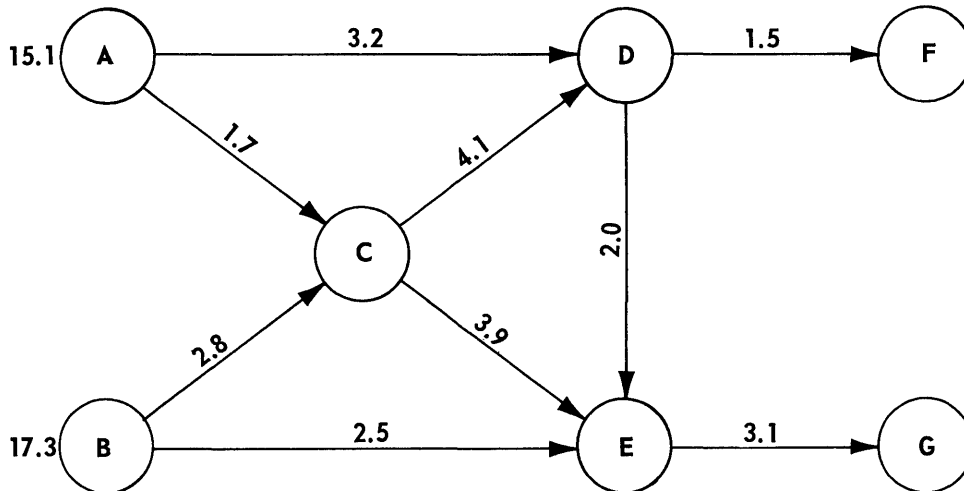


Figure 2. PERT Network – Basic Algorithm

Event	T_E	Activity	T_C
A	15.1	AD	18.3
		AC	16.8
B	17.3	BC	20.1
		BE	19.8
C	20.1	CD	24.2
		CE	24.0
D	24.2	DE	26.2
		DF	25.7
		EG	29.3
E	26.2		
F	25.7		
G	29.3		

Table 1. Event and Activity Times – Basic Algorithm

Events A and B are starting events occurring at times 15.1 and 17.3. Event C occurs at the latest completion time of all its predecessor activities, or 20.1. Similar evaluation proceeds for all events. Events F and G are terminal events occurring at times 25.7 and 29.3.

REVERSING THE BASIC ALGORITHM

The basic algorithm yields estimated event times, T_E , of the terminal events. The basic algorithm may be reversed so that given externally imposed scheduled completion dates for the terminal events, the latest allowable activity time, T_S , can be calculated.

To illustrate the reversed algorithm, refer to Figure 3 and Table 2.

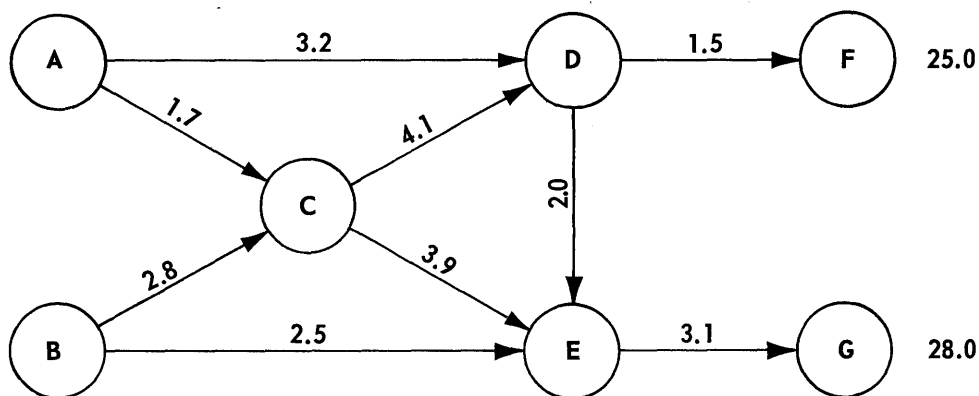


Figure 3. PERT Network – Reversed Algorithm

Event	T_E	Activity	T_S
G	28.0	EG	24.9
F	25.0	DF	23.5
E	24.9	DE	22.9
		CE	21.0
		BE	22.4
D	22.9	CD	18.8
		AD	19.7
C	18.8	AC	17.1
		BC	16.0
B	16.0		
A	17.1		

Table 2. Event and Activity Times – Reversed Algorithm

Events F and G are terminal events, occurring at times 25.0 and 28.0. Event E occurs at time 24.9, and event D occurs at time 22.9, the earliest starting time of all its successor activities. Similar evaluation proceeds for all events. Events A and B are starting events occurring at times 17.1 and 16.0. These starting event times give the latest date at which these events may occur and still meet the terminal event constraints.

SLACK AND CRITICAL PATH

The term “slack” is used to describe the difference between the event time T_E (from the reversed algorithm) and the event time T_E (from the basic algorithm). This comparison shows whether the terminal event constraints can be met.

Table 3 presents the slack times for the preceding PERT network example.

Event	T_E (Basic)	T_E (Reversed)	Slack
A	15.1	17.1	2.0
B	17.3	16.0	-1.3
C	20.1	18.8	-1.3
D	24.2	22.9	-1.3
E	26.2	24.9	-1.3
F	25.7	25.0	-0.7
G	29.3	28.0	-1.3

Table 3. Slack Times – First Calculation

Positive entries under the Slack heading indicate that the present time of an event and the completion times for activities connecting it to the terminal events allow completion of those activities within the terminal event constraints.

Negative entries under the Slack heading indicate that the present time of an event and the completion times for activities connecting it to the terminal events do not allow completion of those activities within the terminal event constraints.

In the example, event B and the path of activities connecting events BCDEG has a slack of -1.3, the lowest slack value for this example. This path is defined as the "critical" path. That is, this path contains the worst case of negative slack and therefore represents the most critical scheduling problem.

All paths, other than the critical path, which have a negative slack entry are termed secondary paths. These paths must be considered when evaluating the effects of reducing activity completion times along the critical path.

In the example, the path DF is a secondary path. Attempts to eliminate the negative slack along the critical path will generally result in a shift of the critical path to some secondary path.

If the completion time of activity EG in the example is reduced by 1.3 weeks, the negative slack conditions are not eliminated, but the critical path has changed as shown by Table 4.

Event	T_E (Basic)	T_E (Reversed)	Slack
A	15.1	17.7	2.6
B	17.3	16.6	-0.7
C	20.1	19.4	-0.7
D	24.2	23.5	-0.7
E	26.2	26.2	-0.0
F	25.7	25.0	-0.7
G	28.0	28.0	0.0

Table 4. Slack Times – Modified Calculation

INPUT

INTRODUCTION

A PERT network for a project is created and maintained for computer evaluation by introducing information from tabulating cards. This input information is termed transaction codes and is divided into two categories: 1) activity transaction codes and 2) nomenclature transaction codes. There are six activity data card formats and three nomenclature card formats.

ACTIVITY TRANSACTION CODES

The six activity data card formats are specified below. A blank column in a field on these cards is interpreted as a zero.

Transaction Code 1

- a. Purpose: To establish a new activity
- b. Card Format:

Column 12	Number "1"
Columns 18-26	Predecessor event number of activity
Columns 34-42	Successor event number of activity
Columns 44-47	Optimistic time estimate in weeks and tenths of weeks.
Columns 48-51	Most likely time estimate in weeks and tenths of weeks.
Columns 52-55	Pessimistic time estimate in weeks and tenths of weeks.
Columns 60-65	Schedule date associated with successor event of the activity, if applicable.
- c. Explanation: Add new activity to PERT network tape. If an original PERT network tape is to be set up, regard the old PERT network tape as containing no activities.

Transaction Code 2

- a. Purpose: To re-estimate times required to complete the activity.
- b. Card format:
 - Column 12 Number "2"
 - Columns 18-26 See transaction code 1
 - Columns 34-42 See transaction code 1
 - Columns 44-47 See transaction code 1
 - Columns 48-52 See transaction code 1
 - Columns 52-55 See transaction code 1
 - Columns 60-65 See transaction code 1

Transaction Code 3

- a. Purpose: To indicate that an activity has been completed and to add a completion date. The successor event is not completed unless all activities which have that event as a successor event are complete.
- b. Card format:
 - Column 12 Number "3"
 - Columns 18-26 See transaction code 1
 - Columns 34-42 See transaction code 1
 - Columns 60-65 Completion date associated with the activity

Transaction Code 4

- a. Purpose: To add a schedule date to an event
- b. Card format:
 - Column 12 Number "4"
 - Columns 34-42 Event Number
 - Columns 60-65 Schedule date
- c. Explanation: Transaction code 4 adds a schedule date to each activity which has as its successor event the one indicated in columns 34-42.

Transaction Code 5

- a. Purpose: To delete an activity from the PERT network tape.
- b. Card format:
 - Column 12 Number "5"
 - Columns 18-26 See transaction code 1
 - Columns 34-42 See transaction code 1

Transaction Code 7

- a. Purpose: To add a starting event with a completion date
- b. Card format:
 - Column 12 Number "7"
 - Columns 34-42 Starting event number
 - Columns 60-65 Completion date of starting event

Activity Transaction Code Examples

Trans Code	Predecessor number	Successor number	Optimistic	Most likely	Pessimistic	Date
12	18-26	34-42	44-47	48-51	52-55	60-65
1	023305324	023346489	0010	0020	0030	051163
1	304345657	304456435		0010	0020	
2	023304555	304848888	0020	0030	0040	080967
2	023300020	023300404	0020	0030	0030	
3	023490045	023490050				063062
4		989999456				102862
5	230345789	234678975				
7		023456789				111661

NOMENCLATURE TRANSACTION CODES

The three nomenclature data card formats are specified below. The Control Data PERT program accepts all three formats² but treats the information on each in the same way by giving the nomenclature indicated in columns 33-80 to the referenced event. Any one of the three transaction codes will perform all three functions. A maximum of 600 nomenclature codes may be input during a single run of the program.

Transaction Code A

- a. Purpose: To add nomenclature to an event
- b. Card format:
 - Column 12 Letter "A"
 - Columns 18-26 Event number
 - Columns 33-80 Nomenclature

Transaction Code C

- a. Purpose: To correct the nomenclature for an event
- b. Card format:
 - Column 12 Letter "C"
 - Columns 18-26 Event number
 - Columns 33-80 Correct nomenclature

Transaction Code D

- a. Purpose: To delete nomenclature from an event
- b. Card format:
 - Column 12 Letter "D"
 - Columns 18-26 Event number
 - Columns 33-80 Leave blank

2. An attempt has been made wherever possible to make the input data formats compatible with other PERT programs. In particular the data formats are similar to those used at the Naval Weapons Laboratory, Dahlgren, Virginia.

Nomenclature Transaction Code Examples

Trans Code	Successor Number	Nomenclature
12	18-26	33-80
A	023305456	Compl rev mach mod from lib
C	023456789	Start rev mech mod from sam
D	023564789	

EVENT NUMBER ASSIGNMENT

The nine digit event number can be assigned in any convenient way. One suggested method is to assign the first three digits to denote the project, the next three digits to denote a PERT network number, and the last three digits to denote the event number. The event number must be all numeric.

INPUT DATA ERROR CHECKING

The computer checks input data; any discrepancy will cause the computer to write an error message on the output report. If an error is unacceptable, the computer will stop after all input data is read. If there are no unacceptable errors, the computer will continue. The data items checked follow:

- a. Dates must be valid. For example, 033261 is not.
- b. The most likely time estimate must be higher than the optimistic, and lower than the pessimistic time estimate.
- c. The activity variance should usually not be greater than 99.9. The relationship between the optimistic, most likely, and pessimistic time estimates should be reasonable. If PERT considers the relationship unreasonable an acceptable error message will be indicated.
- d. The optimistic and pessimistic time estimates should be reasonable. If PERT considers the estimates unreasonable, an acceptable error message will be indicated.
- e. All schedule dates should be future dates.
- f. No completion dates can be future dates.
- g. All events must be shown as numbers.
- h. All input data cards must have the format described above (columns not mentioned must be blank).

NETWORK SIZE

The Control Data PERT program allows a maximum of 1400 activities. This size is determined by the internal sort routine used. A maximum of 600 nomenclature cards may be input during a single run of the program.

OUTPUT

INTRODUCTION

Output available from the PERT program is:

1. An error report listing.
2. A normal report listing.
3. A listing of the information on the new PERT network tape.

The error report is produced if there are errors and precedes all other output for a run. The normal report listing is always produced. The new PERT network tape listing is produced only if a card requesting this output is included in the input data.

ERROR REPORT LISTING

The error report listing displays information about the errors detected during a PERT network evaluation. These errors are classified as acceptable or unacceptable. An acceptable error will produce an error indication but will not stop the network evaluation. An unacceptable error will produce an error indication and stop the network evaluation. If an unacceptable error is detected in the input data, the remainder of the input data is scanned before the program is stopped.

The error indications which may appear on the error report listing follow. In most cases the error is self-explanatory. Information enclosed in parentheses is explanatory and is not included in the error report.

Errors in A, M, and B

A GREATER THAN M	REJECT
B LESS THAN M	REJECT
10A LESS THAN M ($A \neq 0$)	ACCEPT
B GREATER THAN 10M ($M \neq 0$)	ACCEPT
A GREATER THAN 39	ACCEPT
B LESS THAN 2	ACCEPT

Error in the Variance of an Activity

VARIANCE AT LEAST 99.9 ACCEPT

Errors in Calendar Date

These errors are acceptable errors if the transaction code is less than 3 and unacceptable if the transaction code is greater than or equal to 3.

YEAR LESS THAN 59
MONTH EQUAL TO ZERO
MONTH GREATER THAN 12
DAY EQUAL TO ZERO
DAY GREATER THAN 31

Other Date Errors

SCHED DATE LESS NOW (schedule date less than now)

The above error is an acceptable error if the transaction code is 1 or 2, but is unacceptable if the transaction code is 4.

COMPL DATE GREATER NOW (completion date greater than now)

The above is an unacceptable error since all completed activities were completed in the past.

NO SCHEDULE DATE ERROR REJECT

The above error is unacceptable. It occurs if a terminal event has no schedule date, or if an intermediate event has no activities leading from it. The latter possibility generally occurs more often than the former.

EXPECTED DATE LESS NOW ACCEPT EXPECTED WEEK XXX.X

This error occurs if the estimated completion date of an activity is less than the effective date (date now). XXX.X is the estimated completion date of the activity expressed in weeks from the base date December 31, 1958. For all activities whose estimated completion date XXX.X is less than the effective date, the PERT program arbitrarily sets the estimated completion date equal to one week later than the effective date (date now).

Punching Errors

PUNCHING ERRORS REJECT

There are two types of input data cards: Activity date cards and nomenclature cards for events. The only acceptable characters on the activity data cards are decimal digits, all other characters are illegal and are punching errors. This is also true for the event number on the event nomenclature cards.

Transaction Code Errors

CODE 2 EST EQUAL 0	ACCEPT
CODE 3 EST NOT 0	REJECT
CODE 3 DATE 0	REJECT
CODE 4 EST NOT 0	REJECT
CODE 4 DATE 0	ACCEPT
CODE 5 EST NOT 0	REJECT
CODE 5 DATE NOT 0	REJECT
CODE 7 EST NOT 0	REJECT
CODE 7 DATE 0	ACCEPT
NO CARD CODE (transaction code not 1 thru 8)	REJECT

Inconsistent System

INCONSISTENT SYSTEM	REJECT
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If a network is inconsistent, all activities which comprise the inconsistent (circular) path or paths occur with the above error.

Other Errors

Many program checks are included. When a program error occurs, an error message is usually written on the output tape and on the typewriter, after which the computer stops. These program errors should never occur:

CARD CODE NOT 2-8, PG ERR	REJECT
NO EVENT IN RDIR, PG ERR	REJECT
ERROR STOP LOCATION	

ERROR STOP LOCATION indicates where the program would have stopped if there had been a stop instruction at one of the branches of a program check.

NORMAL REPORT LISTING

For each run the event information is listed in three orders. The event information contains the following items for each event.

- Event number
- Nomenclature
- Estimated completion date (expected date)
- Estimated latest allowable date

Schedule date
Actual date (completion date)
Slack
Standard deviation
Probability

This information is printed for each event in ascending order with respect to slack, with respect to expected date and then with respect to successor event number.

Each page of the report has a heading containing the following items:

Week – The effective date (report date) expressed in weeks from the reference date, December 31, 1958.
Page Number
Order Key – Indicates whether events on this page are ordered with respect to slack (S), estimated date (T), or successor event number (E).
Certainty – A decimal fraction indicating the degree of certainty of this report.

For events which have been completed before the last report:

Expected date field will contain 00/00/00
Latest allowable date field will contain 00/00/00
Actual date field will be blank

For events which have been completed after the last report:

Expected date field will contain 00/00/00
Latest allowable date field will contain a legitimate date
Actual date field will contain the completion date of the event

For events which are not complete:

Expected date field will contain a legitimate date
Latest allowable date field will contain a legitimate date
Actual date field will be blank

For events without schedule dates, the probability field will be blank.

For events with schedule dates, the probability field will contain a decimal fraction which is the probability of completing the event on or before its schedule date.

NEW NETWORK TAPE LISTING

For runs on which a new network tape listing is requested, the following items are listed for each activity.

Predecessor event number

Successor event number

Original three time estimates: a, m, b

Recent three time estimates: a, m, b

Estimate of expected activity time (activity time)

Estimate of activity variance (activity variance)

Estimated completion date in weeks for successor event from the reference date, December 31, 1958 (expected time)

Estimated latest allowable date in weeks from the reference date, December 31, 1958 (latest time)

Slack

Estimated completion date for successor event (expected date)

Estimated latest allowable date (latest date)

Schedule date for successor event

Date activity is completed (actual date)

Indicates by Yes or No whether activity is completed

Indicates by Yes or No whether successor event is completed

Nomenclature for successor event

INPUT PREPARATION

NEW NETWORK

The project to be evaluated must be partitioned into activities. These activities are related by the events. A flow chart to pictorially represent the activities and events may be made to aid in preparation of the network.

Each event in the network is given a unique number, schedule completion dates are assigned to each terminal event, starting dates are assigned to each starting event, and the optimistic, most likely, and pessimistic estimates of activity completion time are assigned to each activity. Nomenclature may be included on the events if desired.

When the network has been completely defined, it is transcribed into transaction codes using the following procedure:

<u>Event Type</u>	<u>Transaction Code Used</u>
Starting	7
Intermediate	1
Terminal	1

The scheduled completion date for each event may be transcribed to transaction code 1 or to transaction code 4. Transaction codes A, C or D may be used if they are required.

The transaction codes produced by this procedure represent a new PERT network which may be evaluated on the computer.

OLD NETWORK

When a network has been evaluated on the computer, a magnetic tape copy of the network is kept for subsequent evaluation runs. This tape contains the

current PERT network. If changes are transcribed into transaction codes using the following procedure:

<u>Change Type</u>	<u>Transaction Code Used</u>
Re-estimate completion time	2
Activity completed-add date	3
Add event schedule date	4
Delete activity	5
Add starting event and date	7

These transaction codes and the current network tape represent an updated PERT network.

ADDITIONAL INFORMATION

For each evaluation run on a network, additional information relating to the run must be supplied. This information directs the execution of the PERT program, selects non-standard equipment configurations and conditions the handling of input and output data.

This information is transcribed to cards and may be as follows:

WEEK Card

The WEEK card is the first card in the run deck and contains the effective date of the run. The card format is:

Columns 10-13: WEEK

Columns 60-65: A six decimal digit date

For example:

<u>Columns 10-13</u>	<u>Columns 60-65</u>
WEEK	050661

FIRST Card

When a new network transaction deck is to be run a FIRST card is included in the run deck. The card format is:

Columns 10-14: FIRST

PROB Card

If the certainty of completion times is desired to be different from 0.5, a PROB card is included in the run deck. The card format is:

Columns 10-13: PROB

Columns 20-24: A probability of the form .XXXX where X may range from 0 to 9. Blanks are interpreted as zeros and the decimal point must appear in column 20.

For example:

Columns 10-13	Columns 20-24
PROB	.7
PROB	.83
PROB	.635
PROB	.9999

PMF Card

If a listing of the new PERT network tape is desired as an output from the run a PMF card is included in the run deck. The card format is:

Columns 10-12: PMF

TAPE Card

If the usual tape handlers are not available the tapes may be reasigned by including a TAPE card in the run deck. The format of the card is:

Columns 10-13: TAPE

Columns 20-24: The desired tape address for the "core dump" tape.

Columns 28-32: The desired tape address for the "blank" tape.

Columns 36-40: The desired tape address for the "new PERT network" tape.

Columns 44-48: The desired tape address for the "output" tape.

Columns 60-64: The desired tape address for the "old PERT network" tape.

The tape address is a five digit number with the format CEOUM where:

C is the channel number.

E is 2.

O is zero.

U is the tape handler number.

M is the recording mode (2 for coded or 1 for binary).

Each tape handler is connected to an input/output channel pair. Therefore, tape addresses 32021 and 42021 define the same tape handler.

If a tape address is left blank on the TAPE card, the usual tape address is used.

There are two restrictions on reassignment of tape addresses.

1. The PERT program tape must always be on tape unit 32011.
2. The "input data" tape address cannot be changed by a TAPE card.

END Card

The END card signals the end of a run deck. The card format is:
Columns 10-12: END

RUN DECK ORDER

The deck of cards representing input to the PERT program must be ordered as follows for each network to be evaluated.

WEEK card
FIRST card – if needed
PROB card – if needed
PMF card – if needed
TAPE card – if needed
Nomenclature transaction cards – if any
Activity transaction cards
END card.

If several networks are to be evaluated, the network run decks may be stacked on one input data tape. When stacking decks, the WEEK card of the current deck should follow the END card of the preceding deck. There should be an end-of-file mark separating the decks.

Some card readers require additional blank cards following the data deck to allow reading of all the data cards.

OPERATING INFORMATION

INTRODUCTION

The Control Data PERT program operates as a complete system. The PERT program tape contains all the routines required to run project evaluations. The system accepts magnetic tape input of run data and produces magnetic tapes of output data. Magnetic tape operation is of primary importance to the efficient use of the system.

MAGNETIC TAPE CONFIGURATION

For optimum performance of the system, seven magnetic tapes should be used. The utilization of these tapes and the addresses assumed by the system are shown in Table 5.

Memory Location (octal)	Tape Address	Tape Utilization
00010	52011	Core is dumped on this tape during sort
00011	32021	Blank tape
00012	32031	New PERT network tape
00013	32041	Output tape for reports
00014	52021	Input data tape
00015	52031	Old PERT network tape
	32011	PERT program tape

Table 5. System Tape Assignments

The tape addresses for the various utilizations of the tapes may be changed by a TAPE card for each run, with the restrictions:

1. The "PERT program" tape must be on tape address 32011.
2. The "input data" tape must be on tape address 52021.

If it is necessary to operate the PERT program with less than seven tape handlers, the following procedures should be used:

a. Six tape handlers:

Reassign the "core dump" tape to 32011. Mount the "PERT program" tape on 32011 initially. After the "PERT program" tape rewinds with interlock, replace it with the "core dump" tape. It is not necessary to stop the computer when replacing the tape.

b. Five tape handlers:

Reassign the "new PERT network" tape to 32011 and assign the "old PERT network" tape and "core dump" tape to the same tape address. Mount the "PERT program" tape on 32011 and the "old PERT network" tape initially. After the "PERT program" tape rewinds with interlock, replace it with the "new PERT network" tape. After the "old PERT network" tape rewinds with interlock, replace it with the "core dump" tape.

c. Four tape handlers:

The PERT program should not be run with only four tape handlers; however, it may be run with two restrictions on the operation.

1. "Input data" tape may contain only one network deck.
2. Break point must be set to 00711.

Reassign the "output" tape to 32011, assign the "core dump" tape and the "input data" tape to the same address, and assign the "old PERT network" tape and the "new PERT network" tape to the same address. Mount the "PERT program" tape on 32011 and the "input data" and "old PERT network" tapes initially. Set Break Point = 04000. After the "PERT program" tape rewinds with interlock, replace it with the "output" tape. Set Break Point = 00711 - start. After the "old PERT network" tape rewinds with interlock, replace it with the "new PERT network" tape; then manually rewind the "input data" tape and replace it with the "core dump" tape. When the computer stops at the break point, reset the break point to 77776 and press the start key.

Other equipment configurations may be used by modifying the PERT program.

An on-line printer could replace the output tape and an on-line card reader could replace the input tape. For changes necessary to utilize an on-line card reader, see Appendix 2.

Memory locations 00010 through 00015 always contain the tape addresses of the core dump tape, "blank" tape, "new PERT network" tape, "output" tape, "input data" tape, and "old PERT network" tape in that order. If a permanent tape configuration different from that above is required, the tape addresses in memory locations 00010 to 00015 need only be changed to the desired tape addresses and a new PERT program tape prepared.

OPERATING INSTRUCTIONS

The following steps should be followed to operate the PERT program when the usual tape assignments are to be used.

1. Transfer run deck (or decks) to magnetic tape. This should be done off-line if possible.
2. Mount "PERT program" tape on channel 3, unit 1.
3. Mount "input data" tape on channel 5, unit 2.
4. Mount blank tapes on channel 5, unit 1 and channel 3, units 2 and 4.
5. Mount "old PERT network" tape on channel 5, unit 3.
6. Mount "new PERT network" tape on channel 3, unit 3.

If the computer has an auto-load button, press it, if not:

7. Master and External clear.
8. Step
9. Set U = 740 32011
10. Step
11. Set U = 743 00000
12. Step
13. Start

If more than one run is on the input data tape when the computer stops with U = 760 04000, do steps 5, 6 and 14 for each succeeding run. When the last run is complete, list the "output" tape on channel 3, unit 4.

Additional operator instructions are displayed on the typewriter as the run progresses.

TYPEWRITER MESSAGES

During a run of the PERT program messages are displayed on the typewriter which give the operator operating and error information.

The error messages are:

- P CEOUM: A parity error on channel C, tape unit U. M indicates whether a read or write operation was in progress.
- B CEOUM: A buffer length error on channel C, tape unit U. M indicates whether a read or write operation was in progress.
- ERROR STOP: An unacceptable error was detected.
- CLOUT ERROR: An error was detected in the calling sequence for the output subroutine. This error should never occur.

The run must be re-started to recover from these errors.

The operation information messages are:

REMOVE CEOUM OLD MASTER FILE: Remove tape on channel C, tape unit U.

REMOVE CEOUM NEW MASTER FILE: Remove tape on channel C, tape unit U.

NORMAL STOP: A PERT run has been completed.

HIT START FOR NEXT RUN, IF NO FURTHER RUNS, LIST CEOUM: If input data is stacked on one input tape, and if the old and new PERT network tapes are mounted for the next run, press the start key for the next run. If there are no further runs, list the tape on channel C, tape handler number U.

XXXXX RECORDS: The sort subroutine has sorted XXXXX records.

EXAMPLE MESSAGES

The following list of messages resulted from a PERT program run. The run was an update of an old PERT network and there were no unacceptable errors detected.

Remove 52031 old master file

00254 records

00254 records

00254 records

00254 records

00254 records

Remove 32031 new master file

Normal stop

Hit start for next run, if no further runs, list 32041

OPERATING PRECAUTIONS

If as the result of a transcription error, an activity happens to be its own indirect successor, the condition will be detected by the computer and an error message will indicate the activities which comprise the circular network. The amount of computer time that is required to detect and determine a circular network is rather lengthy. Thus, the computer operator is cautioned not to stop the computer under the impression it is in a loop.

Each time a PERT network is updated a new network tape is produced. In order to avoid confusion and loss of information, some system of tape bookkeeping is recommended. An example of such a system is shown below.

- a. Each time a new PERT network tape is produced, the event is recorded so that network number, effective date, and reel number appear together as shown in Table 6.

NETWORK NUMBER 300

Effective Date	Reel Number
05-03-61	3
05-17-61	8
05-31-61	16
06-14-61	33
06-28-61	1

Table 6. Tape Bookkeeping Table

The information in Table 6 tells that for network 300 the "new PERT network" tape for the first run was reel number 3. On 5-17-61 network 300 was updated and the "old PERT network" tape, reel number 3, was used to produce a "new PERT network" tape, reel number 8. On 5-31-61 network 300 was updated again with reel 8 used as "old PERT network" tape and reel 16 was the "new PERT network" tape.

- b. Keep two or three "old PERT network" tapes so that if the most recent "old PERT network" tape is destroyed, it will not be necessary to start from the beginning.

EXAMPLE

SAMPLE PROBLEM

The PERT network shown in Figure 4 will be used to illustrate a typical problem. The dates below starting events are starting dates. The dates above terminal events are scheduled completion dates. The numbers below each activity line are the three time estimates a , m , and b of the time required to complete each activity. The time estimates are stated in weeks. The number enclosed in each "bubble" is the event number.

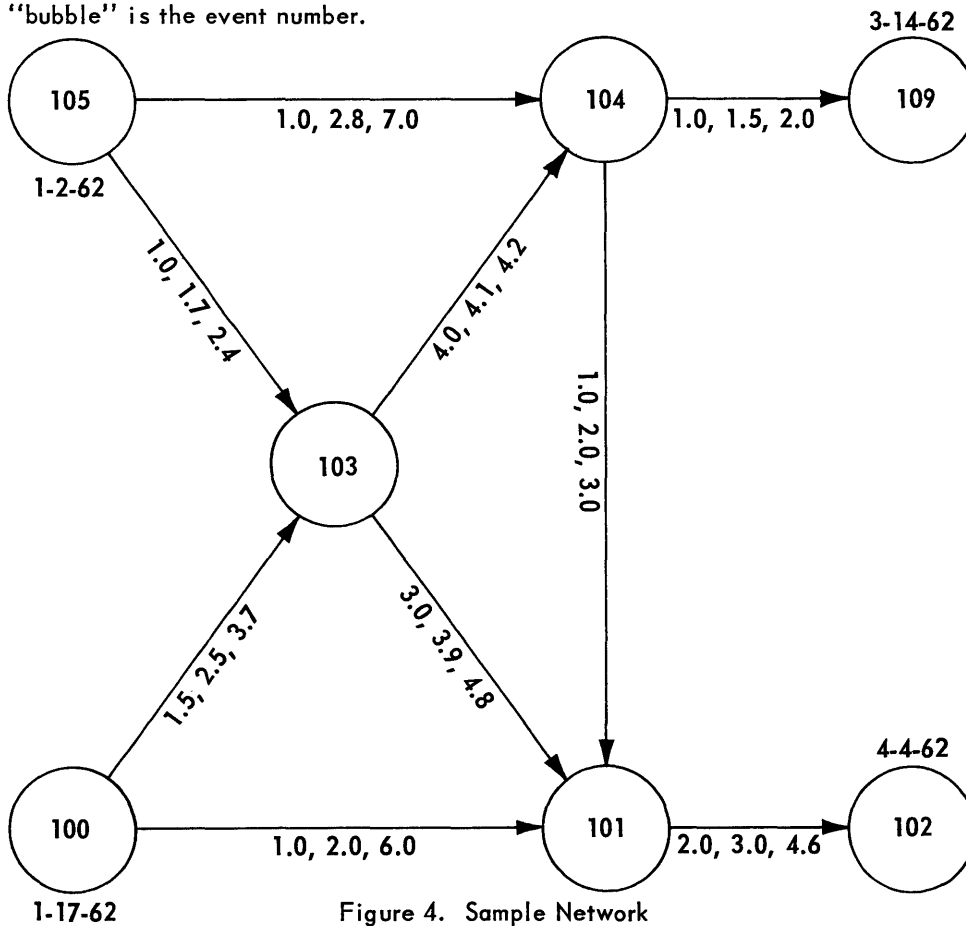


Figure 4. Sample Network

Representation of the PERT network in Figure 4 by PERT transaction codes is shown in Table 7.

Trans Code	Predecessor Number	Successor Number	Optimistic	Most likely	Pessi-mistic	Date
7		105				010262
7		100				011762
1	105	104	10	28	70	
1	105	103	10	17	24	
1	100	103	15	25	37	
1	100	101	10	20	60	
1	103	104	40	41	42	
1	103	101	30	39	48	
1	104	109	10	15	20	031462
1	104	101	10	20	30	
1	101	102	20	30	46	040462

Table 7. Sample Network Transaction Codes

Since event numbers are three digit numbers, the first six digits of the nine digit event number are blank. The computer will interpret each of these blank columns as zero columns. Similarly, tenths and hundredths are left blank in time estimates.

The control information cards to complete a run deck for this network are shown in Table 8.

Card Columns					
10-14	20-24	28-32	36-40	44-48	60-65
WEEK					011762
FIRST					
PMF					
TAPE			52041		
END					

Table 8. Sample Network Control Cards

The run deck order is shown in Figure 5.

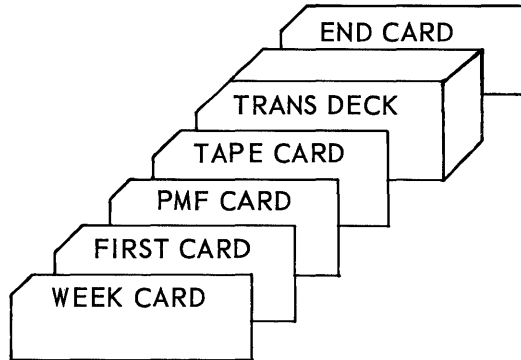


Figure 5. Sample Network Run Deck

The output listings of a run on this network are shown in Figure 6 through Figure 10.

Figure 6 is an error report listing showing that event number 104 has an estimated completion date less than the report date. This indicates the activities should have been completed or re-estimates of the completion times should have made.

Figure 7 is a normal report listing of output with events ordered on slack.

Figure 8 is a normal report listing of output with events ordered on expected completion date.

Figure 9 is a normal report listing of output with events ordered on successor event number.

Figure 10 is the optional listing of the new PERT network tape.

GLOSSARY

Activity	A sub-task of a project selected such that it may not begin until all predecessor activities have been completed.
Complete Path	A sequence of connected events such that a starting and terminal event is included.
Critical Path	The complete path having the least slack.
Event	A relationship between activities.
Inconsistent Path	A path which contains more than one occurrence of the same activity.
Inconsistent System	A PERT network containing an inconsistent path.
Predecessor	An activity or event which precedes an event or activity.
Secondary Path	A complete path which is not on the critical path.
Slack	The time difference between the expected completion date and the latest allowable completion date.
Starting Event	An event which has no predecessor activities.
Successor	An activity or event which succeeds an event or activity.
Terminal Event	An event which has no successor activities.

APPENDIX I

PERT PROGRAM TAPE PREPARATION

The PERT program tape may be prepared from the symbolic program information or from an existing program tape.

- a. To prepare a program tape from the symbolic deck:
 1. Assemble the symbolic deck obtaining a listing of the assembled program and octal program cards.
 2. Load program into core.
 3. Set the contents of memory location 00003 equal to 10013.
 4. Mount blank tape on channel 3, tape unit 1.
 5. Master and external clear.
 6. Step.
 7. Set P = 03672 (mnemonic location PERTWTM).
 8. Start.

The new master tape will be written on channel 3, tape unit 1.

- b. To prepare a program tape from a previous program tape:
 1. Mount PERT program tape on channel 3, tape unit 1.
 2. Set break point at 04000 (mnemonic location PERT).
 3. Read in PERT system.
 4. When computer stops at break point, mount blank tape on channel 3, tape unit 1.
 5. Master and external clear.
 6. Step.
 7. Set P = 03672.
 8. Start.

The new master tape will be written on channel 3, tape unit 1.

APPENDIX II

ON-LINE CARD READER OPERATION

If it is desired to use an on-line card reader in place of an input data tape, the PERT program must be modified as follows:

1. The upper instruction of location 04000 (mnemonic location PERT) should be changed from 'ENA 0 00000' to 'ENA 0 00001'.
2. The card read subroutine should be checked to assure its suitability for the on-line card reader to be used. The subroutine is located at memory location 05233 (mnemonic location RDCD).

These changes should be incorporated into the PERT program tape (See Appendix 1).

When using an on-line card reader, the tape assignments assumed by the system are shown in Table 2-1.

Memory Location	Tape Address	Tape Utilization
00010	52011	Core is dumped on this tape during sort
00011	32021	Blank tape
00012	32031	New PERT network tape
00013	32041	Output tape for reports
00015	52031	Old PERT network tape
	32011	PERT program tape

Table 2-1. On-line Card Reader
Tape Assignments

If less than six tape handlers are available, the tapes may be reassigned and operated as follows:

1. Five tape handlers.

Reassign the "core dump" tape to 32011. Mount the "PERT program" tape on 32011 initially. After the "PERT program" tape rewinds with interlock, replace it with the core dump tape.

2. Four tape handlers.

Reassign the "new PERT network" tape to 32011 and assign the "old PERT network" tape and the "core dump" tape to 32031. Mount the "PERT program" tape on 32011 and the "old PERT network" tape on 32031 initially. After the "PERT program" tape rewinds with interlock, replace it with the "new PERT network" tape and after the "old PERT network" tape rewinds with interlock, replace it with the "core dump" tape.

P E R T S Y S T E M
DATE 1/17/62 WEEK 159.0

PAGE 1

PREDECESSOR	SUCCESSOR	TYPE OF ERROR			
000000105	000000103	EXPECT DATE LESS NOW	ACCEPT	EXPECTED WEEK	158.6

Figure 6. Error Report Listing

PERT SYSTEM REPORT									
REPORT DATE 01/17/62		WEEK 159,0		PAGE 1 8,50					
EVENT	NOMENCLATURE	EXPECTED	LATEST	SCHEDULE	ACTUAL	SLACK	STD	PROB	
		DATE	ALLOWABLE DATE	DATE	DATE		DEV		
000-000-100		00/00/00	01/12/62		01/17/62	=,7	0		
000-000-103		02/04/62	01/30/62			=,7	,4		
000-000-104		03/04/62	02/27/62			=,7	,4		
000-000-101		03/18/62	03/13/62			=,7	,5		
000-000-102		04/09/62	04/04/62	04/04/62		=,7	,7	.13	
000-000-109		03/15/62	03/14/62	03/14/62		=,1	,4	.36	
000-000-105		00/00/00	01/18/62		01/02/62	2,2	0		

Figure 7. Normal Report Listing (ordered by slack)

PERT SYSTEM REPORT									
REPORT DATE 01/17/62		WEEK 159.0			PAGE 1 T.50				
EVENT	NOMENCLATURE	EXPECTED	LATEST	SCHEDULE	ACTUAL	SLACK	STD	PROB	
		DATE	ALLOWABLE DATE	DATE	DATE		DEV		
000-000-105		00/00/00	01/18/62		01/02/62	2.2	0		
000-000-100		00/00/00	01/12/62		01/17/62	-.7	0		
000-000-103		02/04/62	01/30/62			-.7	.4		
000-000-104		03/04/62	02/27/62			-.7	.4		
000-000-109		03/15/62	03/14/62	03/14/62		-.1	.4	.36	
000-000-101		03/18/62	03/13/62			-.7	.5		
000-000-102		04/09/62	04/04/62	04/04/62		-.7	.7	.13	

Figure 8. Normal Report Listing (ordered by expected completion date)

PERT SYSTEM REPORT									
REPORT DATE 01/17/62		WEEK 159,0			PAGE 1 E,50				
EVENT	NOMENCLATURE	EXPECTED DATE	LATEST ALLOWABLE DATE	SCHEDULE DATE	ACTUAL DATE	SLACK	STD DEV	PROB	
000-000-100		00/00/00	01/12/62		01/17/62	-.7	0		
000-000-101		03/18/62	03/13/62			-.7	.5		
000-000-102		04/09/62	04/04/62	04/04/62		-.7	.7	.13	
000-000-103		02/04/62	01/30/62			-.7	.4		
000-000-104		03/04/62	02/27/62			-.7	.4		
000-000-105		00/00/00	01/18/62		01/02/62	2.2	0		
000-000-109		03/15/62	03/14/62	03/14/62		-.1	.4	.36	

Figure 9. Normal Report Listing (ordered by successor event number)

PERT MASTER FILE												PAGE 1,50	
REPORT DATE 01/17/62												WEEK 159,0	
PREDECESSOR	SUCCESSOR	ORIGINAL			RECENT			ACTIVITY	ACTIVITY	EXPECTED	LATEST	SLACK	
DATE	DATE	A	M	B	A	M	B	TIME	VARIANCE	TIME	TIME		
EXPECTED	LATEST	SCHEDULE	ACTUAL	COMPLETED	COMPLETED	SHORT	REPORT	NOMENCLATURE					
DATE	DATE	DATE	DATE	ACTIVITY	SUCCESSOR	PATH	CODE						
000-000-000	000-000-100	000-000-100	0,0	0,0	0,0	0,0	0,0	0	0	159,0	158,3	0,7	
00/00/00	01/12/62	00/00/00	01/17/62	YES	YES								
000-000-103	000-000-101	000-000-101	3,0	3,9	4,8	3,0	3,9	4,8	3,9	.1	167,6	166,9	0,7
03/18/62	01/13/62	00/00/00	00/00/00	NO	NO								
000-000-104	000-000-101	000-000-101	1,0	2,0	3,0	1,0	2,0	3,0	2,0	.1	167,6	166,9	0,7
03/18/62	03/13/62	00/00/00	00/00/00	NO	NO								
000-000-100	000-000-101	000-000-101	1,0	2,0	6,0	1,0	2,0	6,0	2,5	.7	167,6	166,9	0,7
03/18/62	03/13/62	00/00/00	00/00/00	NO	NO								
000-000-101	000-000-102	000-000-102	2,0	3,0	4,6	2,0	3,0	4,6	3,1	.2	170,7	170,0	0,7
04/09/62	04/04/62	04/04/62	00/00/00	NO	NO								
000-000-105	000-000-103	000-000-103	1,0	1,7	2,4	1,0	1,7	2,4	1,7	.1	161,5	160,8	0,7
02/04/62	01/30/62	00/00/00	00/00/00	NO	NO								
000-000-100	000-000-103	000-000-103	1,5	2,5	3,7	1,5	2,5	3,7	2,5	.1	161,5	160,8	0,7
02/04/62	01/30/62	00/00/00	00/00/00	NO	NO								
000-000-103	000-000-104	000-000-104	4,0	4,1	4,2	4,0	4,1	4,2	4,1	.0	165,6	164,9	0,7
03/04/62	02/27/62	00/00/00	00/00/00	NO	NO								
000-000-105	000-000-104	000-000-104	1,0	2,8	7,0	1,0	2,8	7,0	3,2	1,0	165,6	164,9	0,7
03/04/62	02/27/62	00/00/00	00/00/00	NO	NO								
000-000-000	000-000-105	000-000-105	0,0	0,0	0,0	0,0	0,0	0,0	0	0	156,9	159,1	2,2
00/00/00	01/18/62	00/00/00	01/02/62	YES	YES								
000-000-104	000-000-109	000-000-109	1,0	1,5	2,0	1,0	1,5	2,0	1,5	.0	167,1	167,0	0,1
03/15/62	03/14/62	03/14/62	00/00/00	NO	NO								

Figure 10. Optional listing