NASA CR-144942
D6-42377-5

TIMELINE ANALYSIS PROGRAM (TLA-1) FINAL REPORT

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April 1976

Prepared under contract NAS1-13741 by

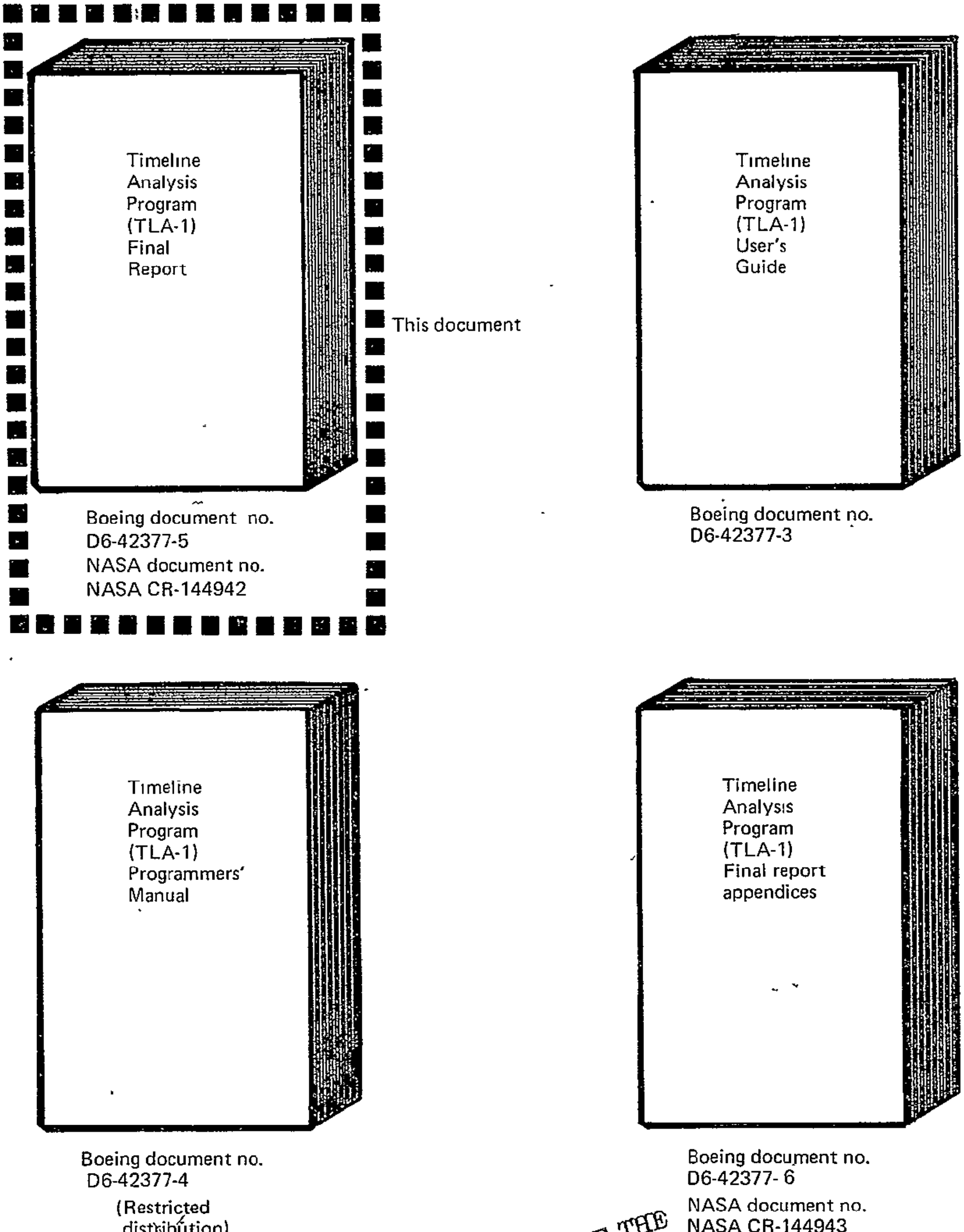
Boeing Commercial Airplane Company
P.O. Box 3707
Seattle, Washington 98124

for
Langley Research Center
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(NASA-CR-144942) TIMELINE ANALYSIS PROGRAM (TLA-1) FINAL REPORT (BOEING COMMERCIAL AIRPLANE CO., SEATTLE) 159 P HC $6.75 N76-26027
CSCL 05A UNCLAS
G3/81 41623

TIME LINE ANALYSIS PROGRAM (TLA-1)

DOCUMENTATION FAMILY



1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-144942		

4. Title and Subtitle	5. Report Date
TIMELINE ANALYSIS PROGRAM (TLA-1)– Final Report	April 1976
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
K. H. Miller	D6-42377-5
	10. Work Unit No.
9. Performing Organization Name and Address	11. Contract or Grant No.
Boeing Commercial Airplane Company P.O. Box 3707 Seattle, Washington 98124	NAS1-13741
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Final Report
NASA-Langley Research Center Hampton, Virginia 23665	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This document is the final report for the Timeline Analysis Program (TLA-1) produced under NASA contract NAS1-13741. TLA-1 is a crew workload anlaysis computer program that was developed and expanded from previous Boeing workload analysis progams. TLA-1 was created for use on the NASA-Langley Terminal Controlled Vehicle Program. This document describes the derivation of input data for, the data processing of, and the output data from the TLA-1 model. Also described are eight scenarios that were created, programmed, and analyzed as verification of this model.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Flight deck, Model 737, Task analysis, Crew systems, NASA 515, Timeline, Controls and displays, Workload analysis computer program	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unlcassified	151	

*For sale by the National Technical Information Service, Springfield, Virginia 22151

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TIMELINE ANALYSIS PROGRAM (TLA-1)

FINAL REPORT

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1.0 SUMMARY

This document is the final report for the Timeline Analysis Program, NASA contract NAS1-13741. The report describes the derivation, details, and application of a crew workloading analysis computer program, called TLA-1 (TimeLine Analysis program–Model 1), that was created for use on the Terminal Controlled Vehicle (TCV) program at NASA-Langley.

The application of TLA-1 requires an analyst to define (1) a scenario, (2) tasks, (3) events and procedures, (4) flight phases, and (5) subsystems. The analyst codes data relevant to these factors on preprinted data coding forms. These data are keypunched and then processed by using the TLA-1 program on the CDC 6600 computer to provide a variety of digital reports and graphical plots that provide a variety of statistical measures of crew workload.

Eight scenarios were developed, based on the NASA 515 aircraft operating in the Atlanta Airport terminal area. Procedures and tasks for both the forward flight deck and aft flight deck were detailed. Some of these data cases were processed by using TLA-1, and samples of every report and plot option were produced.

The software for the TLA-1 model and data cases was implemented on the NASA-Langley CDC 6600 computing system. NASA analysts and programmers were trained in the use of this software.

This final report, including the Appendices (Boeing document D6-42377-6), the TLA-1 User's Guide (Boeing document D6-42377-3), and the TLA-1 Programmer's Guide (Boeing document D6-42377-4), and the software and data package constitute the deliverable documentation for this program.

2.0 INTRODUCTION

2.1 THE NEED FOR TASK/WORKLOAD ANALYSIS ON THE TCV PROGRAM

NASA's Terminal Configured Vehicle (TCV) program is an advanced technology development activity focused on conventional transport aircraft that will routinely operate in reduced weather minima in future high-density terminal areas equipped with new landing systems, navigational aids, and increased ATC automation presently under development by the FAA and DOT.

The broad objectives of the program are to evaluate new concepts in the airborne systems (avionics and air vehicle) and operational flight procedures for (1) reducing approach and landing accidents, (2) reducing weather minima, (3) increasing air traffic controller productivity and airport and airway capacity, (4) saving fuel, (5) and reducing noise by more efficient terminal area techniques.

A Boeing 737-100 series airplane was obtained, and a second flight deck and an array of computers and monitors were installed in the passenger cabin (fig. 1). The airplane (NASA 515) was designated the research support flight system (RSFS). The RSFS is designed to be normally flown from the forward flight deck by using the primary flight control system, and from the aft deck by using a fly-by-wire, triple-redundant, digital flight control computer system. From the aft flight deck, the airplane can be flown under simulated Category III (CAT III) operations with safety assured through monitoring and takeover capability by the forward flight deck crew.

Since piloting tasks using advanced controls and displays in the future terminal area environment will differ from present concepts, it is imperative to ensure that these tasks will not become overly complex, demanding, or critical to safe operation. Task and workload analysis for the NASA 515 is therefore a necessity.

2.2 WORKLOAD ASSESSMENT METHODS

2.2.1 INTRODUCTION

Statements about "reducing operator workload" have frequently been included in lists of objectives for any crew systems design effort. If care is taken that the operator is not underloaded to the point of decreased motivation and vigilance, there should be no quarrel with the objective. However, even a cursory review of the literature shows an unusual diversity, and often vagueness, in the way the term "operator workload" is defined and used.

In determining how workload should be measured, one needs to keep in mind that it may not be possible to measure operator workload directly but that it should be possible to derive the needed measure by appropriate combinations of relevant quantitative empirical laws or functional relationships.

A comprehensive discussion of the scope of workload measurement theory and practice is found in ref. 1.

2.2.2 CONCEPTS OF WORKLOAD MEASUREMENT

Interest in accurate operator workload assessment and prediction develops because questions such as the following require meaningful answers during the design of equipment and the development of operating, training, and personnel selecting procedures:

- How easy is the equipment to operate?
- How much attention is required during equipment operation?

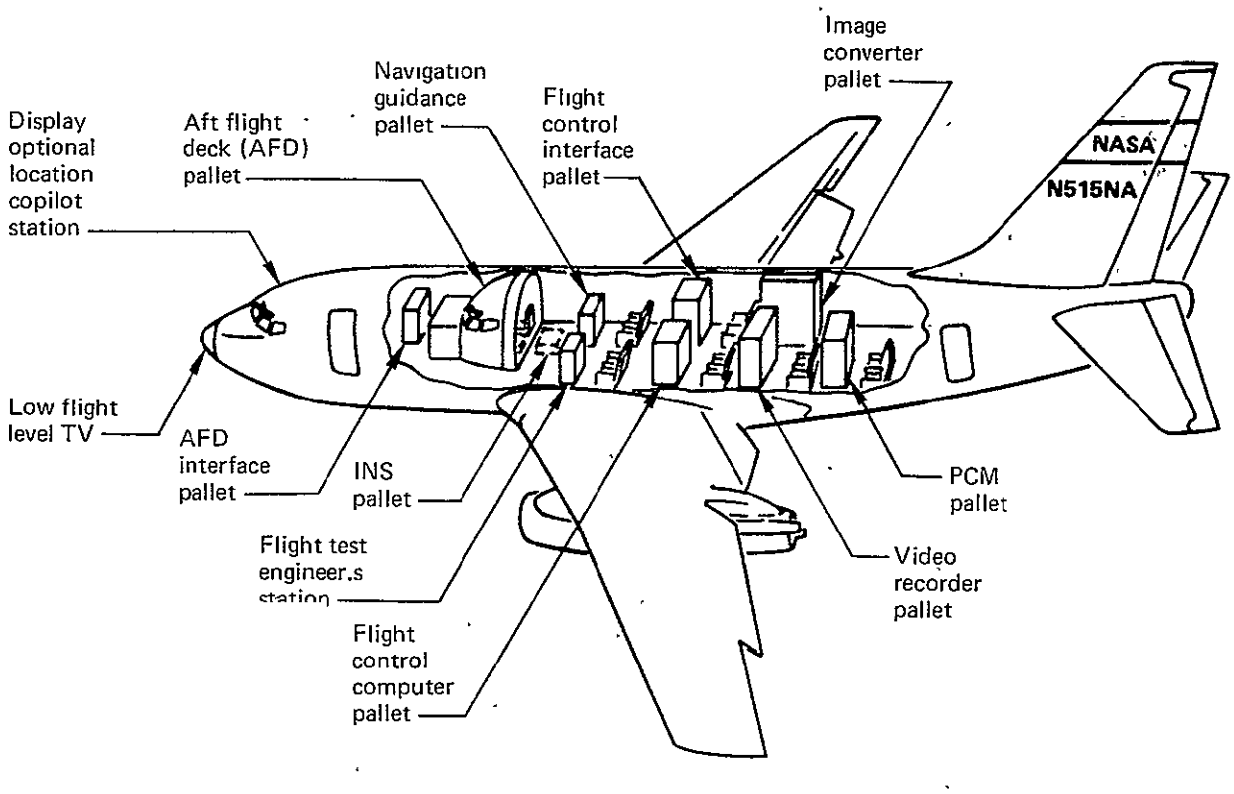


Figure 1. Research Support Flight System Internal Arrangements

- How much learning is involved to master the equipment?
- How well will the operator be able to perform additional foreseen and unforeseen tasks?

All these questions are directed toward finding an indication of the extent to which an operator is occupied by a task.

Basically, four categories of workload measurement methods have been identified:

1. Information processing methods
2. Operator activation-level methods
3. Equipment design-implicit methods
4. Time-and-motion methods

The following sections briefly discuss each of these methods.

2.2.2.1 Information Processing Methods

The use of information processing methods to determine operator workload is based on the premise that the human operator possesses a fixed, limited channel capacity and that workload is either the degree to which tasks additional to a primary one can be accomplished or the degree to which auxiliary tasks interfere with the accomplishment of the primary task. The underlying concept here is similar to that of time-and-motion techniques, except that the emphasis is shifted toward a quantitative determination of "excess channel capacity" as a measure of operator workload.

2.2.2.2 Operator Activation-Level Methods

Briefly stated, the "activation" or "arousal" hypothesis maintains that the level of physiological activity within the central nervous system (CNS) is increased both by the mental demands made by the working situation and by the intensity of physical stimuli. In the area of workload assessment, it is hypothesized that input load is a determinant to the activation level that is reflected in the physiological activity of the individual. Thus, physiological measurement techniques are used to correlate changes in heart rate, sinus arrhythmia, EEG, cortical evoked potentials, integrated EMG, respiration rate, and pupillary dilation, as well as others, with various task conditions.

2.2.2.3 Equipment Design-Implicit Methods

Studies in this category maintain that changes in operator performance are directly associated with changes in workload. Thus, performance improvements that can be related to changes in equipment or procedures are also assumed to indicate a reduction in operator workload. Subjective rating of task difficulty is generally combined with operator performance measures to deduce that operator workload has changed.

Unfortunately, most studies of this type include only a brief statement that operator workload has been changed but do not state how workload was defined or how the conclusion was reached.

2.2.2.4 Time-and-Motion Methods

The time-and-motion approach to workload evaluation relies heavily on detailed task analyses that require some techniques derived from time-and-motion engineering. This approach is used primarily during system development and represents the broadest approach to workload assessment, since the primary concern is to determine the operability of a proposed system. The question becomes simply: Can the operator satisfactorily accomplish all the tasks allocated to him within the time frame available to meet mission phase and/or system requirements?

This is the workload measurement method that is employed in the Timeline Analysis program (TLA-1).

2.3 THE TIMELINE ANALYSIS (TLA-1) PROGRAM

The TLA-1 program was created to improve and expand the capabilities of an existing validated Boeing task/workload model[1] for use on the TCV program. TLA-1 will support NASA-TCV objectives by: (1) producing a detailed analytic model for performing task and workload analyses on alternative control-display concepts in the TCV and (2) developing a baseline set of data for comparing crew workload in the fore and aft cabs of the TCV in a commercial airline environment.

[1]The workload model that is the basis for TLA-1 is called Workload Evaluation for Cockpit Crew (WECC). WECC was developed, applied, and validated as part of the Boeing 747 certification program. Data were accepted by FAA as part of the certification package.

3.0 SYMBOLS AND ABBREVIATIONS

ADF/RMI	automatic direction finder/radio magnetic indicator
AFD	aft flight deck
AGCS	advanced guidance and control system
APU	auxiliary power unit
ARTCC	air route traffic control center
ATA	Air Transport Association
ATC	air traffic control
ATT CWS	attitude control wheel steering
AUD	auditory
AVC	weighted average channel
AVE	average only
A+1	average plus 1σ
CAS	channel activity summary
CAT III	Category III
CI	course indicator
CNS	central nervous system
COG	cognition
COM	communication
CSD	constant speed drive
CWP	crewman workload profile
CWS	control wheel steering
CWS	crewman workload summary statistics
DME	distance measuring equipment

EADI	electronic attitude director indicator
EPR	engine pressure ratio
EV	external vision
FAA	Federal Aviation Administration
FDI	flight director indicator
FFD	forward flight deck
FL	flight level
IFR	instrument flight rules
ILS	instrument landing system
INS	inertial navigation system
IV	internal vision
KIAS	knots indicated airspeed
LF	left foot
LH	left hand
MFD	multifunction display
MLS	microwave landing system
MNS	mission scenario
MOT	motor
MTL	mission timeline
NAVAID	navigational aid
NCDU	navigation control and display unit
N_{COC}	number of channel overload contributors
N_i	number of time intervals
$N_{\Delta T}$	number of study-time intervals in which a work overload occurs

PCM	power control module
PTA	planned time of arrival
RF	right foot
RH	right hand
R_{INT}	ratio of total channel overload contributors to total interval time
R_{MSN}	ratio of total channel overload contributors to total mission time
RNAV	area navigation
R_{PHS}	ratio of total channel overload contributors to total phase time
RSFS	research support flight system
SAS	subsystem activity summary
Selcal	selective call unit
SID	standard instrument departure route
SR1, . . ., SR4	standard report request
SSA	subsystem activity
STAR	standard arrival route
S_W	workload sum
S_{W2}	sum of the squares of workload
T	slide time, turn time
TCA	task channel activity
TCV	terminal configured vehicle
TFR	terrain following radar
t_{IE}	interval end time
T_{INT}	total interval time
t_{IS}	interval start time

T_{ISF}	first interval in which task contributes to workload
T_{ISL}	last interval in which task contributes to workload
TLA-1	Timeline Analysis Program, Model 1
TLS	task list
TST	test
t_T	task duration time
t_{TE}	task end time
t_{TS}	task start time
VBL	verbal
VIS	visual
VOR/RMI	very high frequency (VHF) omnidirectional radio/radio magnetic indicator
$\overline{W}$	mean workload
W_A	channel workload for a study-time interval
W_C	channel workload
W_{CT}	percent channel workload
$W_{CT,N}$	allocated channel N activity
WECC	workload evaluation for cockpit crew
W_G	channel group workload
WLH	workload histogram
WLS	workload summary
W_{OVLD}	total channel overload contribution
2D	horizontal path mode
3D	vertical path mode
4D	time path mode

Δt	study interval
ΔT_{INT}	total interval time
ΔT_{MSN}	total mission time
ΔT_{PHS}	total phase time
Δt_T	task duration time
σ	standard deviation of the workload
σ^2	workload variance

4.0 TLA-1 PROGRAM OVERVIEW

Figure 2 shows the overall TLA-1 analytical and data processing procedure. Each element in figure 2 will be briefly discussed in this section. Detailed descriptions of the derivation and use of the various items are given in other sections of this report. The TLA-1 User's Guide (ref. 2) and Programmer's Guide (ref. 3) provide additional detailed information.

Application of TLA-1 includes three major phases:

1. Input data preparation (sec. 4.1)

2. Data processing (sec. 4.2)

3. Output data analysis (sec. 4.3)

4.1 INPUT DATA PREPARATION

Four activities are involved in the preparation of the TLA-1 input data:

1. Scenario development

2. Task data derivation

3. Task timeline development

4. Input data coding

Scenario development and task data derivation are performed first and can be done independently. Task timeline development and input data coding are performed after the first two activities are completed.

4.1.1 SCENARIO DEVELOPMENT

Crew workload is a measure of how well the crew can accomplish a given set of tasks within the available time. The set of tasks to be performed and the time available for performance are dictated by the scenario.

A scenario is a time-based sequence of events that defines the significant milestones that occur during the mission being studied. The following events are defined in a flight mission scenario:

- Begin taxi

- Taxi maneuvers on ramps

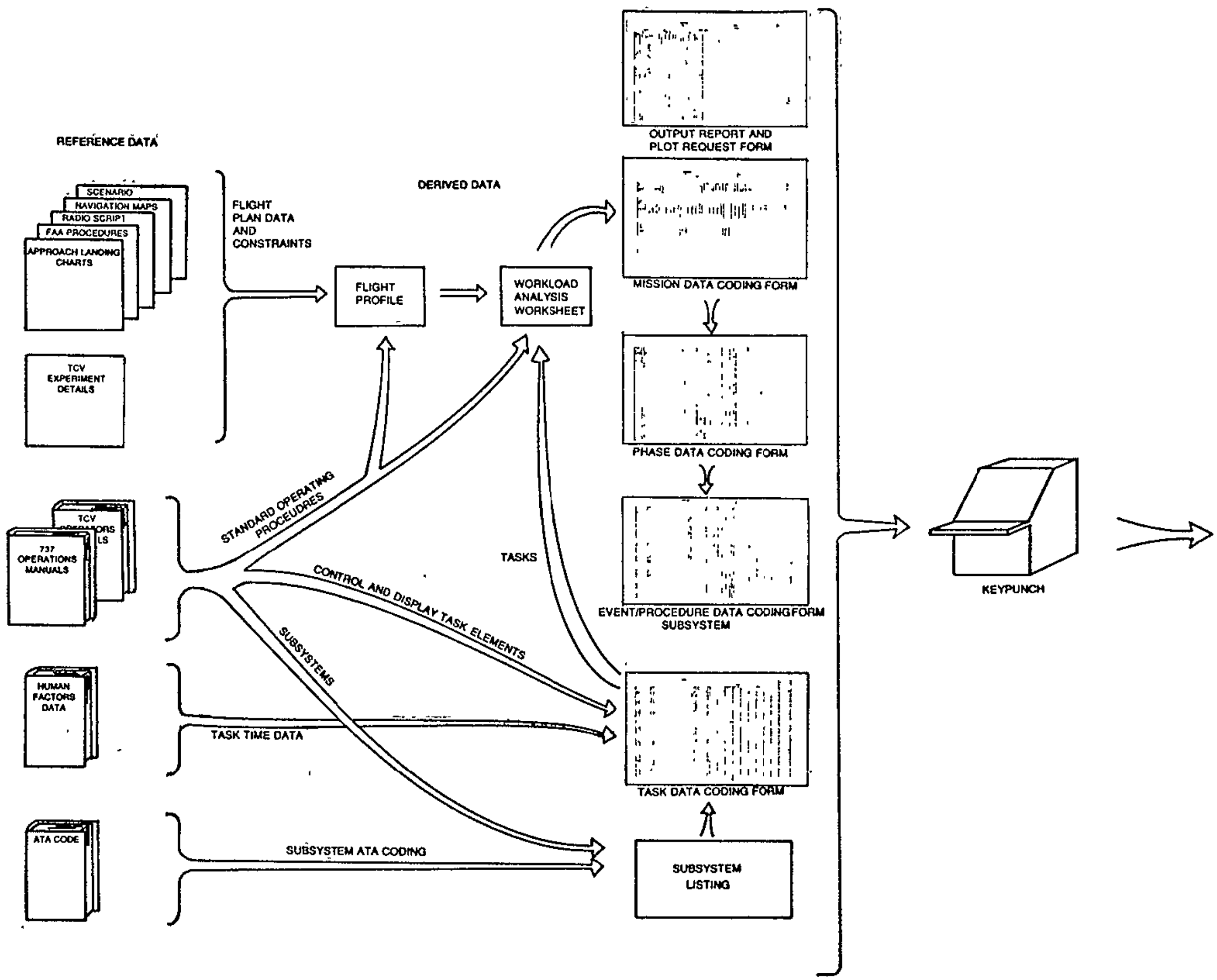


Figure 2.—TLA-1 Analytical Process

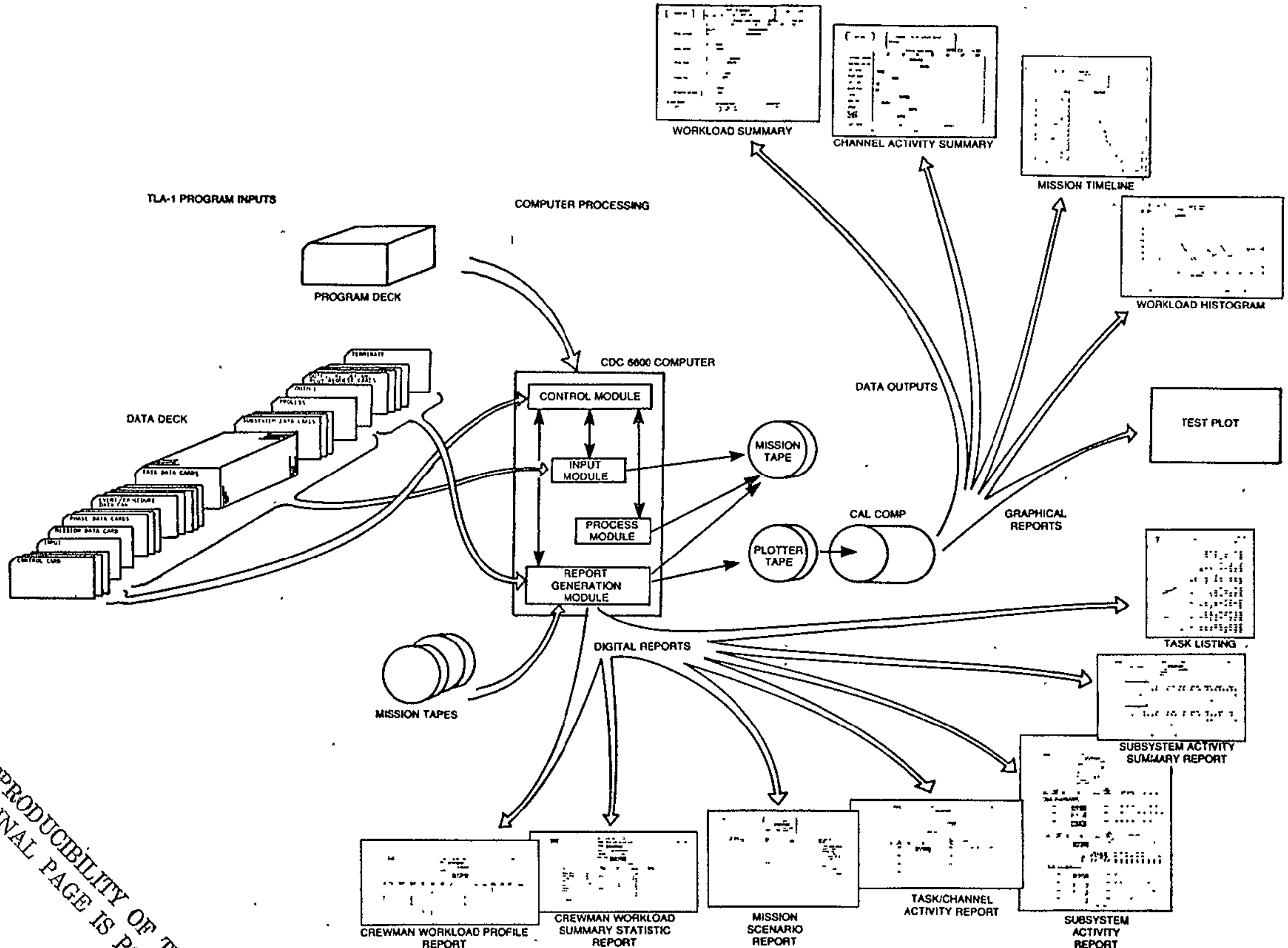


Figure 2.—Concluded

- Brake release
- Takeoff
- Gear up
- Flap retractions–each step in retraction sequence
- Horizontal maneuvers–start/end times of each maneuver
- Vertical maneuvers–start/end times of each maneuver
- Speed changes–start/end times of each transition
- Navaid crossover/handover
- Flap extensions–each step in extension sequence
- ILS or MLS localizer and glideslope intercept points
- Gear down
- Touchdown
- Taxi maneuvers on ramps
- Park
- Shutdown
- Radio messages incoming/outgoing–complete text of each message, frequencies used, etc.
- Malfunctions

The analyst must define the initiation time of each event.

Creation of the scenarios is based on the data derived from mission flight plans, TCV experiment test plans, flight information maps, approach and landing charts, ATC operation data, aircraft performance data, and aircraft operation manuals. The scenarios that were developed to verify the TLA-1 software are described in detail in section 5.0.

4.1.2 TASK DATA DERIVATION

In TLA-1, tasks are used as the basic work units from which all crew workload statistics are derived. Tasks are identified and cataloged for every control and display, every verbal communication, and every other crew action. A task catalog containing over 2000 tasks was derived (App. Five, ref. 4).

The tasks are categorized by subsystems. Each task description contains a task code number, a task description/name, task duration time, and the channel activity (left hand, right hand, left foot, right foot, external vision, internal vision, cognition, auditory, and verbal). These factors are discussed in detail in section 6.0.

The data from which the tasks are derived include:

1. Aircraft operation manuals
   a. Checklists
   b. Procedures

2. Human factors data
   a. Eye fixation times
   b. Reach times
   c. Control activation times
   d. Display monitoring times

3. Task simulation
   a. Verbal communication delivery times
   b. Task execution times

4.1.3 TASK TIMELINE DEVELOPMENT

After the scenarios and tasks have been defined, the analyst develops the detailed task sequences (procedures) required to execute the scenario.

A workload analysis worksheet (fig. 3) has been prepared for the analyst to use for detailing the procedures. In the process of filling in the details on this format, the analyst specifies all the data that will be entered in the various input data coding forms (discussed in sec. 4.1.4).

The analyst will use the following as reference data for the procedure detailing:

1. Aircraft operation manuals
   a. Normal procedures
   b. Abnormal procedures
   c. Checklists

2. The scenario

3. The task catalog

The detailing is organized by defining flight phases (sec. 7.2) and events and procedures (sec. 7.3). The analytical process of detailing the scenarios on the worksheet requires careful attention to detail. This is the only place that all tasks, events, procedures, phases, timing relationships, and crew interactions are totally visible in an integrated format.

TLA-1 WORKLOAD ANALYSIS WORKSHEET

PAGE ____ OF ____

MISSION TITLE					CONFIGURATION											RUN DATE	
PHASE/EVENT/PROCEDURE DATA					TASK DATA												
CODE NO.	NAME/DESCRIPTION	START TIME HR	START TIME MIN	START TIME SEC	TASK CODE NO.	TASK NAME/DESCRIPTION	SIT	TASK DURATION SECONDS	MISSION TIME HR	MISSION TIME MIN	MISSION TIME SEC	TASK START TIME HR	TASK START TIME MIN	TASK START TIME SEC	SLIDE (SEC) −	SLIDE (SEC) +	CREW
090006	RETRACT FLAPS TO FLAPS 1			33						37	15						
090007	REACH 3000 FT ABOVE RWY		1	11						37	53						
090011	RETRACT FLAPS TO FLAPS 0		1	31						38	13						
090056	ENGAGE VERT PATH GUIDANCE MODE		1	31	2H 07	AUTO SW	1	1.42		38	13			0	2	2	P
					2H 08	AUTO HS	1	1.34						1.42			
					2H 35	HOZ PATH SW	1	1.37						2.76			
					2H 36	HOZ PATH ITS	1	.78						4.13			
					2H 39	VERT PATH SW	1	1.36						4.91			
					2H 40	VERT PATH ITS	1	.78						6.27			
					2K 14	MON MFD	2	10						7.05			
090057	CROSS WPTOZ (SIDZ) AUTOPILOT MANEUVERS A/C TO 088 HDG		1	36	2K 14	MON MFD	2	10		38	18			0			P
					2K 33	MON CURVED TREND VECTOR	1	10						0			
					2K 47	MON TRACK ANGLE	1	10						0			
					2K 52	MON FLT PATH	1	10						0			
090067	MONITOR AUTO HEADING CHANGE		1	36						38	18						
030007	MON ENGINE INSTRUMENTS		1	40						38	22						
090012	TURN COMPLETED ON HDG 088		1	42						38	24						
090013	REACH 250 KNOTS		2	00						38	42						
090051	INST SCAN - A1		2	00						38	42						
030007	MON ENG INST		2	40						39	22						
090076	SET MFD MAP SCALE TO 32 NMI		1	48	2K 10	SEL 32 NMI	1	2.68		38	30			0			P
					2K 17	MON MFD	1	2.37						2.68			

Figure 3.—Workload Analysis Worksheet

4.1.4 INPUT DATA CODING

The analyst uses six sets of input data, with the following fixed-format coding forms:

1. Subsystem coding form
2. Task data coding form
3. Event/procedure data coding form
4. Phase data coding form
5. Mission data coding form
6. Report request coding form

These forms are briefly discussed in the following sections, and complete details are found in other sections of this report.

4.1.4.1 Subsystem Coding Form

The subsystem coding form (fig. 4) is used to define aircraft subsystems.

4.1.4.2 Task Data Coding Form

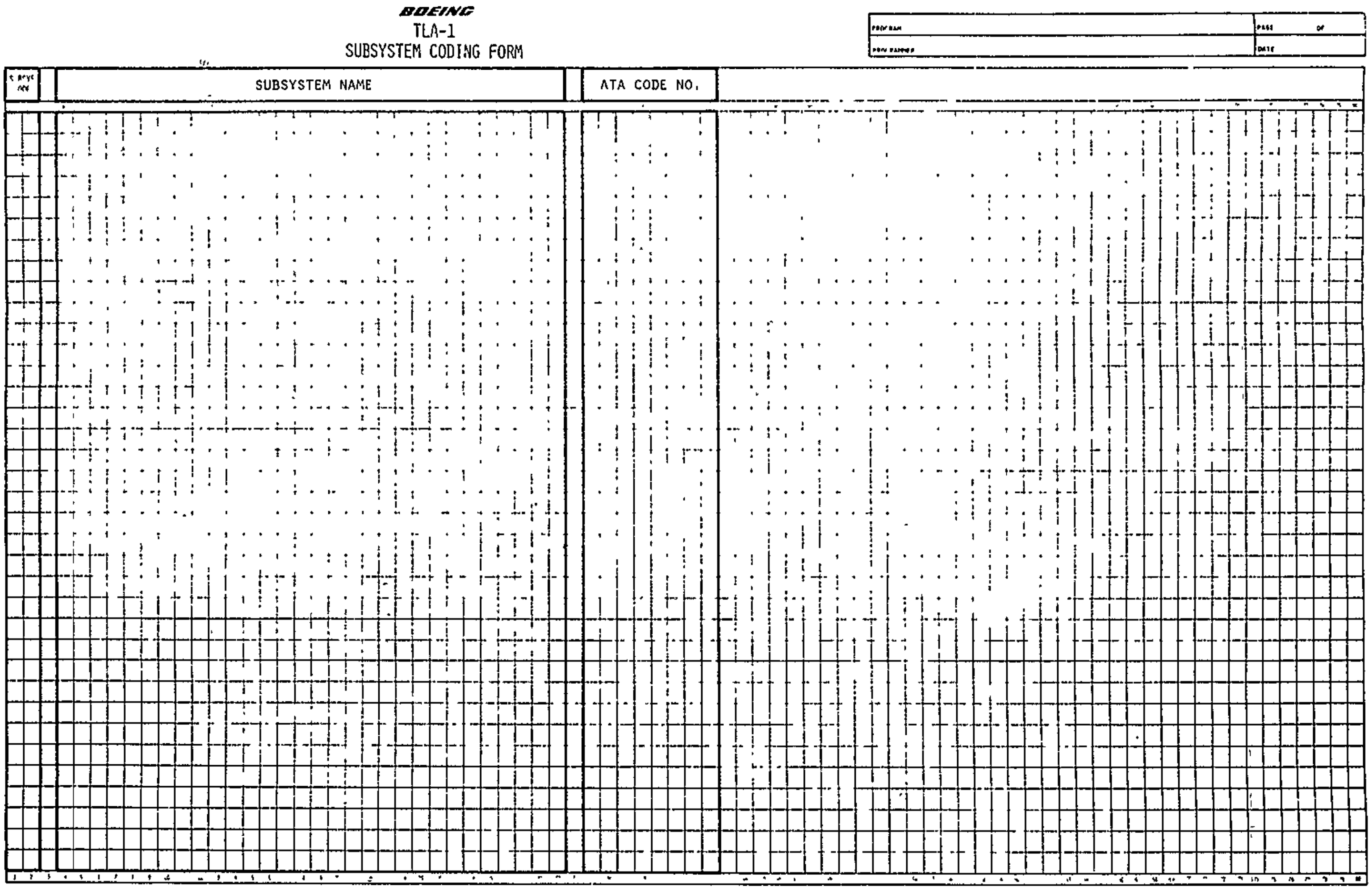
Task data coding forms (fig. 5) are filled out during the task data derivation stage. (See secs. 4.1.2 and 6.0.) The task is totally defined on this form by a unique task code number, a task description, a situation number, the task duration time, and the channel activity allocation.

4.1.4.3 Event/Procedure Data Coding Form

Event/procedure data coding forms (fig. 6) are filled out after the workload analysis worksheets are completed. (See secs. 4.1.3 and 7.0.) All the data to be entered on these coding forms come directly from the worksheets.

Events (see sec. 7.3.1) are defined by a unique code number and a description and are generally used to enter comments or milestones into output reports and plots. Events are distinguished from procedures because events have no tasks associated with them.

Procedures (see sec. 7.3.2) are defined by a unique code number, a title, and a listing of the sequence of tasks that are used in the procedure. Each task in the sequence is defined by the task code number, the initiation time of the task, the allowable initiation time limits, the crewmember who performs the task, and the task situation number.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SUBSYSTEM CODING FORM

SUBSYSTEM NAME

ATA CODE NO.

Figure 4.—Subsystem Coding Form

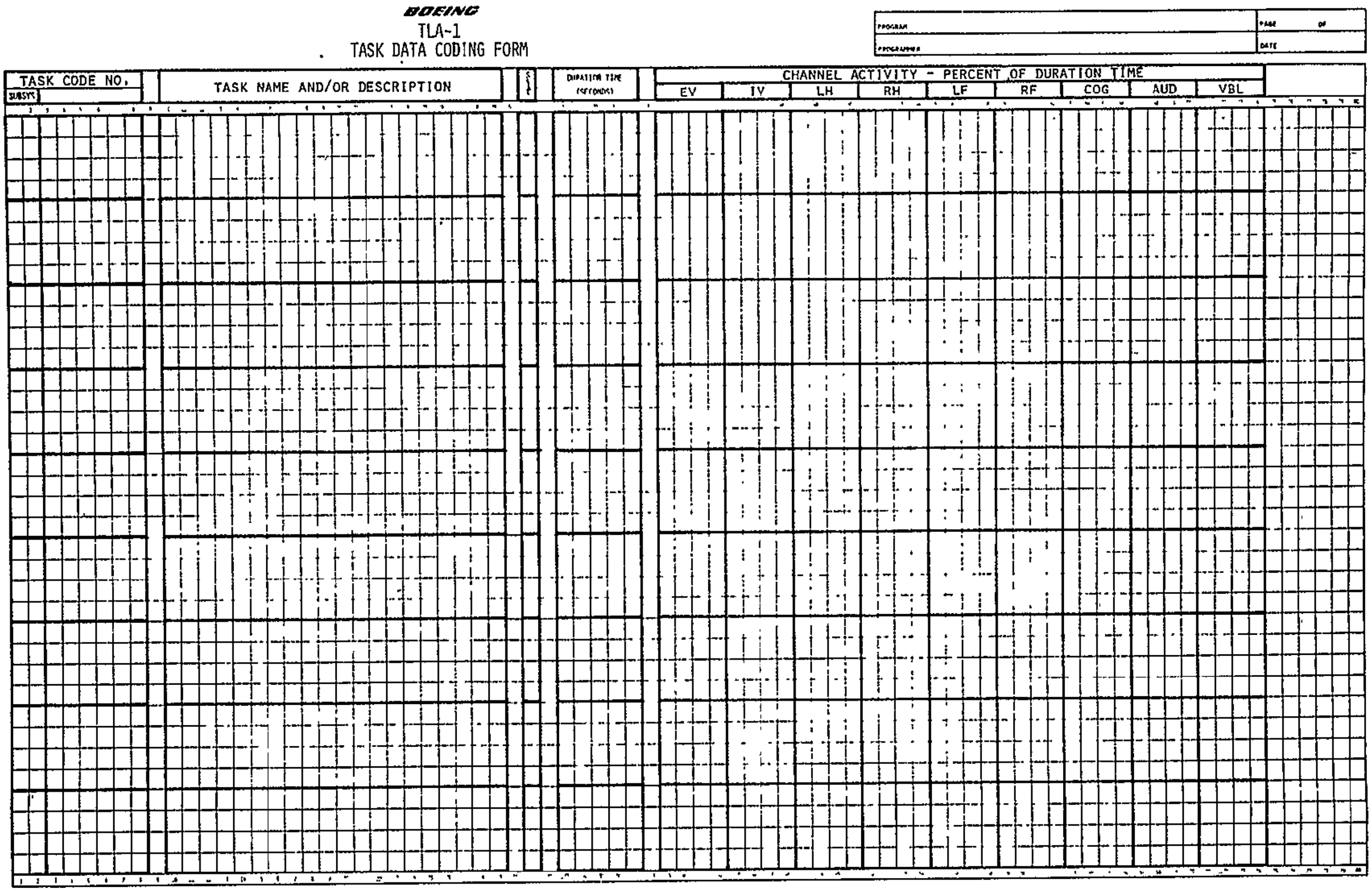

Figure 5.—Task Data Coding Form

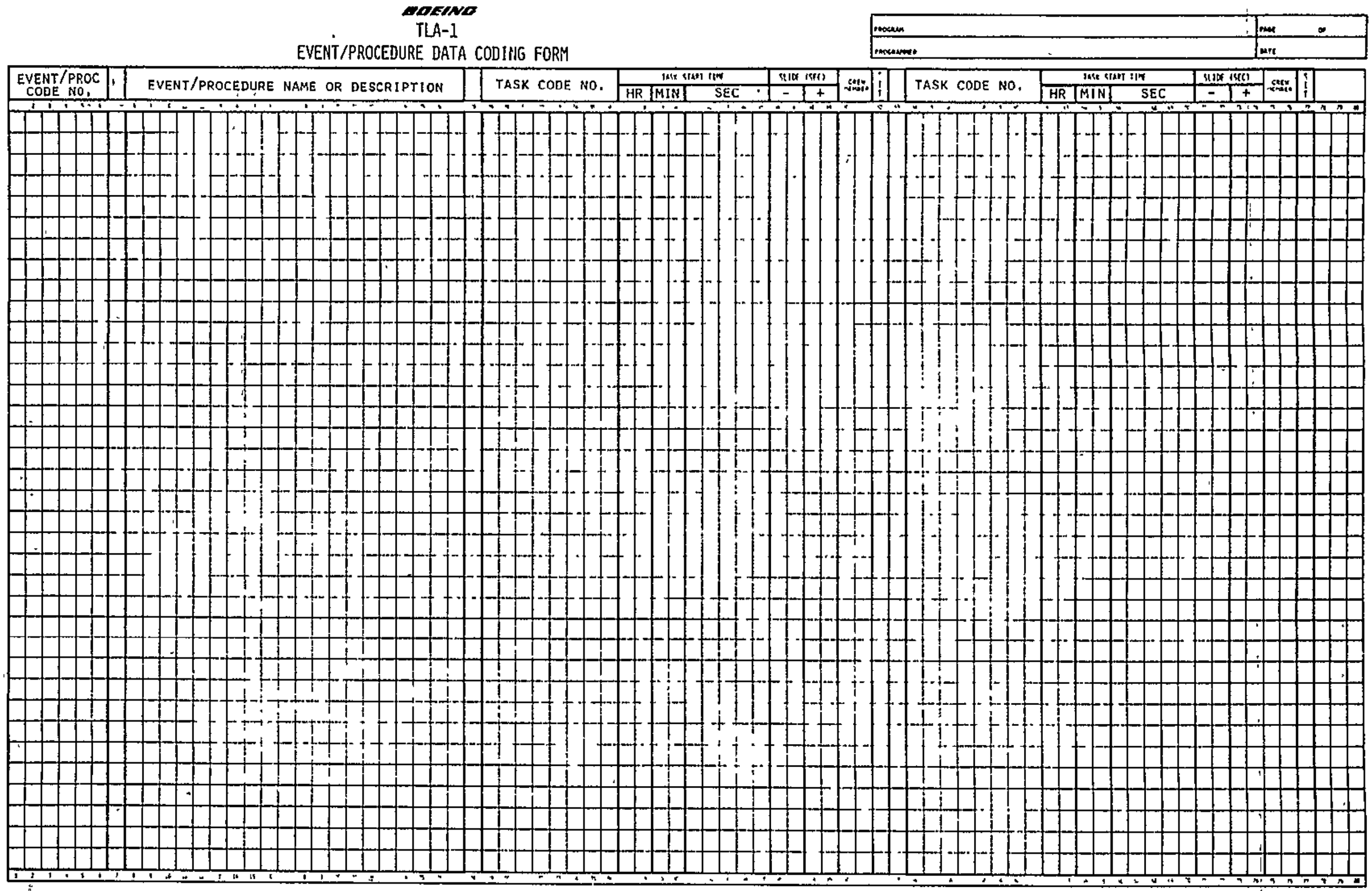

Figure 6.—Event/Procedure Data Coding Form

4.1.4.4 Phase Data Coding Form

The various flight phases (takeoff, cruise, etc.) are defined by a phase code number, a descriptive name, and a listing of the sequence of events/procedures with their respective start times. (See sec. 7.2.) The data to be filled in one these forms (fig. 7) come directly from the workload analysis worksheets.

4.1.4.5 Mission Data Coding Form

The mission data coding form (fig. 8) is used to define the computational parameters; mission title, configuration, crewmembers, and sequence of flight phases and their respective start times. The flight phase data are taken from the workload analysis worksheets. The rest of the data is created by the analyst. (Refer to sec. 7.2.)

4.1.4.6 Report Request Coding Form

One of the most powerful features of TLA-1 is the wide variety of workload analysis data formats that are available. Six digital reports and four data plots can be requested. By specifying different variables for each of these output formats, literally thousands of data records can be selected for output for a mission. Obviously, not every conceivable report and plot will be requested at any one time. The report request coding form (fig. 9) is used to list the types of outputs and the variables. The various reports and plots are discussed in detail in section 8.2.1.3.

Definition has been made of standard sets of reports and plots that can be specified by number. The items in these standard report sets have been selected to provide a general visibility of the workload situation for a scenario. As high workload problems are isolated, the analyst can be more selective of the output types and exercise tighter control over the variables so that successive data outputs can expose the nature of the workload problems in more detail.

4.2 DATA PROCESSING

The program is divided into the following four modules (fig. 10):

1. *Control*–The control module processes all control cards and initiates the other three modules.

2. *Input*–All mission data are input through the input module and output to an external permanent file.

3. *Processor*–The processor module performs all the calculation functions and outputs the results to an external file. The input to the processor comes from the data stored by the input module.

4. *Report generation*–The report generation module receives inputs of report requests and acts to produce the requested reports by using the data from the two external files created by the input module and the processor module. As many as three sets

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TLA-1

PHASE DATA CODING FORM

PROGRAM	PAGE OF
PROGRAMMER	DATE

PHASE CODE NO.	PHASE NAME	EVENT/PROC CODE NO.	EVENT/PROC START TIME HR	MIN	SEC	EVENT/PROC CODE NO.	EVENT/PROC START TIME HR	MIN	SEC	EVENT/PROC CODE NO.	EVENT/PROC START TIME HR	MIN	SEC	EVENT/PROC CODE NO.	EVENT/PROC START TIME HR	MIN	SEC

Figure 7.—Phase Data Coding Form

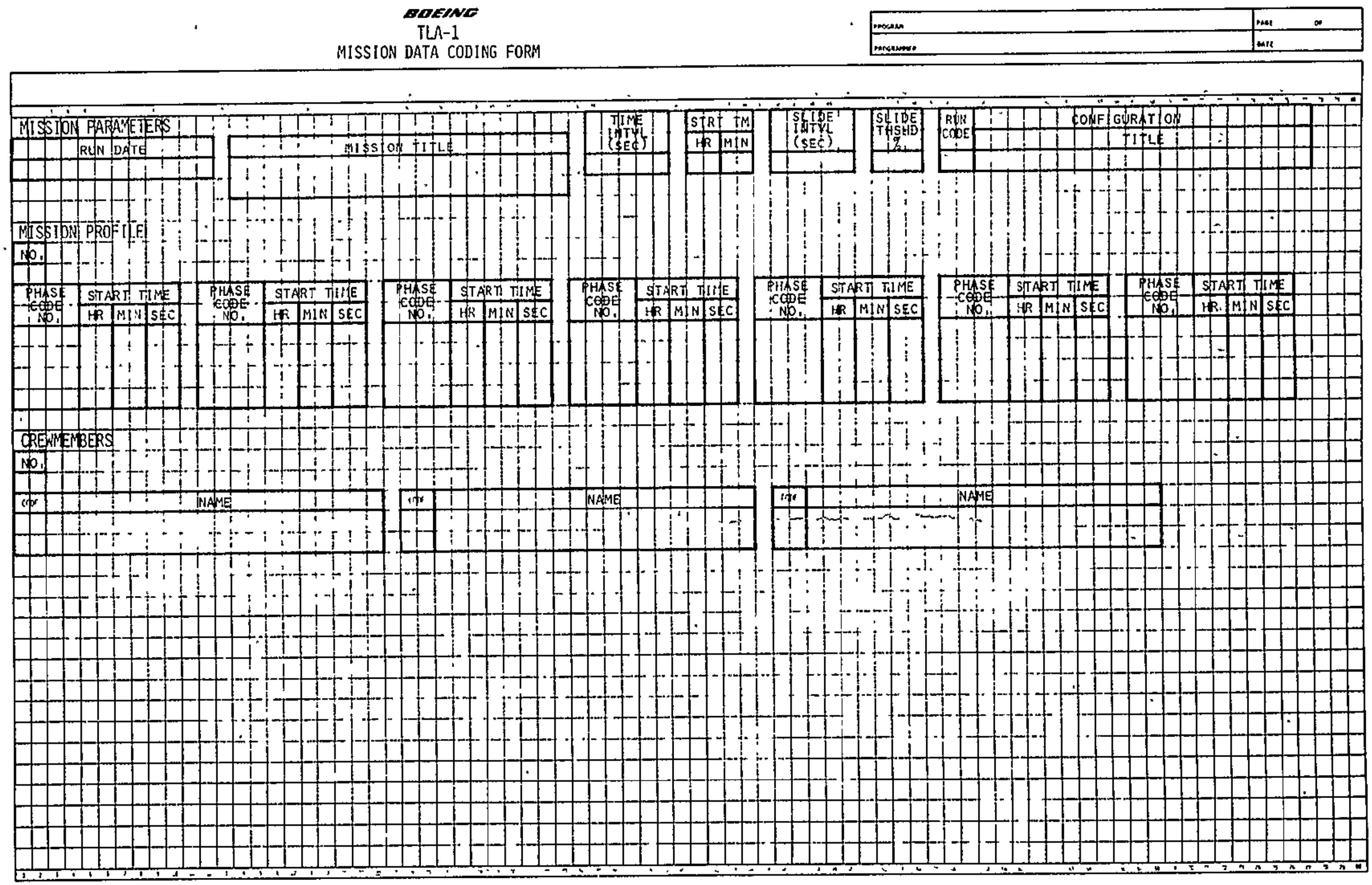


Figure 8.—Mission Data Coding Form

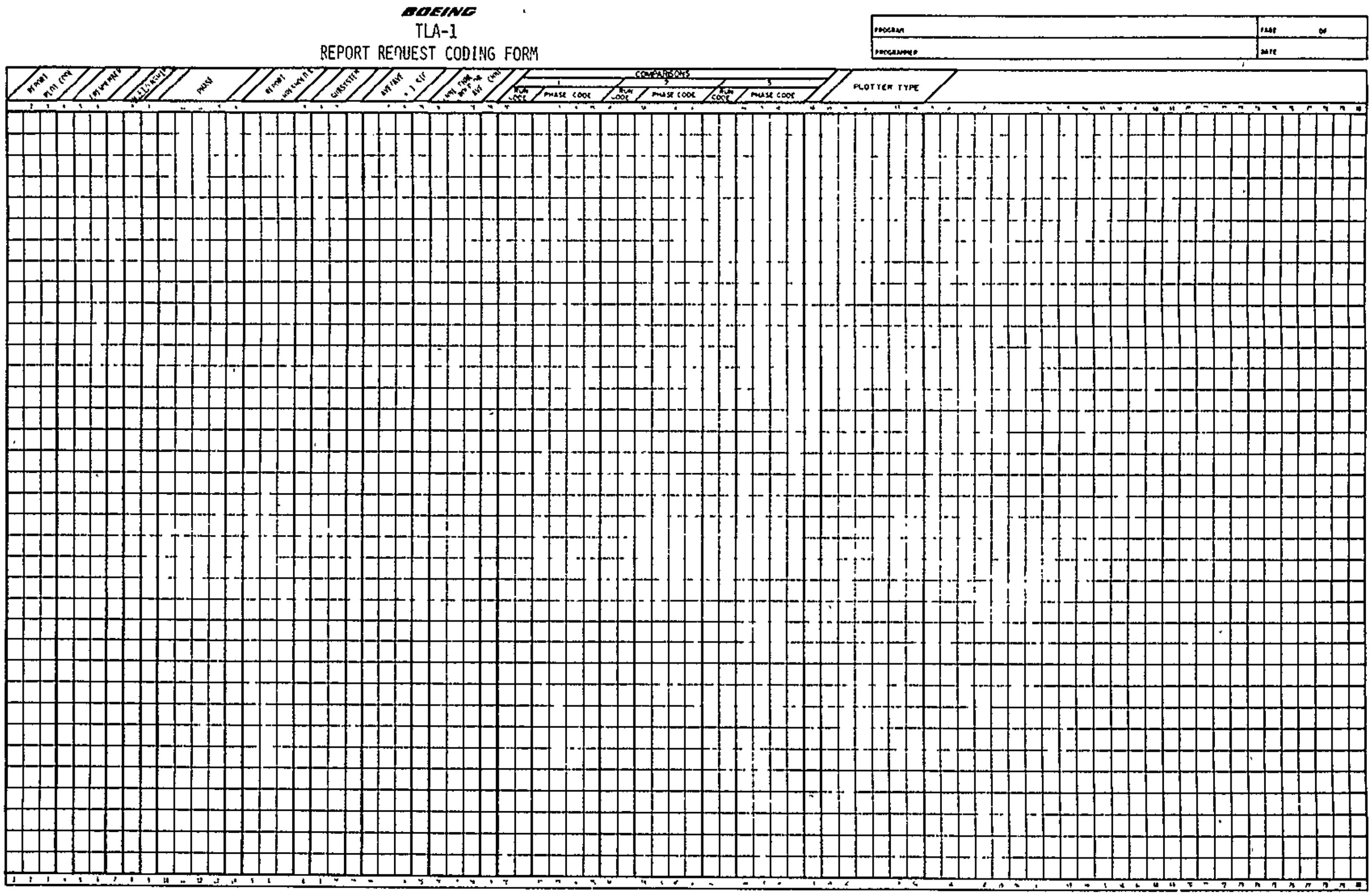


Figure 9.—Report Request Coding Form

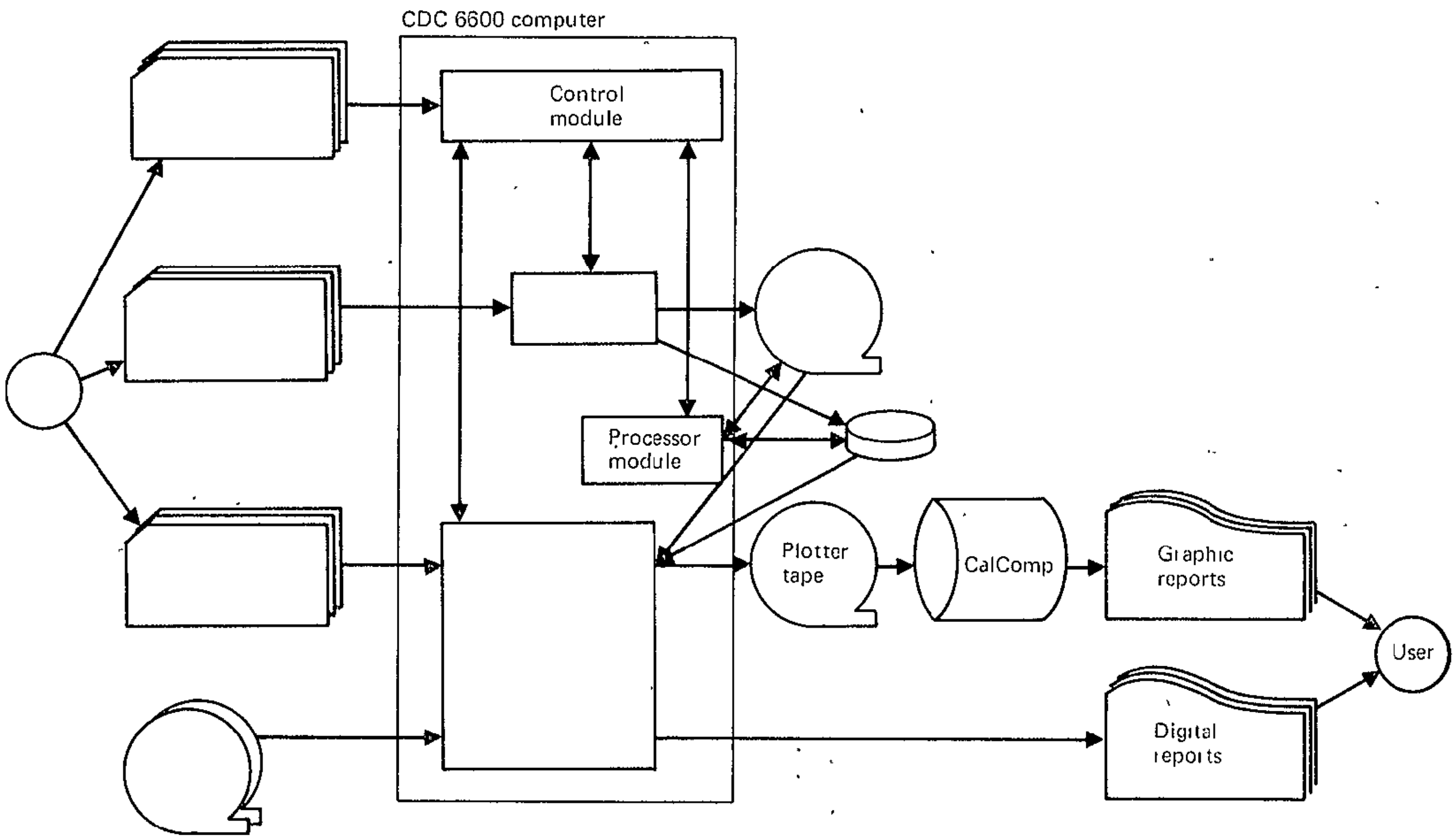


Figure 10.—TLA-1 System Diagram

of external files (different configurations of the same mission) may be input to create some reports.

This section will briefly discuss these modules. Complete details are in section 8.0 and in the TLA-1 User's Guide (ref. 2) and the TLA-1 Programmer's Guide (ref. 3).

4.2.1 INPUTS

Inputs to TLA-1 are from two sources: card and tape. The following sections describe the card types and formats and the tape inputs.

4.2.1.1 Card Inputs

Card inputs to TLA-1 are of three classes: control specifications, mission data, and report request specification.

The control specifications cause the functions to be executed. The mission data prescribe in detail a mission timeline task. The report request specification causes reports to be generated.

4.2.1.1.1 Control Card.–Control card input is used to initiate four functions: (1) input, (2) process, (3) output, and (4) terminate.

The input control card function causes the mission specification data to be input from cards, listed, and output to the mission tape.

The process control card function causes the mission data from the mission tape to be read, performs all functions specified in section 4.2.2, and outputs the processing results to a second file on the mission tape.

The output control card function causes the report request specification cards and one, two, or three mission tapes to be read and causes the requested reports and plot tapes to be created.

The terminate control card function causes all files to be closed and causes termination of program execution.

4.2.1.1.2 Mission Data Input.–The mission data input is classified into the following five types discussed in sections 4.1 and 8.2:

1. Mission specification (See sec. 8.2.1.2.1.)

2. Phase specification (See sec. 8.2.1.2.2.)

3. Event/procedure specification (See sec. 8.2.1.2.3.)

4. Task specification (See sec. 8.2.1.2.4.)

5. Subsystem specification (See sec. 8.2.1.2.5.)

4.2.1.1.3 Report Request Specification.–There are 15 different inputs that are used to specify the reports to be generated. They are divided into three types:

1. Digital report request (See secs. 4.3.2 and 8.2.1.3.1.)

2. Graphic report request (See secs. 4.3.3 and 8.2.1.3.2.)

3. Class output request (See sec. 8.2.1.3.3.)

4.2.1.2 Mission Tape Input

This tape consists of two files: one contains the mission data card input and the other contains the processor module output. This tape is read by the output module to derive the data to be used on the reports and plots.

4.2.2 PROCESSING FUNCTIONS

This section describes the following functions to be performed to produce data for the output reports: (1) task processing, (2) phase statistics, (3) task-situation time shift, (4) task-channel activity calculations, and (5) subsystem activity calculations. Complete details are in section 8.3.

4.2.2.1 Task Processing

The task processing function uses the task-situation channel workloads and performs the following:

1. Calculates the time intervals spanned by the task situation

2. Calculates the workload contributions to study-time intervals

3. Updates the study-time interval workload sums

4. Calculates the channel group workload

5. Calculates the weighted average channel workload

4.2.2.2 Phase Statistics

The following statistics are calculated across all time intervals in a phase for each channel, each channel group, and the weighted average channel:

1. Workload sum S_W

2. Sum of the squares of workload S_{W2}

3. Mean workload $\overline{W}$

4. Workload variance σ^2

5. Standard deviation of the workload σ

4.2.2.3 Task-Situation Time Shift Function

After all task processing has been completed, the shift function will be performed if the option is specified. The shift function checks each time interval in turn to determine if any channel workload exceeds a specified shift threshold criterion. If a channel workload exceeds the shift threshold, an attempt is made to slide start times of those task situations contributing to the workload excess. Only those task situations that have the slide option specified are used to attempt reduction of the excess workload.

4.2.2.4 Task-Channel Activity Calculations

This set of calculations gives the percent of interval time that a task-situation channel workload contributes to an interval total channel workload if the interval total channel workload exceeds a report threshold.

4.2.2.5 Subsystem Activity Calculations

The purpose of the subsystem activity calculations is to measure how much of the time the subsystem is involved in workloads exceeding given thresholds.

4.3 OUTPUT DATA

Program outputs are to tape, printer, and plotter.

4.3.1 MISSION DATA TAPE

A tape consisting of two files will be used to store the mission data input and the processed data for later use by the report generation function. The first file will contain the mission data input, and the second will contain the processor output used by the report generation function.

4.3.2 DIGITAL PRINTER OUTPUT

The output to the printer consists of seven reports:

1. Mission scenario (sec. 8.4.2.1)

2. Crewman workload profile (sec. 8.4.2.2)

3. Crewman workload summary statistics (sec. 8.4.2.3)

4. Task-channel activity (sec. 8.4.2.4)

5. Subsystem activity (sec. 8.4.2.5)

6. Subsystem activity summary (sec. 8.4.2.6)

7. Task list (sec. 8.4.2.7)

The following sections describe these reports, which are generated as a result of report requests.

4.3.2.1 Mission Scenario Report

The mission scenario report outputs a timeline of the workload for specified mission phases. For each task, the time interval for the performance of the task and the activity time are output. The start time and description of each phase and event are also output. See section 8.4.2.1 for an example. If the report is for the shifted mission scenario, the amount of the shift is also output.

4.3.2.2 Crewman Workload Profile Report

The crewman workload profile report provides a timeline output of the channel activity (percent utilization) by channel and by channel classes (vision, motor, and communciation) as well as a weighted average of activity for all channels. See section 8.4.2.2 for an example.

4.3.2.3 Crewman Workload Summary Statistics Report

The crewman workload summary statistics report provides a statistical summary of the channel activity, the channel group activity, and the weighted channel activity over a specified flight phase and for a specified crewman. The report gives for each of these activities, the sum and sum squared of the workload, the average workload, the variance of the workload, and the standard deviation of the workload. See section 8.4.2.3 for an example.

4.3.2.4 Task-Channel Activity Report

The task-channel activity report provides a list of all tasks that contribute to a channel workload exceeding a specified threshold. The report is for a specified crewman, for a specified phase, and for a shifted or unshifted option. See section 8.4.2.4 for an example.

4.3.2.5 Subsystem Activity Report

The subsystem activity report provides a measure of the task-channel workload activity exceeding a specified threshold that is associated with a given subsystem. The report gives measures of this workload relative to study intervals, phase duration, and mission duration. See section 8.4.2.5 for an example.

4.3.2.6 Subsystem Activity Summary Report

The subsystem activity summary report provides a summarization of the subsystem activity report and extends the summary across the entire mission. For each channel that uses a specified subsystem, the report gives the percent of interval time that a channel workload exceeds the report threshold and the percent of mission duration that a channel workload exceeds the report threshold. See section 8.4.2.6 for an example.

4.3.2.7 Task List Report

The task list report lists tasks, the associated situations, the duration of the task situation, and the channel workloads. It is used only to create a task catalog. See section 8.4.2.7 for an example.

4.3.3 GRAPHICAL PLOTTER OUTPUT

Plotter output consists of the following plots:

1. Workload summary (sec. 8.4.3.3)

2. Channel activity summary (sec. 8.4.3.1)

3. Workload histogram (sec. 8.4.3.2)

4. Mission timeline (sec. 8.4.3.4)

4.3.3.1 Workload Summary

The workload summary plot is a bargraph of comparative workloading of channel groups as well as overall average workloading between two or three configurations for a specified flight phase and specified crewmember. It presents the average workloading and/or the standard deviation for the channel groups, under the specified shifted or unshifted option. See section 8.4.3.3 for an example.

4.3.3.2 Channel Activity Summary

The channel activity summary bargraph presents the percent of workloading and workloading standard deviation of channels and of the weighted channel average workloading for a specified mission, crewmember, flight phase, and shift/unshift option. See section 8.4.3.1 for an example.

4.3.3.3 Workload Histogram

The workload histogram depicts average percent workload versus time in the mission. It can have one, two, or three configurations plotted. The peak workload threshold is shown. See section 8.4.3.2 for an example.

4.3.3.4 Mission Timeline

The mission timeline plot presents the event occurrence and procedure start time, the task activity, and the interval of time the activity is under way. The task/event/procedure code number, task/event/procedure description, and time duration or time of occurrence are shown. See section 8.4.3.4 for an example.

5.0 SCENARIO DERIVATION

5.1 INTRODUCTION

During the creation of TLA-1, eight scenarios were developed to provide a set of baseline missions that are based on flight operations in a real-world terminal area environment. As flight deck configurations and procedures are changed during the TCV program, new factors can be incorporated into the scenarios. The workload data from these new missions can then be compared to the data from the baseline scenarios to determine the relative workload improvements or degradations caused by the changes.

These scenarios were used as example data cases that were fully programmed into TLA-1 coding to demonstrate how TLA-1 input data are to be coded. Processing of these data cases created examples of all TLA-1 ouput reports and plots. The scenarios were also used as a forcing function to cause the development of a wide range of preprogrammed procedures that provide fully-detailed building blocks from which new TCV scenarios can be constructed. In addition, the scenarios provide the analyst with models of the degree of detail required when constructing new scenarios for TLA-1 analysis.

There are two general categories of scenarios–forward flight deck (FFD) and aft flight deck (AFD)–with four variations for each category. (See table 1.) The scenarios are described in detail in the following sections.

All the scenarios are based on operations within the terminal area of the Hartsfield Atlanta International Airport. The following flight phases are included:

1. Prestart
2. Startup
3. Taxi out
4. Takeoff
5. Climb-to-cruise

Outbound from Atlanta

6. Cruise

7. Descent
8. Approach
9. Landing
10. Taxi in
11. Shutdown

Inbound to Atlanta

Table 1.—Scenario Classification

Scenario name	Features		
	Cockpit	Approach and landing procedures	Anomalies ?
Scenario 1A	FFD	ILS	No
Scenario 1B	FFD	ILS	Yes
Scenario 2A	FFD	MLS	No
Scenario 2B	FFD	MLS	Yes
Scenario 3A	AFD	ILS	No
Scenario 3B	AFD	ILS	Yes
Scenario 4A	AFD	MLS	No
Scenario 4B	AFD	MLS	Yes

The time-based listing of events provided in the scenarios includes the following:

- Taxi maneuvers–before takeoff and after landing
- Noise abatement takeoff
- Aircraft configuration changes during flight
    - Gear extension/retraction
    - Flap extension/retraction
- Horizontal and vertical maneuvers
- Aircraft speed changes
- ATC/pilot communications text
- ATC facility handoff points
- Navaid tuning requirements
- ILS/MLS intercept points
- Landing

The scenarios were derived from data collected during a visit to the Atlanta ARTCC, the Atlanta Tower, and the FAA Southern Regional Office (refs. 5 through 16) and from Boeing 737 aircraft operation and performance manuals (refs. 5 and 17 through 22).

The detailed scenarios are found in Appendices One through Four (ref. 4).

5.2 SCENARIO DESCRIPTIONS

5.2.1 SCENARIO 1A

Scenario 1A is based on the NASA 515 FFD and conventional ATC procedures and navaids. The horizontal profile is shown in figure 11, and the vertical profile is shown in figure 12. The detailed scenario is in Appendix One (ref. 4).

In this and all the other scenarios, the aircraft is parked at a gate at the northeast side of the Atlanta Airport terminal (fig. 13). After pushback and startup, the aircraft taxis across the apron to Taxiway D. Ground Control instructs NASA 515 to hold short of Runway 8 to allow arrival and departure traffic to clear. After the traffic is cleared, the pilot is given clearance to taxi across Runway 8 and is again instructed to hold short of the intersection of Taxiway C to allow traffic to cross. The aircraft then proceeds to Taxiway L and onto Runway 9L where it is cleared for takeoff. The aircraft turns to heading 105 after crossing the Runway 27R middle marker (fig. 14). This is the noise abatement track for Runway 9L departures.

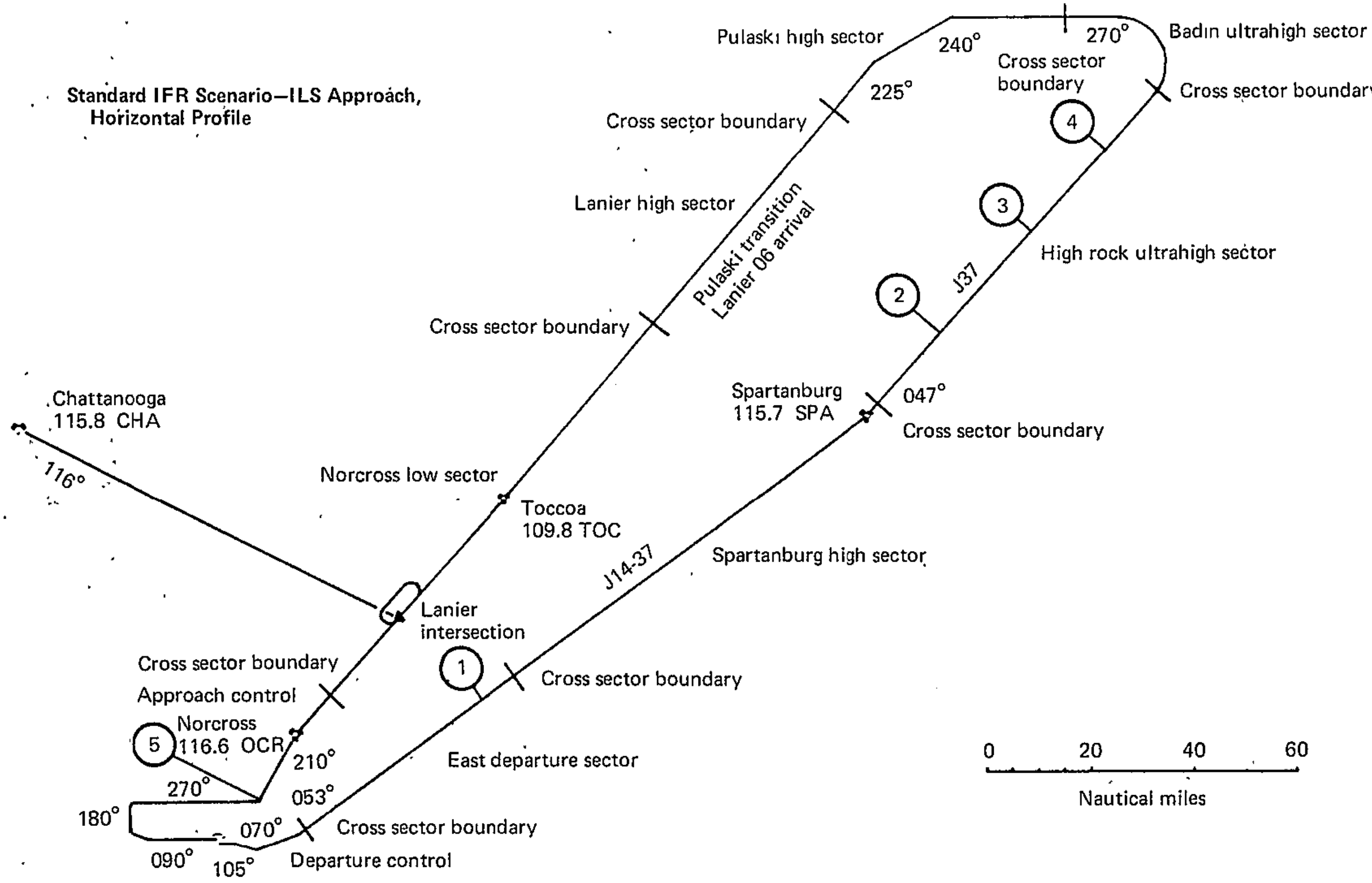


Figure 11.—Horizontal Mission Profile for Scenarios 1A and 1B

Standard IFR Scenario—ILS Approach,
Vertical Profile

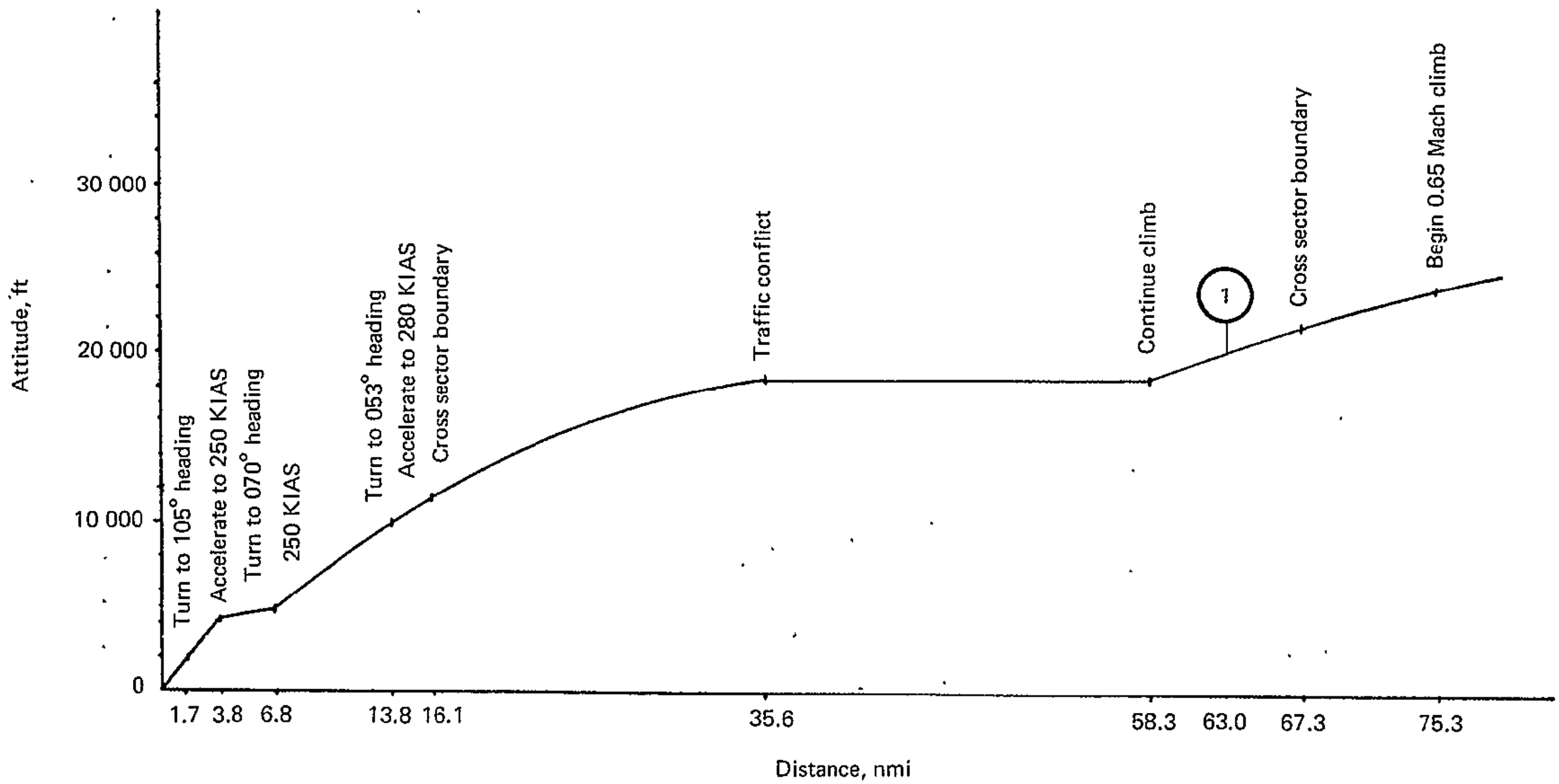


Figure 12.—Vertical Mission Profile for Scenarios 1A and 1B

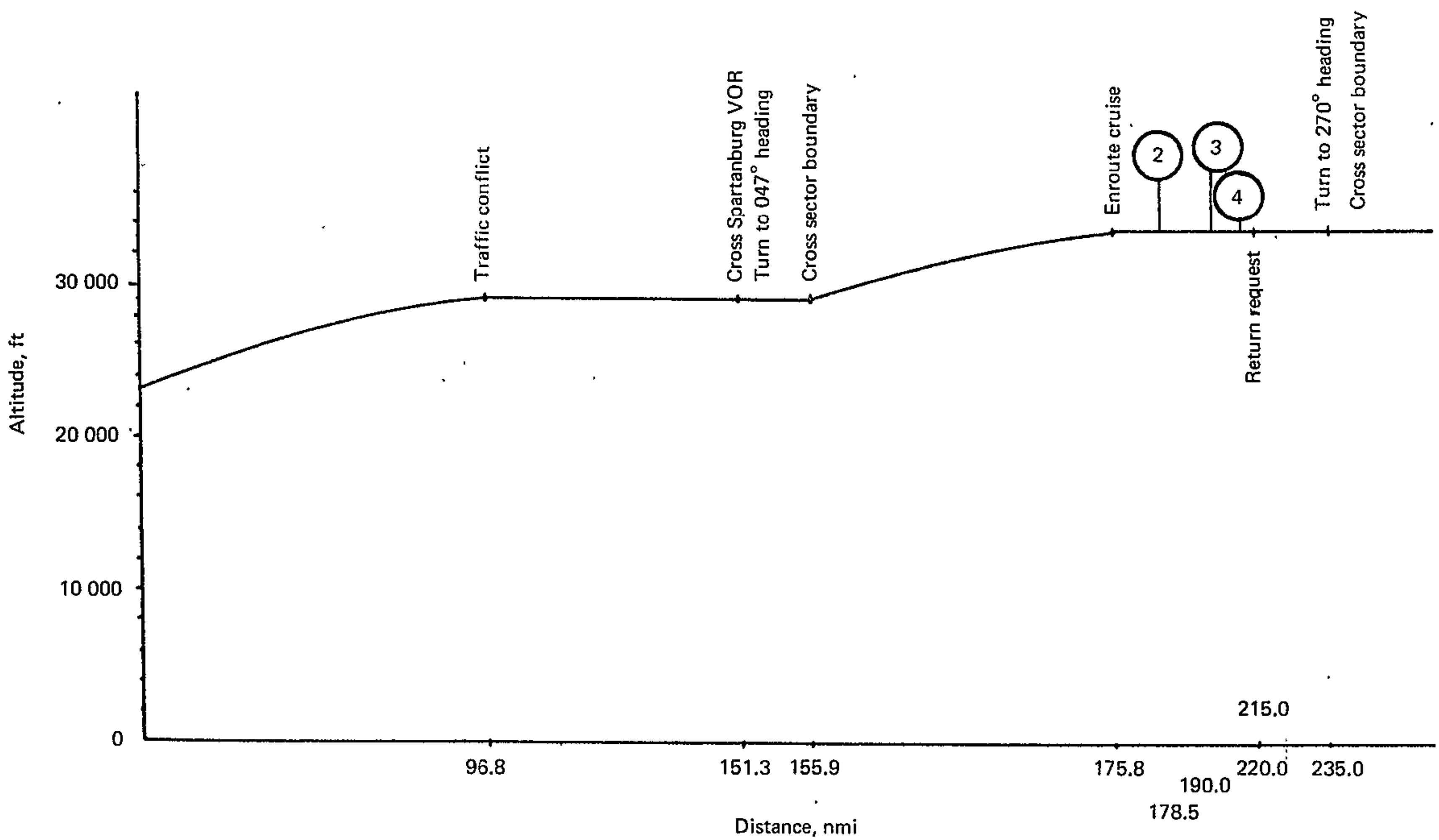


Figure 12.—(Continued)

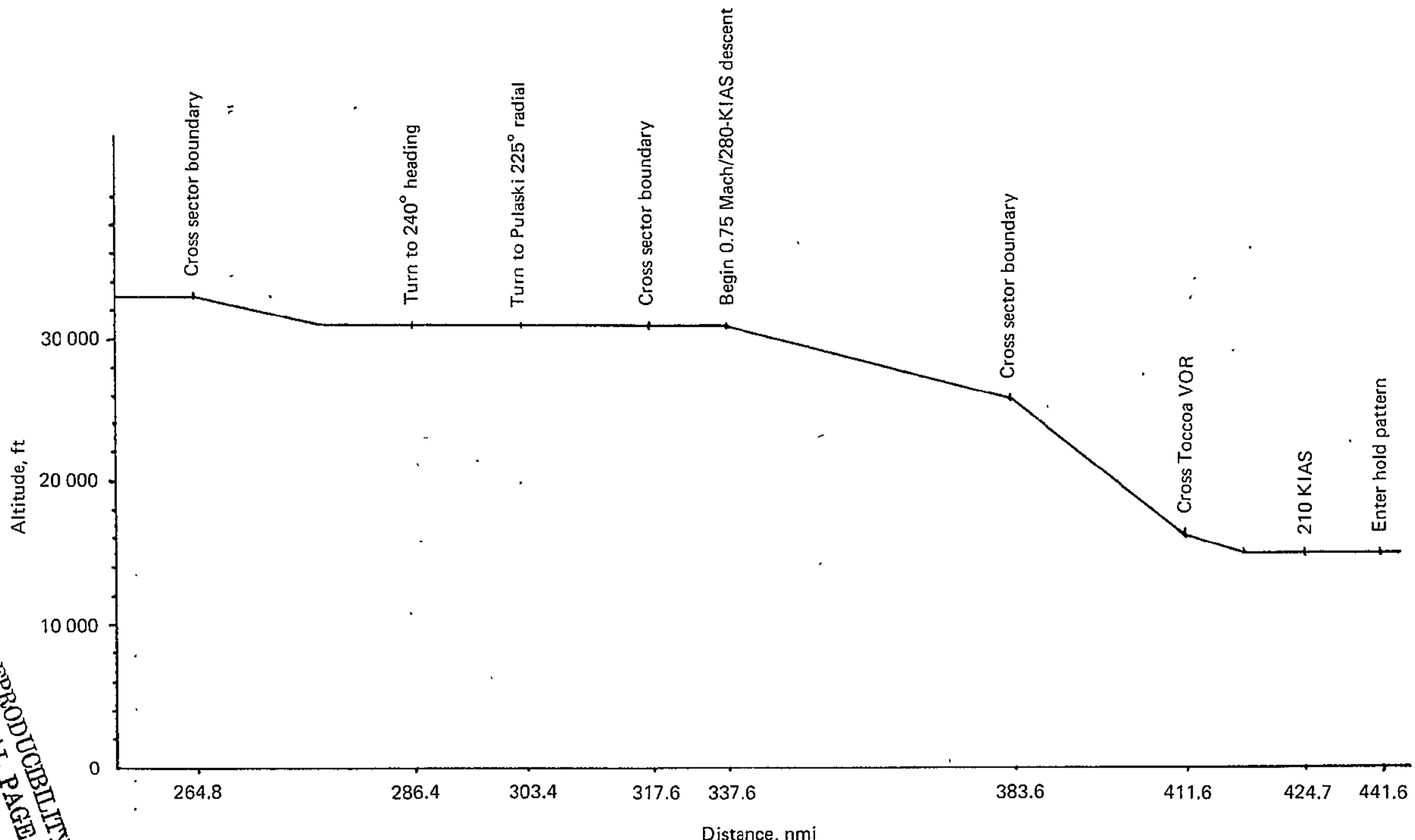


Figure 12.—(Continued)

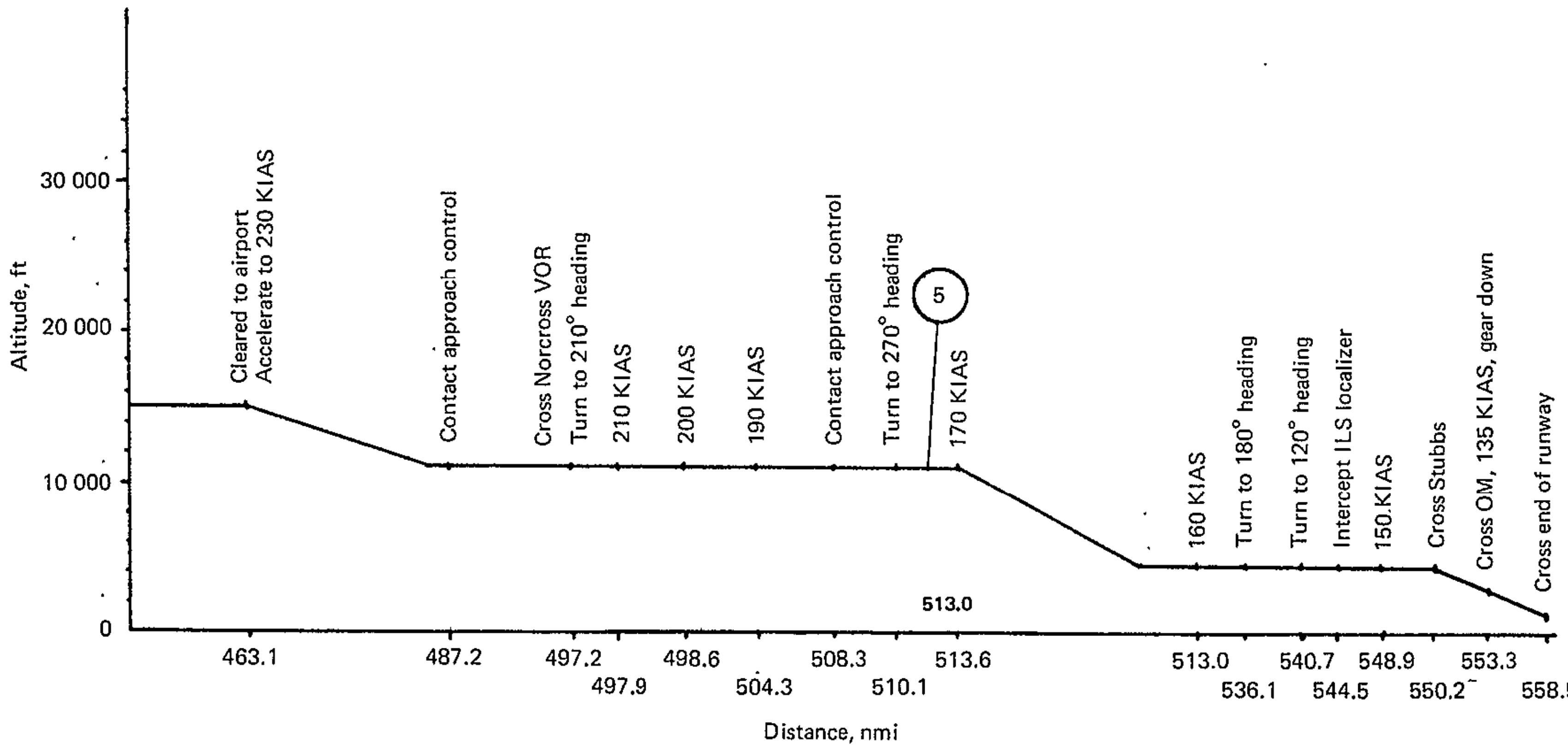


Figure 12.—(Concluded)

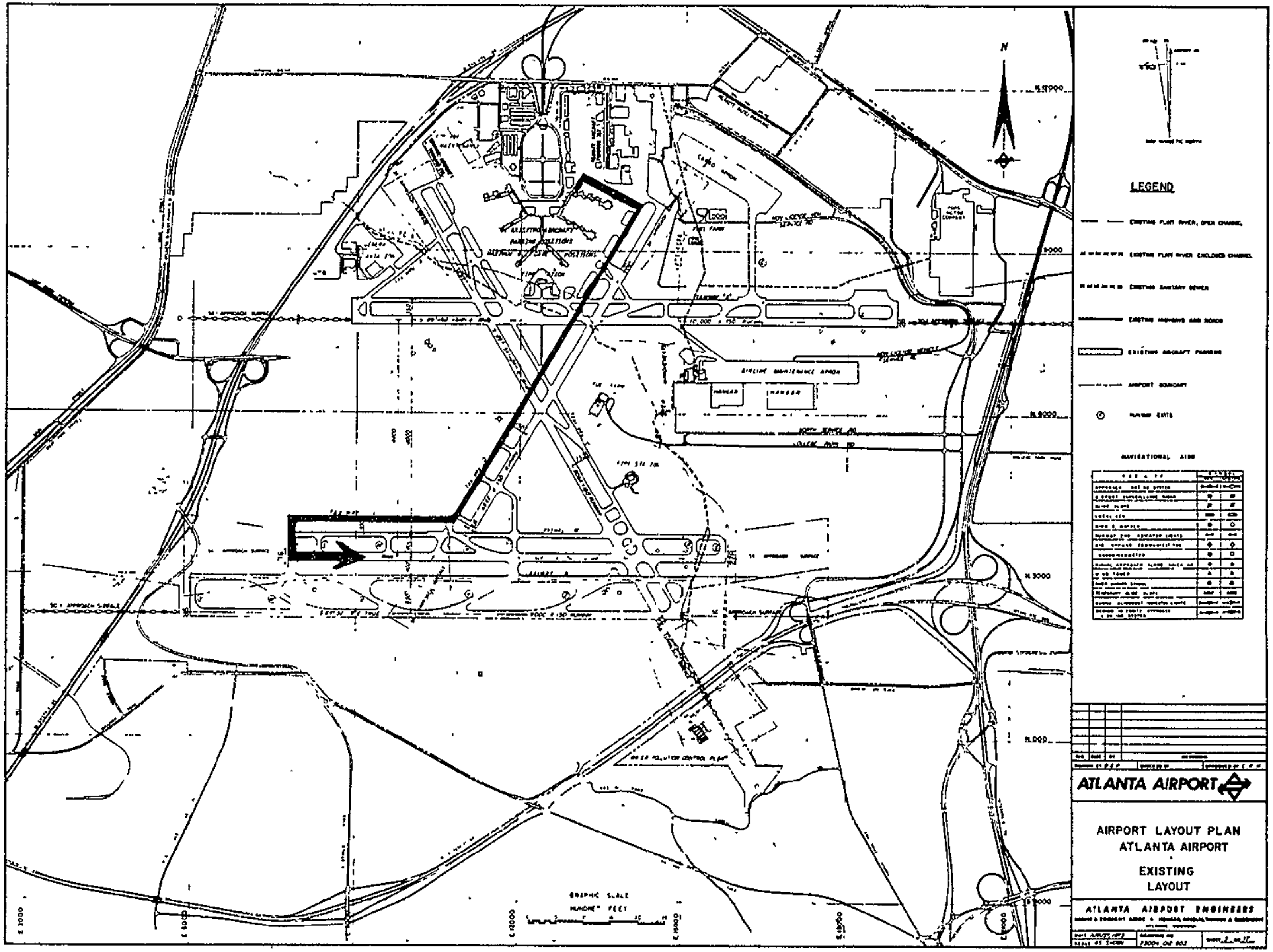


Figure 13.—Hartsfield Atlanta International Airport

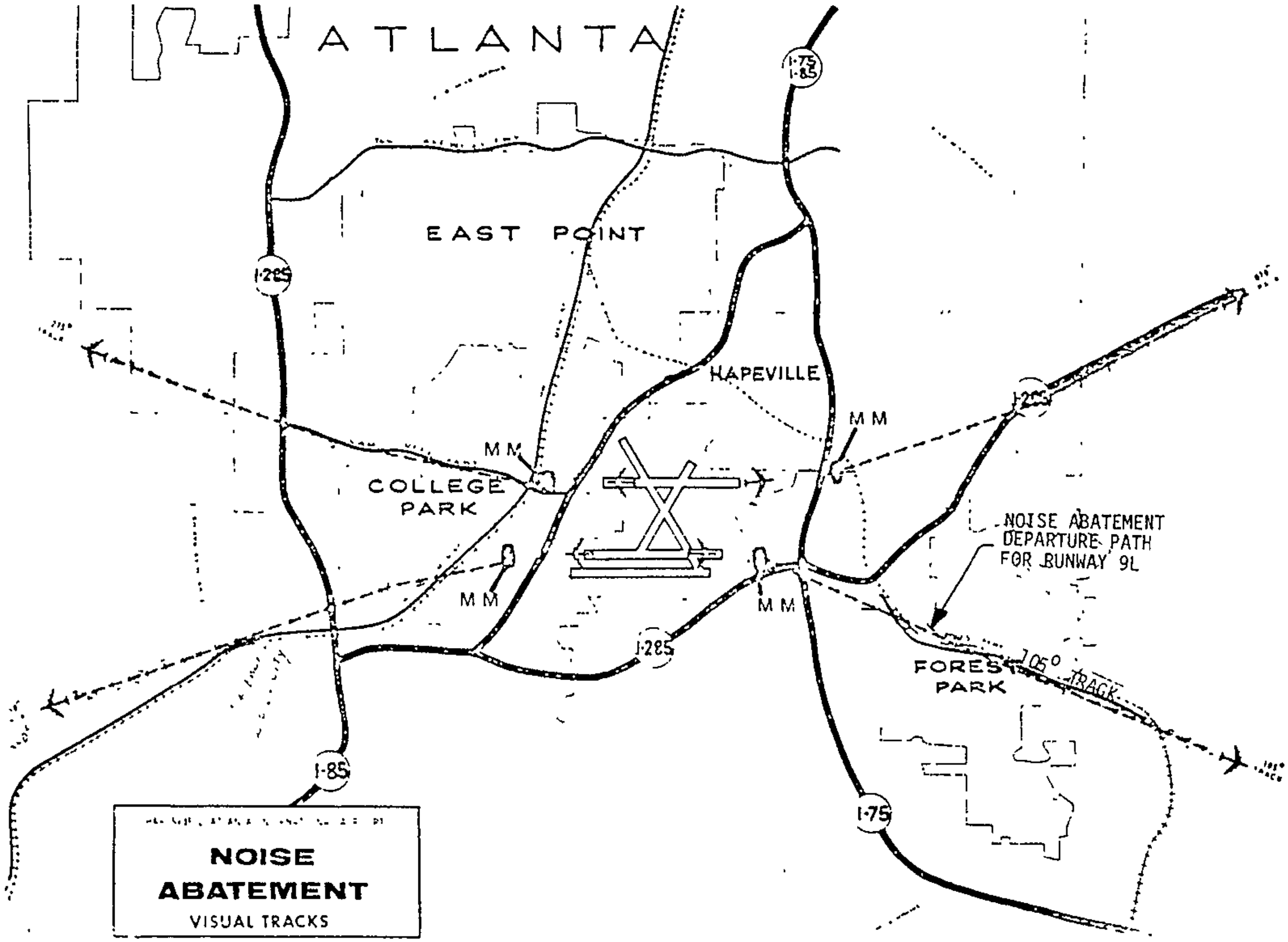


Figure 14.—Noise Abatement Departure Path for Runway 9L

Scenarios 1A, 1B, 2A, and 2B proceed as follows. After reaching 4000 feet, NASA 515 is given vectors to intercept Jet Route 37. En route to cruise altitude, NASA 515 is directed to hold FL 180 to avoid crossing inbound traffic. The aircraft then resumes climbing to FL 330, the en route cruise altitude.

After reaching cruise altitude, the pilot requests a return routing to Atlanta. In scenarios 1A and 2A, this request was put into the scenario to keep the area of study confined to the Atlanta terminal area. In scenarios 1B and 2B, a series of malfunctions will create a definite need for the aircraft to return to Atlanta (secs. 5.2.2 and 5.2.4).

For return routing to Atlanta, ATC gives NASA 515 vectors to intercept the Lanier 06 STAR (fig. 15). While on approach, NASA 515 is instructed to go into a holding pattern. In scenarios 1A and 1B, the final approach is via the conventional ILS procedures for Runway 8.

In all of the scenarios, NASA 515 lands on Runway 8 and departs the runway onto Taxiway D. The aircraft returns to its departure gate and the aircraft is shut down.

5.2.2 SCENARIO 1B

Scenario 1B is based on the FFD and conventional ATC procedures and navaids. This scenario is basically the same as scenario 1A except that on this flight there is a series of malfunctions and the pilot is incapacitated.

Figures 11 and 12 have circled numbers to show the points on the flightpath where the various anomalies occur and the types of anomalies. The anomalies are:

	Occurrence	Type	Where anomaly occurs
(1.)	Hydraulic system B overheat	Hydraulic system failure	During climb
(2.)	Hydraulic system B low pressure	Flight control failure	During cruise
(3.)	Oil filter bypass	Engine failure	During cruise
(4.)	No. 2 generator drive CSD low oil pressure	Electrical system failure	During cruise
(5.)	Pilot incapacitation	Crewmember incapacitation	Prior to final approach

These anomalies are used in scenarios 1B, 2B, 3B, and 4B. The details of scenario 1B are in Appendix One (ref. 4).

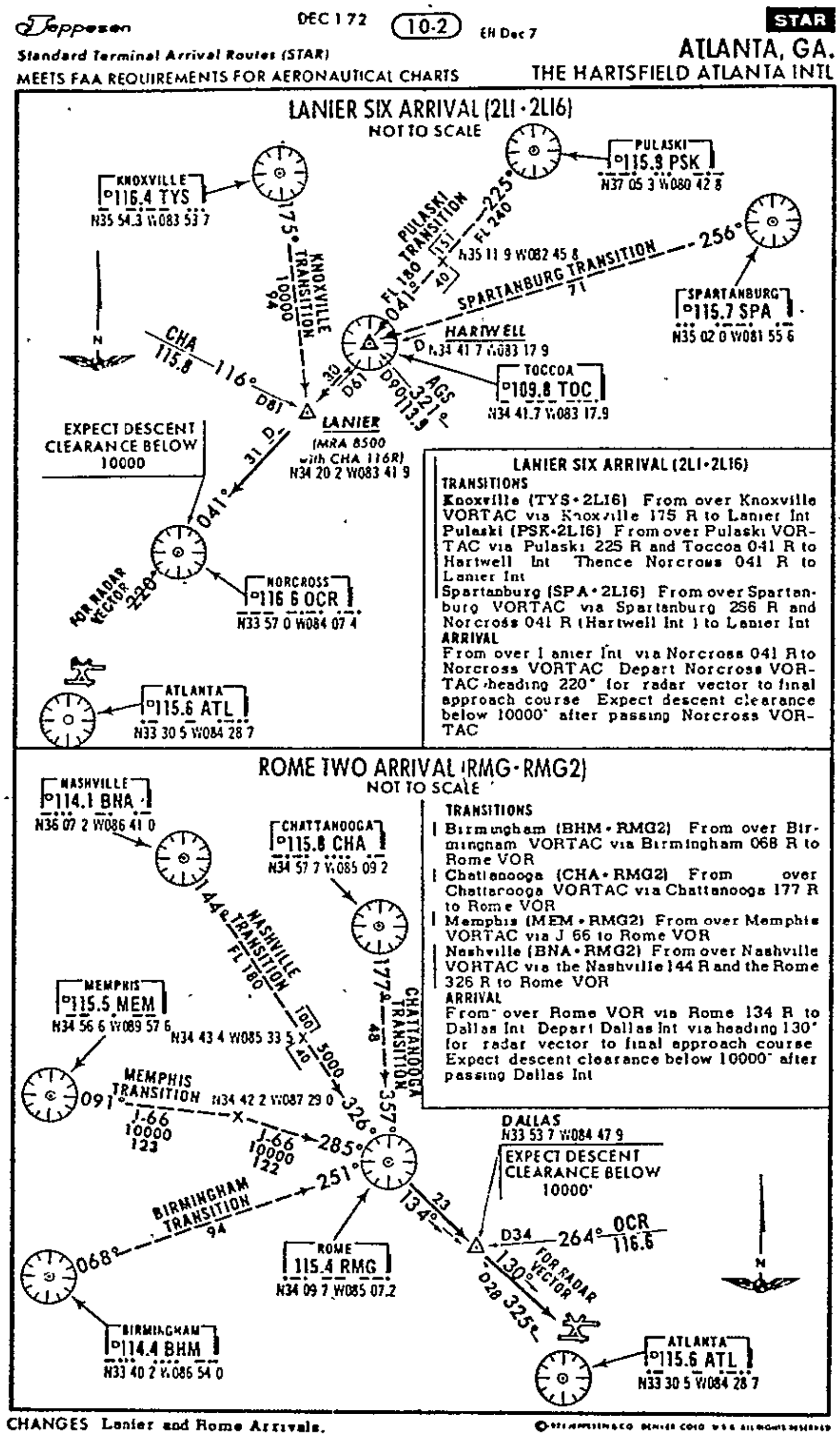


Figure 15.—Lanier 06 STAR

5.2.3 SCENARIO 2A

Scenario 2A is based on the FFD and on microwave landing system (MLS) approach and landing. This scenario is identical to scenario 1A from the beginning up to the point where the aircraft starts down the downwind leg on final approach. In scenario 2A, the final approach is based on MLS landing procedures on Runway 8. Figure 16 shows the horizontal profile, and figure 17 shows the vertical profile. The details of this scenario are in Appendix Two (ref. 4).

The MLS provides flight director glide slope and direction commands starting at 60° angle from the runway threshold. Subsequently, the downwind leg of the approach is considerably shorter than on an ILS approach. After capture of the MLS signal, the MLS procedure postulated involves a two-segment glidepath (6° initial and 3° final glide slopes).

5.2.4 SCENARIO 2B

Scenario 2B is identical to scenario 2A except for the addition of the series of anomalies described in scenario 1B (sec. 5.2.2). Figure 16 shows the location and nature of the anomalies on the horizontal profile map. Details of this scenario are in Appendix Two (ref. 4).

5.2.5 SCENARIO 3A

Scenario 3A and scenarios 3B, 4A, and 4B are based on the AFD and on advanced navigation concepts structured around existing RNAV routing between Atlanta and Washington, D.C.

To develop realistic scenarios for exercising the AFD instrumentation, it was necessary to make some assumptions concerning: (1) the state of the art for ATC and navaids, (2) the automatic guidance modes to be used, and (3) the flight plan data available in the aircraft's data bank. The following assumptions were made:

1. All SID's, STAR's, and AIRWAYS for the Atlanta teminal area are stored in memory.
2. The SID's and STAR's are based on existing RNAV routes in the area.
3. The SID's and STAR's will include new waypoints where required to replace ATC vectoring commands.
4. After takeoff clearance, the only ATC commands transmitted will be handoff instructions or instructions for controlling potential conflicts or unusual situations.
5. ATC will have the means required to compute valid planned time of arrival (PTA) at the final approach fix point.
6. Lakeside LOM will be the final approach fix point for Runway 8 arrivals.

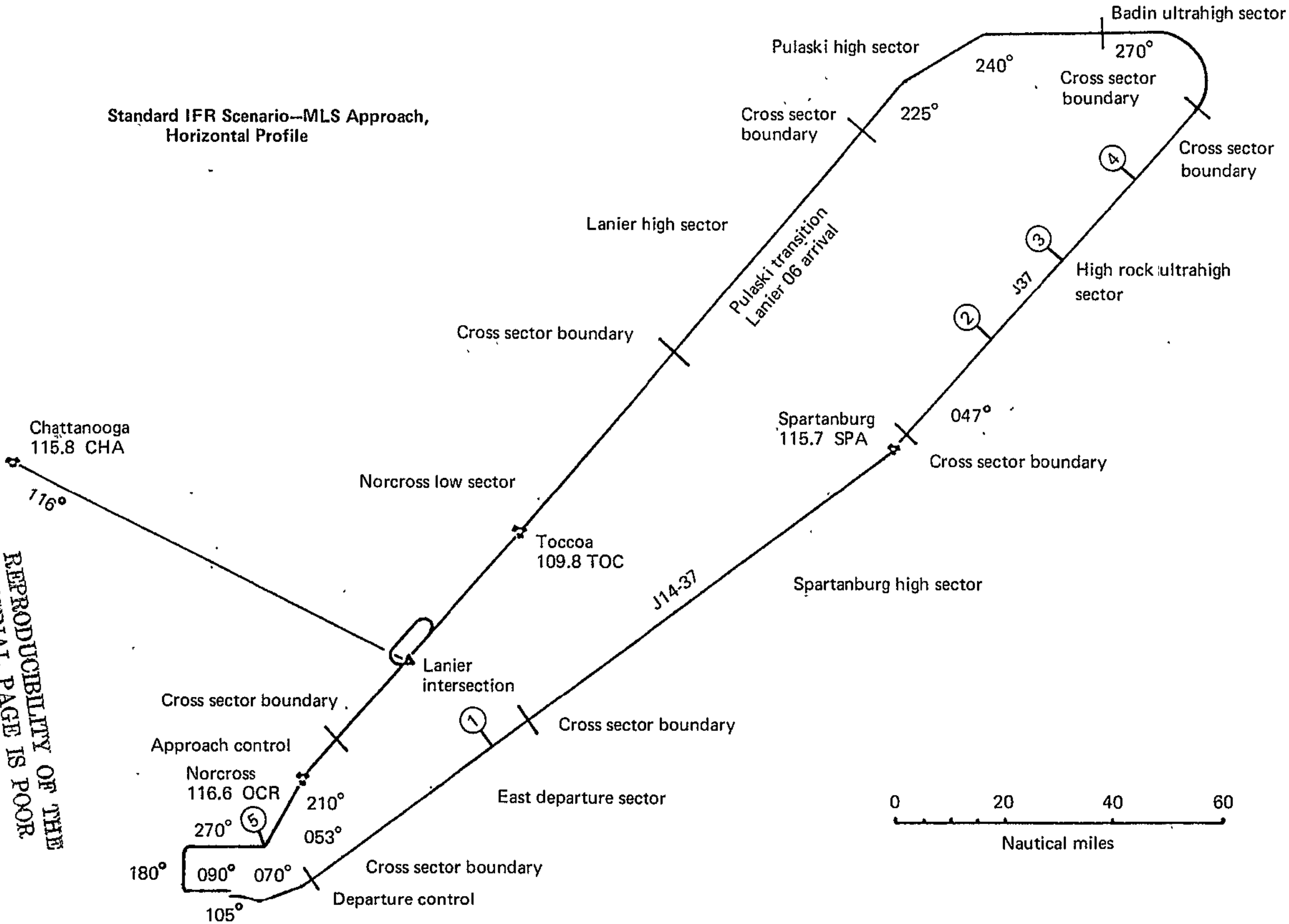


Figure 16.—Horizontal Mission Profile for Scenarios 2A and 2B

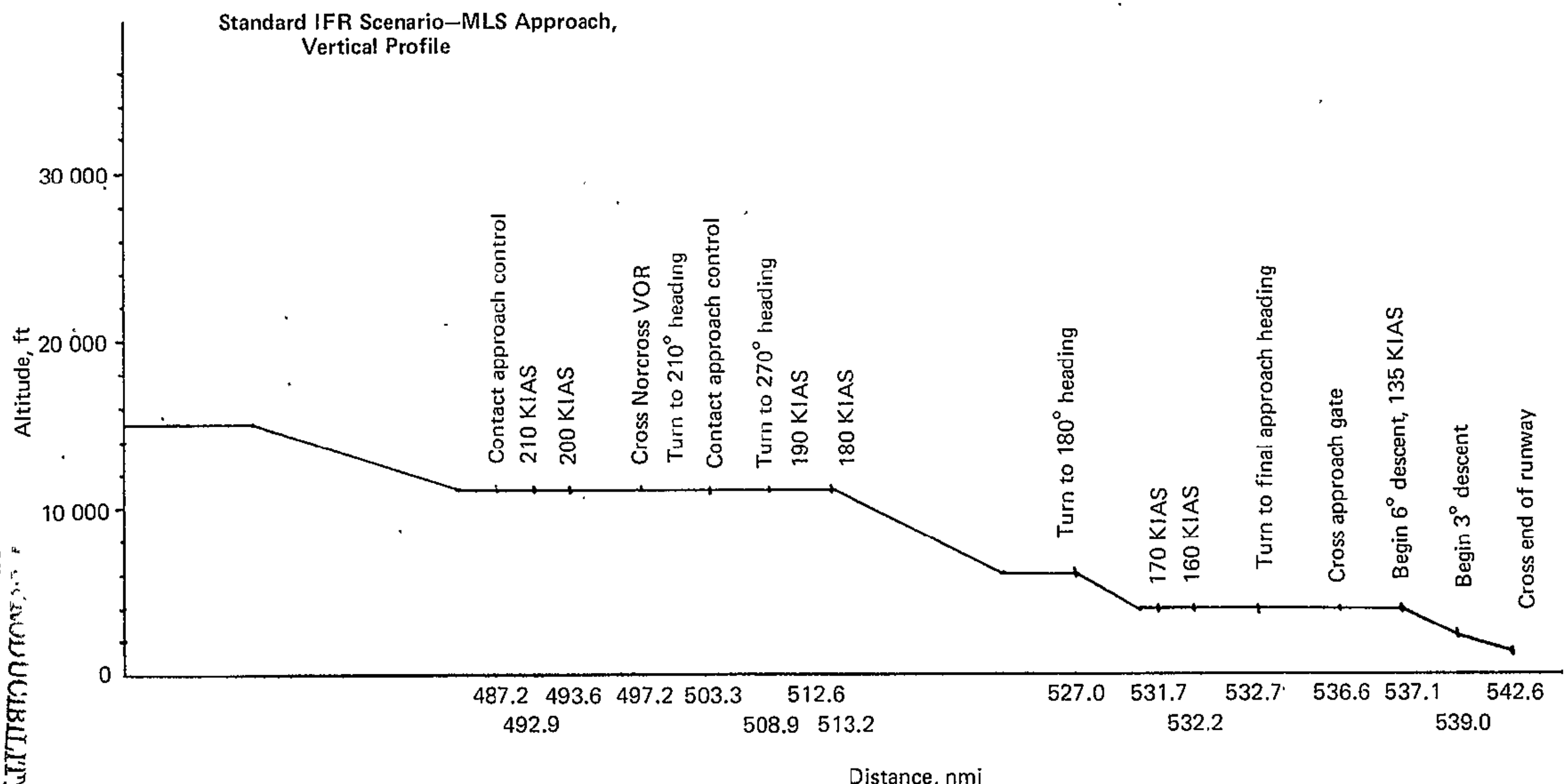


Figure 17.—Vertical Mission Profile for Scenarios 2A and 2B

7. The SID's, STAR's, and navaid names will be revised as required to keep the name character lengths compatible with the current NASA 515 programming requirements.

8. Takeoff will be done in the ATT CWS mode.

9. The climb-to-cruise flight phase will be done in the 3D (vertical path) mode. This assumes that a valid 3D path can be predefined.

10. When the aircraft diverts from the preplanned routing, control will be in the 2D (horizontal path) mode.

11. The STAR will be flown in the 4D (time path) mode. This assumes that a valid 4D path can be defined.

12. The STAR 4D data will be computed by ATC within 3 to 5 minutes from request.

The horizontal profile for scenario 3A is shown in figure 18, and the vertical profile is shown in figure 19. Details of this scenario are in Appendix Three (ref. 4).

The on-ground portion of scenario 3A is almost identical to that described for scenario 1A, the only variations being in the communications dialog.

The en route navigation is prestored in the aircraft's computer based on departure waypoints. The routing to Washington National is based on the existing J86R RNAV route.

The aircraft is flown on a 3D profile on departure. The only ATC communications are to hand off and to instruct NASA 515 to level off during climb to avoid conflicting traffic. After passing the conflict, the aircraft is flown 3D to get back on the prestored flight plan. After reaching cruise altitude of 33 000 ft, the pilot requests an unscheduled return to Atlanta.

After giving initial vectors to start the return routing to Atlanta, ATC gives NASA 515 instructions to return via the SHINE 01 STAR, which is preprogrammed in memory, and a PTA at Lakeside is given. The pilot selects the appropriate 4D path and initiates the 4D navigation procedures. On the way back, ATC gives NASA 515 a new PTA.

The approach is based on the same ILS approach used in scenario 1A. The pilot elects to use the AUTOLAND mode for the landing. After touchdown, the scenario is identical to that described for scenario 1A.

5.2.6 SCENARIO 3B

Scenario 3B is basically the same as scenario 3A except that the same series of anomalies described for scenarios 1B and 2B is imposed. Figure 18 shows the horizontal profile for this scenario. Details of scenario 3B are in Appendix Three (ref. 4).

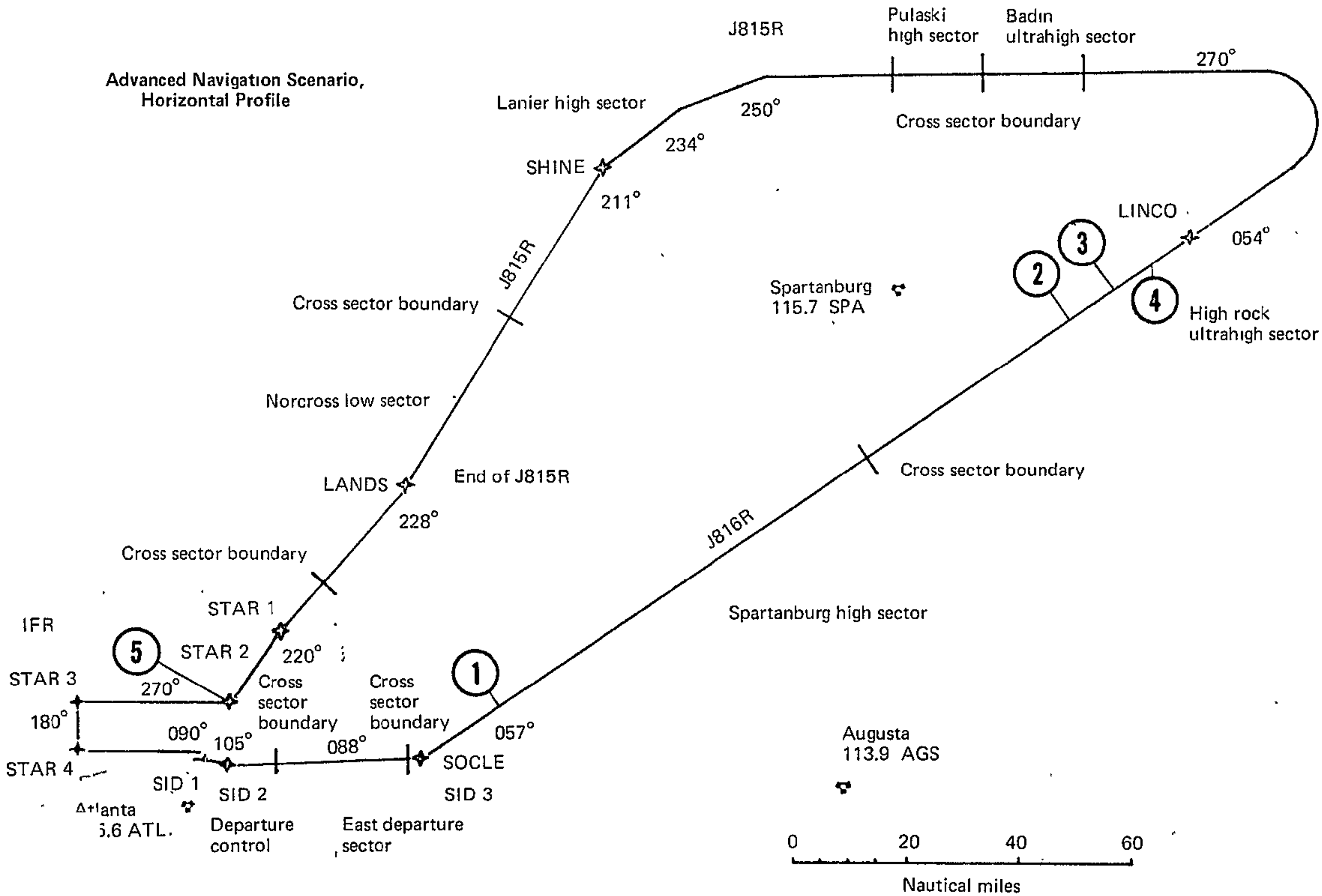


Figure 18.—Horizontal Mission Profile for Scenarios 3A and 3B

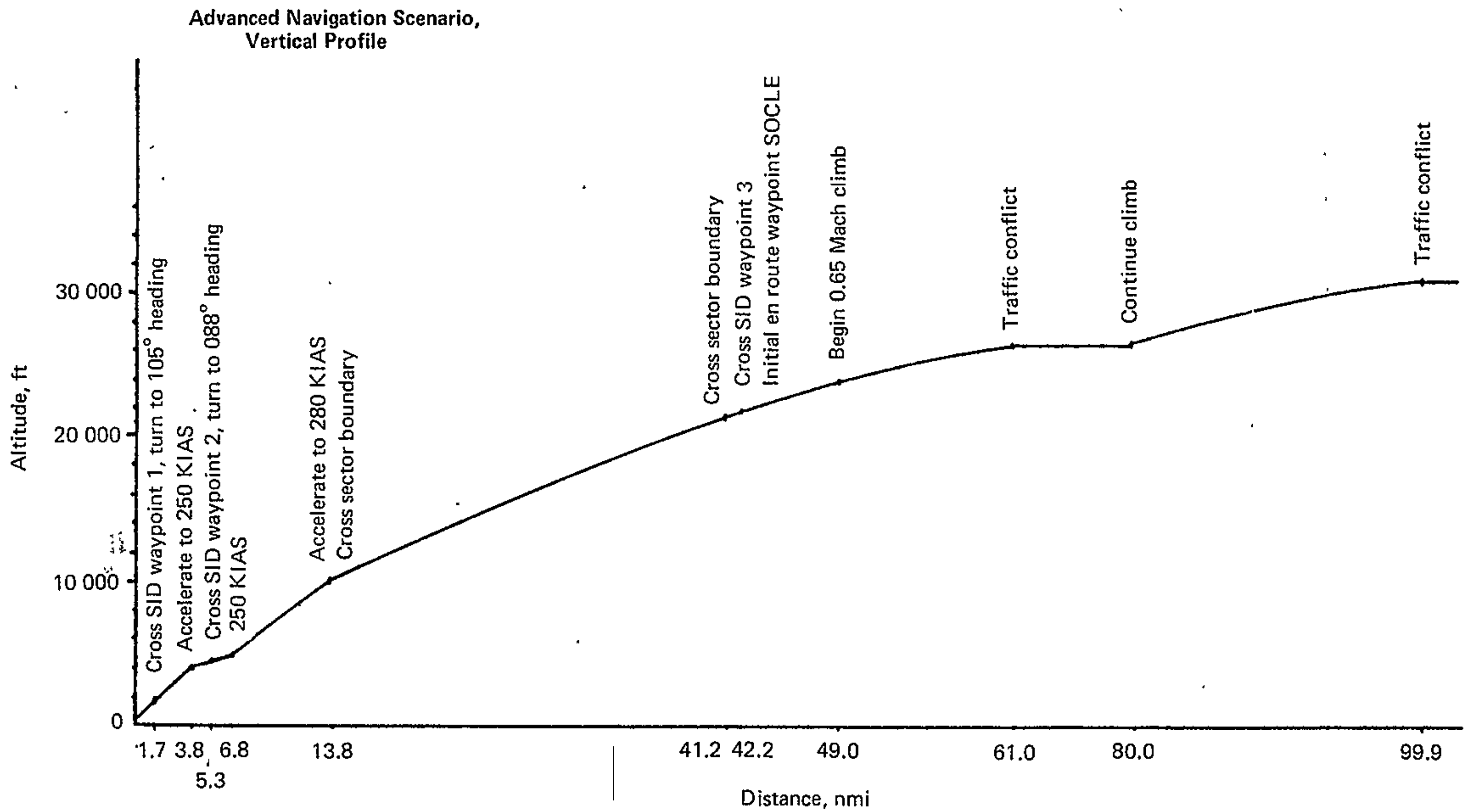


Figure 19.—Vertical Mission Profile for Scenarios 3A and 3B

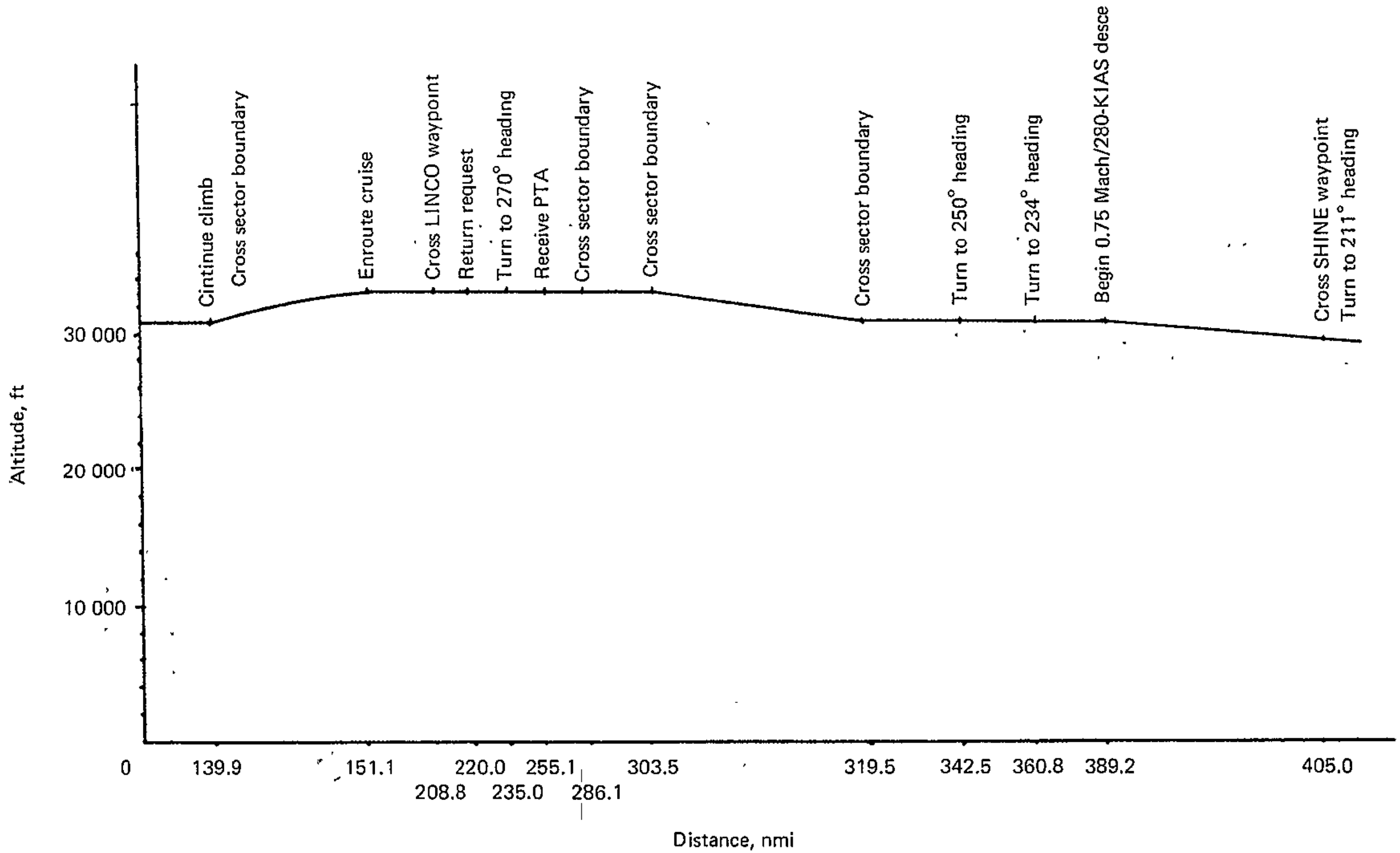


Figure 19.—(Continued)

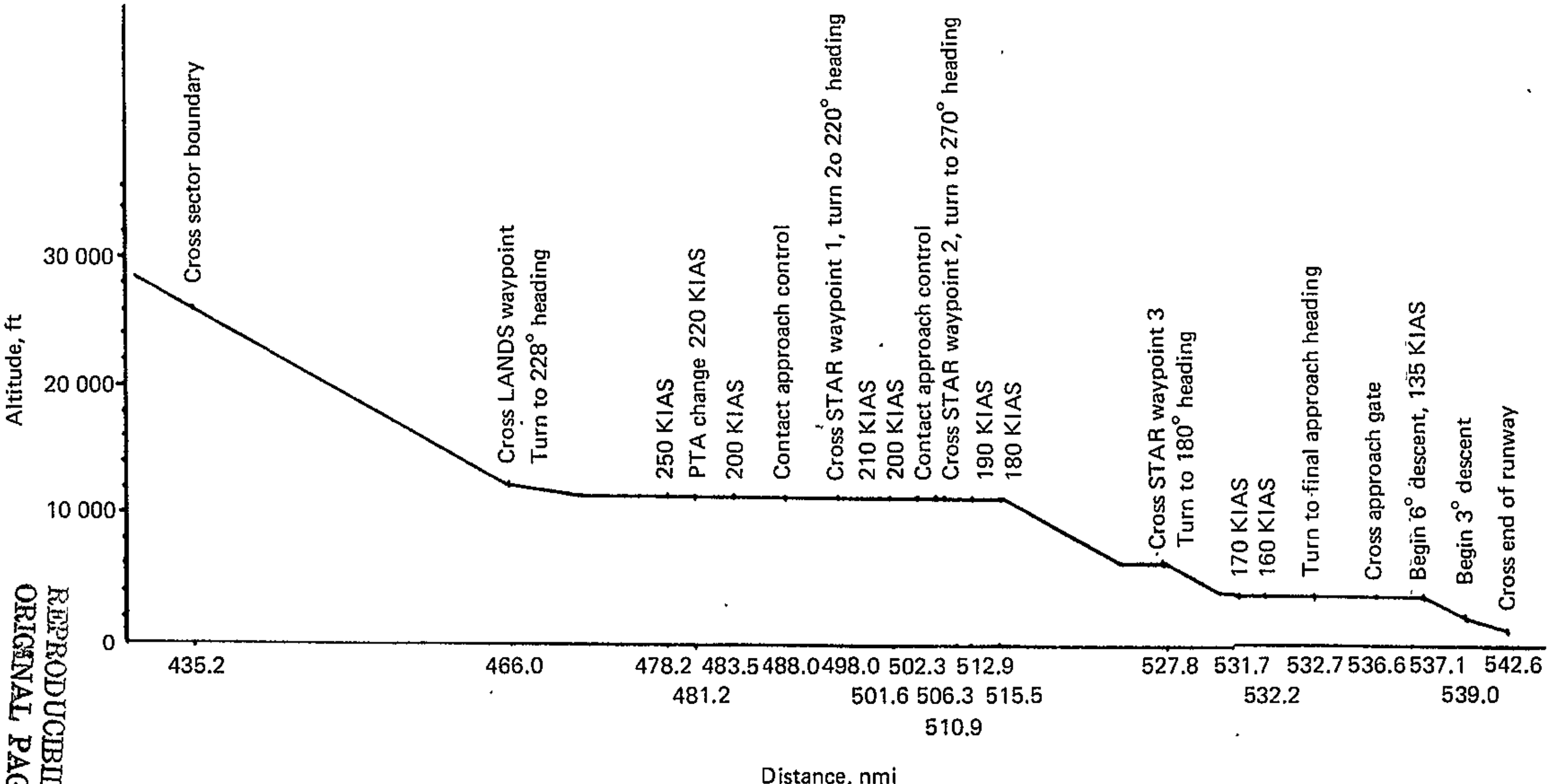


Figure 19.—(Concluded)

5.2.7 SCENARIO 4A

Scenario 4A is identical to scenario 3A up to the point where the aircraft begins the downwind leg. From this point on, the approach and landing are based on an MLS system. After touchdown, this scenario is identical to scenario 3A. The horizontal profile for this scenario is shown in figure 20, and the vertical profile is shown in figure 21. Details of scenario 4A are in Appendix Four (ref. 4).

5.2.8 SCENARIO 4B

Scenario 4B is identical to scenario 4A except that the series of anomalies used in scenarios 1B, 2B, and 3B is also imposed here. The horizontal profile of this scenario is shown in figure 20. Details of this scenario are in Appendix Four (ref. 4).

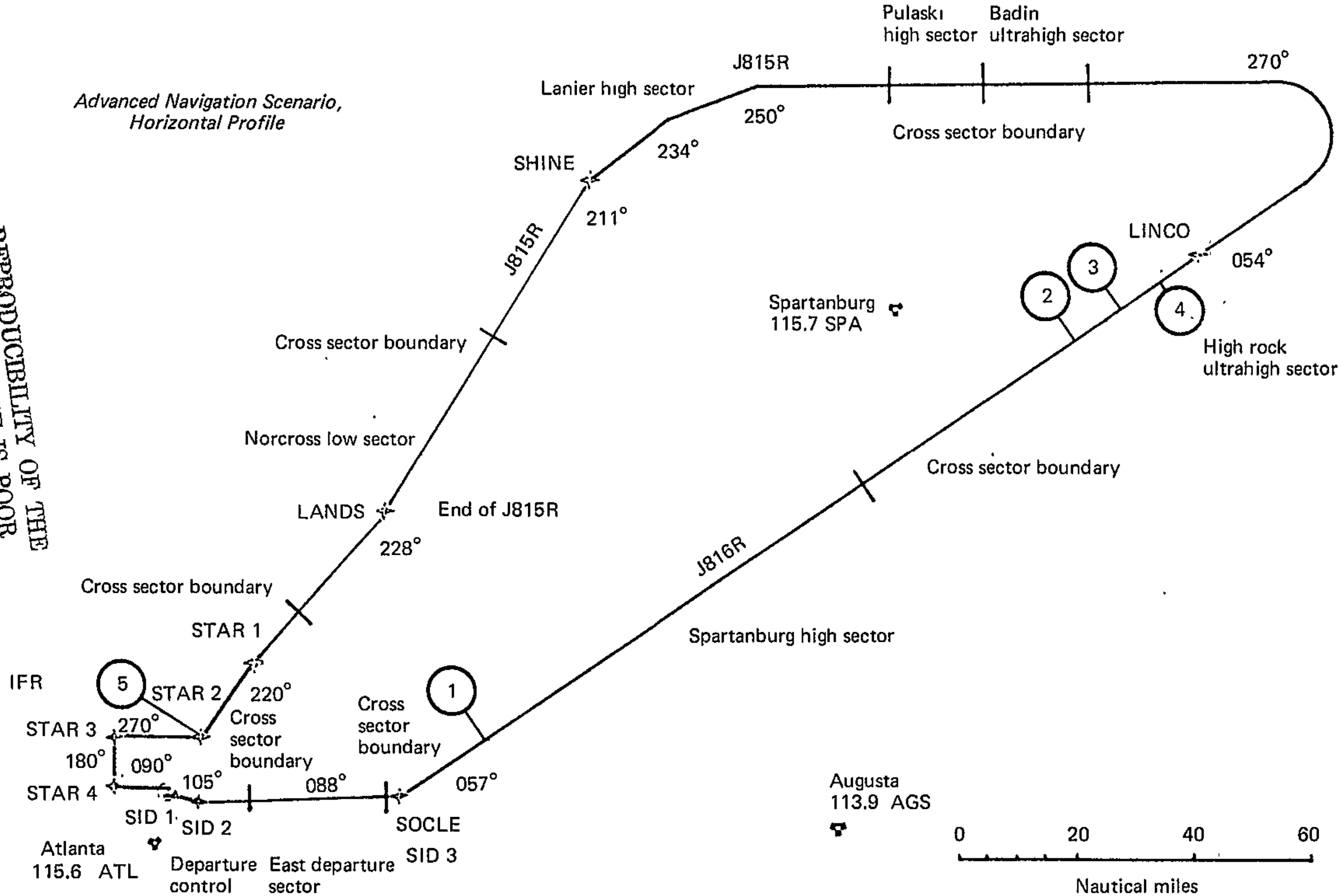


Figure 20.—Horizontal Mission Profile for Scenarios 4A and 4B

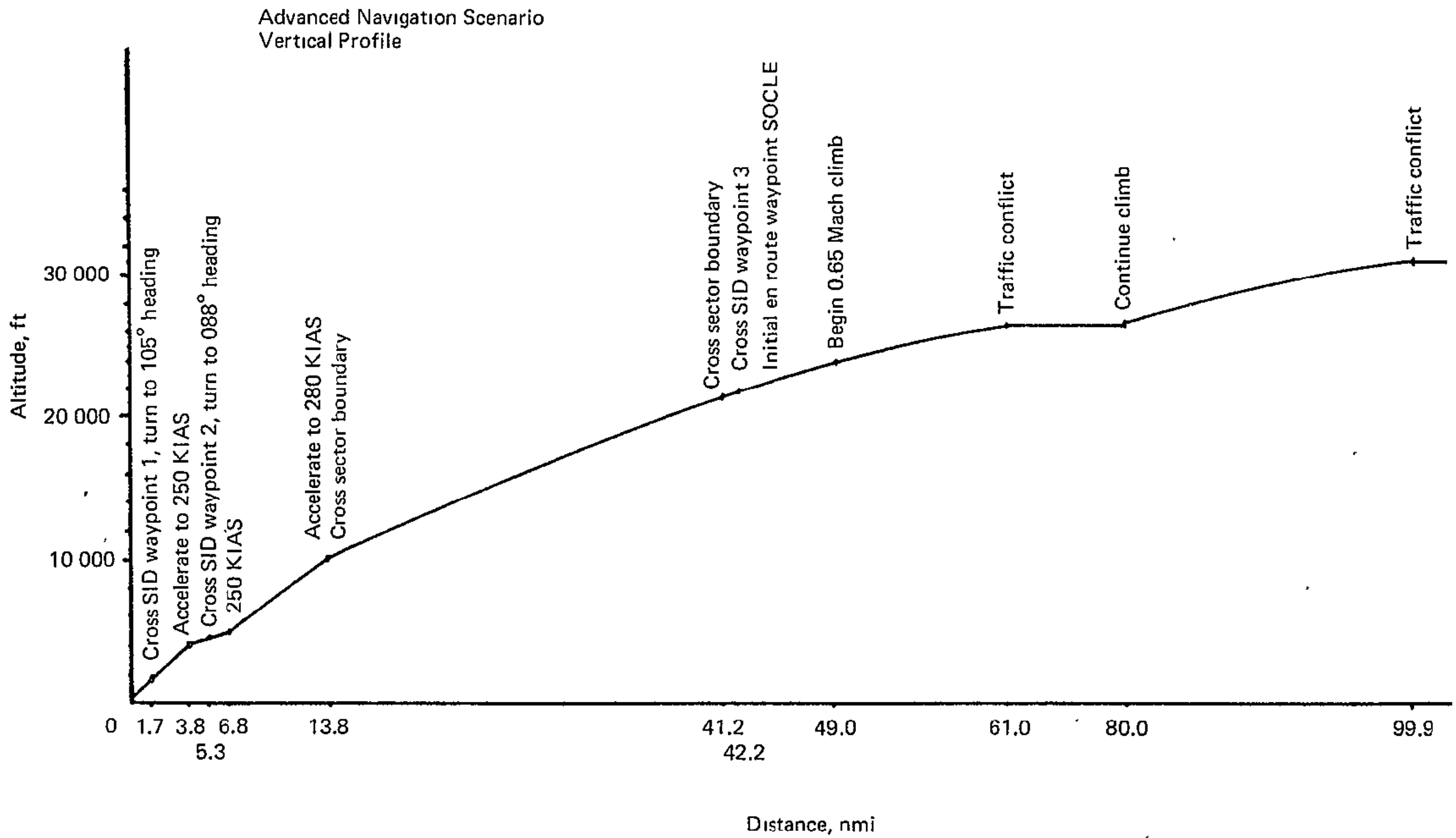


Figure 21.—Vertical Mission Profile for Scenarios 4A and 4B

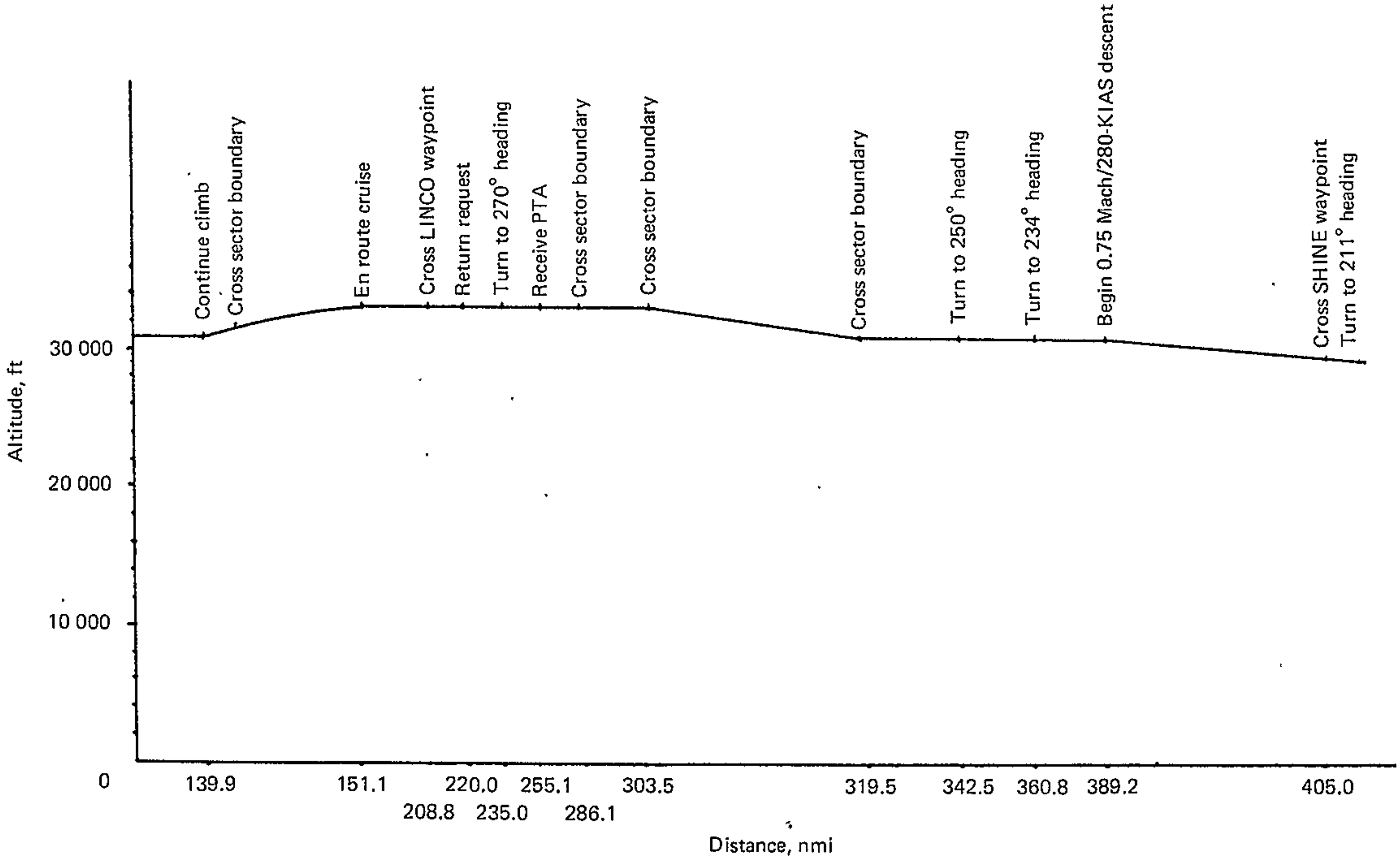


Figure 21.—(Continued)

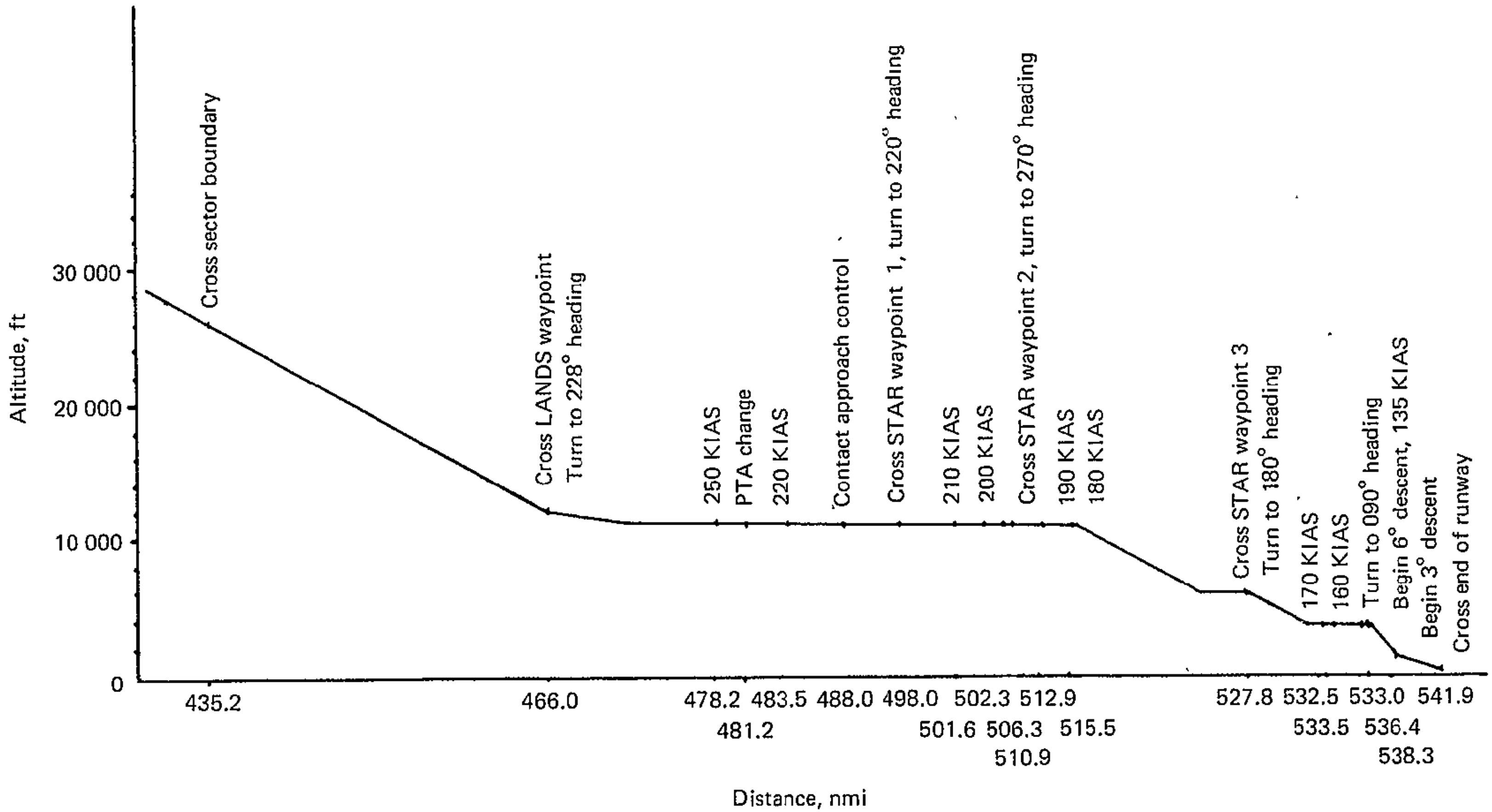


Figure 21.—(Concluded)

6.0 TASK DERIVATION

6.1 INTRODUCTION

In TLA-1, tasks are used as the basic work units from which all crew workload statistics are derived. The level of detail to which the tasks must be defined is described in section 6.3.

Tasks have been identified and cataloged for virtually every control and display in the NASA 515 FFD and AFD. In addition, tasks have been defined for every verbal communication required during an entire flight for all the scenarios described in section 5.0. Tasks have also been defined for all crew actions that are required in the flight but do not fit into the preceding categories. Altogether, over 2000 tasks have been identified and entered into a "Task Catalog for the NASA 515." (See App. Five, ref. 4.)

The TCV program analysts who use TLA-1 will use this task catalog to construct the procedures associated with the test flight scenarios to be analyzed. The analyst will add to the catalog to fill in missing or new tasks as they are identified.

Figure 22 shows a typical page from the task catalog. Each task is totally described by the following fields of data:

Field of data	Column	Explanation of derivation
Task code	1-8	Section 6.3
Task name	10-29	Section 6.3
Situation	31	Section 6.5
Duration time	33-37	Section 6.4
Channel activity	39-74	Section 6.6

6.2 COCKPIT INSTRUMENTATION CONFIGURATIONS

Tasks have been defined for specific NASA 515 FFD and AFD control and display configurations. The configurations used in this study are described in this section.

6.2.1 FORWARD FLIGHT DECK

The FFD instrumentation configuration used in this study was taken from reference 18 and updated to reflect the actual configurations observed on NASA 515 in February 1975. In order to provide a more realistic conventional 737 cockpit configuration for comparison with the advanced AFD cockpit configuration, all controls and displays whose sole purpose was to provide interfaces with the AFD were ignored.

The control and display configurations for the NASA 515 FFD used in the derivation of tasks are shown in Appendix Six (ref. 4).

BOEING
TLA-1
TASK DATA CODING FORM

PROGRAM	PAGE OF
PROGRAMMER	DATE

TASK CODE NO. (SUBSYS)	TASK CODE NO.	TASK NAME AND/OR DESCRIPTION		DURATION TIME (SECONDS)	EV	IV	LH	RH	LF	RF	COG	AUD	VBL
7A	28	ACTUATE ANNUN PNL	1	2.28		10	100				20		
		RECALL SW	2	1.93		10	100				20		
7A	29	CHECK SYS B	1	.90		100					20		
		SW'S OFF	2	1.52		100					20		
7A	30	CHECK ENG NO. 1 SYS A	1	1.36		100					20		
		HYD PUMP SW SET TO											
		ON											
7A	31	CHECK ENG NO. 2 SYS A	1	.75		100					20		
		HYD PUMP SW SET TO											
		ON											
7A	32	MON HYD SYS SW'S	1	2.0		100					20		
7A	33	MON MASTER CAUTION	1	.70		100					20		
		AND ALL ANNUN PNL	2	.54		100					20		
		LTS ILLUMINATED											
7A	34	SET GROUND INTER-	1	1.48		100	100				20		
		CONNECT SW TO OPEN	2	2.58		100		100			20		
7A	35	SET GROUND INTER-	1	1.48		100	100				20		
		CONNECT SW TO CLOSED	2	2.58		100		100			20		
7A	36	MON ALL ANNUN LTS	1	.53		100					20		
		OFF											

CHANNEL ACTIVITY – PERCENT OF DURATION TIME (columns EV through VBL)

Figure 22.—Task Data Coding Form—Example

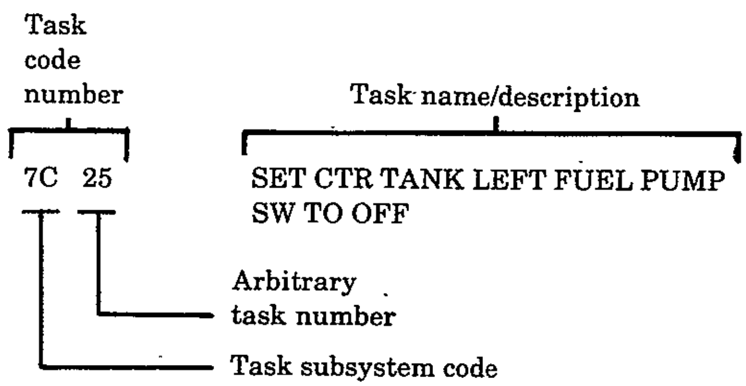
6.2.2 AFT FLIGHT DECK

The AFD instrumentation configuration was taken from reference 23 and updated to reflect the actual configuration observed on the NASA 515 in February 1975. For the reasons explained in section 6.2.1, all controls and displays that were used to interface with the FFD were ignored. In addition, it was assumed that all controls and displays in the AFD were operational.

The control and display configurations for the NASA 515 AFD used in the derivation of tasks are shown in Appendix Seven (ref. 4).

6.3 DERIVATION OF TASK NAMES AND TASK CODE NUMBERS

Each task is given a name and task code number as shown in the following example.



The first two characters in the task code are a subsystem code and the second set of characters is an arbitrary task number (see sec. 6.3.1.) The task name specifies the action taken (SET, ADJUST, MONITOR, etc.), the subject (the control, display, verbal, or auditory item), and, when appropriate, the exact position of a control or display element. (See secs. 6.3.2 and 6.3.3.)

6.3.1 TASK CODE NUMBERS

The TLA-1 tasks are categorized by subsystems. The subsystem categories are listed in table 2 and in Appendix Eleven (ref. 4). Each subsystem category is given a two-character alphanumeric code. The subsystem code is always the first two characters of a task code. An arbitrary task number was assigned to each task as it was taken from the various references. The sequence of task numbers is in no way related to the order of appearance in procedures. Up to six characters are allowed for each task number.

6.3.2 CONTROL-RELATED TASKS

Every control shown on the FFD and AFD panels has one or more tasks associated with it. (See sec. 6.2 and Apps. Six and Seven of ref. 4.) Table 3 lists the various types of

Table 2.—Subsystem Categories

Communications

1A	VHF-1 FFD
1B	VHF-2 FFD
1F	Interphone
1G	Public address
1H	Ground crew call
1J	Voice recorder
1M	Selcal
1N	Transponder
1P	Voice
1Q	VHF-1 AFD
1R	VHF-2 AFD
1S	VHF-3 AFD
1T	Loudspeaker

Electronic displays

2H	Advanced guidance and control system (AGCS)
2J	Electronic attitude director indicator (EADI)
2K	Multifunction display (MFD)
2L	Navigation control display unit (NCDU)

Flight Instruments

3A	Indicated airspeed indicator
3F	Mach airspeed indicator
3H	Corrected barometer altitude indicator
3J	Radio altimeter
3K	Altitude alert system
3L	Vertical speed indicator
3M	Elapsed time indicator
3N	Clock
3P	Standby attitude reference indicator
3R	Flight director indicator (FDI)
3S	Course indicator (CI)
3U	Total air temperature indicator
3V	Approach progress display
3W	Instrument comparator display

Flight Controls

4A	Primary alttitude controls
4B	Propulsion controls
4C	Thrust reverser controls
4D	Landing gear and brakes
4E	Flaps
4F	Speed brakes
4G	Trim
4H	Auto flight control
4M	Nose wheel steering
4N	Leading-edge devices

Navigation

5D	ADF/RMI 1
5E	VOR/RMI 2
5G	VOR/RMI 1
5H	VOR/RMI 2
5K	Standby compass
5P	DME-1
5Q	DME-2
5U	VHF/NAV-1 FFD
5V	VHF/NAV-2 FFD
5W	VHF/NAV-1 AFD
5X	VHF/NAV-2 AFC
5Y	VHF/NAV-3 AFD

Sensor Systems

6A	Weather radar
6C	Television

Aircraft Subsystems

7A	Hydraulics
7B	Electrical
7C	Fuel
7D	Air-conditioning
7E	Pressurization
7F	Propulsion
7G	Lights
7H	Oxygen
7J	Anti-ice
7K	Rain removal and defog
7L	APU
7M	Engine starting
7P	Fire/overheat/smoke detect
7Q	Doors

Crew

8A	Vision
8B	Maps/charts/checklists/reference data
8C	Seats/seatbelts
8D	Emergency equipment
8E	Personal equipment

Table 3.—Control-Related Tasks

Control type	Number of tasks for this type	Example tasks: Task code	Example tasks: Task name/description
Toggle switch			
Two position	Two	1A 05	Set VHF-1 COMM TFR SW to LEFT.
		1A 06	Set VHF-1 COMM TFR SW to RIGHT.
Three-position	Three		(Similar to above)
Guarded	One task for each position		(Similar to above)
Rotary switch	One task for each switch position	1N 01	Set ATC FUNC SEL SW to OFF.
		1N 02	Set ATC FUNC SEL SW to STDBY.
		1N 03	Set ATC FUNC SEL SW to ON.
		1N 04	Set ATC FUNC SEL SW to LO SENS.
Thumbwheel	One task for each thumbwheel		(None used on the NASA 515)
Lever			
With detents	One task for each detent position	4D 01	Set LANDING GEAR LEVER to UP position.
		4D 02	Set LANDING GEAR LEVER to OFF position.
		4D 03	Set LANDING GEAR LEVER to DOWN position.
No detents	One task for each significant position	4B 05	Advance THRUST LVRS to VERTICAL position.
		4B 06	Advance THRUST LVRS to FULL THRUST position.
		4B 08	Retract THRUST LVRS to IDLE position.
Rotary knob	One	1Q 04	Adjust VHF-1L volume.
Handwheel	One	4M 01	Actuate NOSE GEAR STEERING WHEEL.
Pushbutton			
On/off	One	1N 07	Press ATC IDENT SW.
Push-on/ push-off	Two	2K 20	Select NAVAIDS OPTION.
		2K 40	Deselect NAVAIDS OPTION.

controls, the number of tasks associated with each type, and examples. The control-related tasks were derived from references 18 and 23.

6.3.3 DISPLAY-RELATED TASKS

Every analog, digital, and discrete indicator shown on the FFD and AFD panels has one or more tasks associated with it. (See sec. 6.2 and Apps. Six and Seven, ref. 4.) Table 4 lists the various types of displays, the number of tasks associated with each type, and examples. The display-related tasks were derived from references 18, 23, and 24.

6.3.4 AUDITORY TASKS

Auditory tasks fall into two groups–monitoring of audible signals and monitoring of verbal communications. Table 5 lists the various types of auditory tasks and examples. The audible signal-monitoring tasks were derived from reference 18. The verbal auditory tasks were derived from the incoming radio communications specified in the scenarios (sec. 5) and from the internal cockpit requests and reports required by the checklists and other normal procedures found in reference 17.

6.3.5 VERBAL TASKS

Verbal tasks fall into two groups–internal cockpit callouts and communications via radio or intercom. Table 6 lists the types of verbal tasks and examples. The internal cockpit callouts and intercom verbal tasks were derived from the checklists and procedures in reference 17. The radio communications were derived from the scenarios. (See sec. 6.0.)

6.3.6 MISCELLANEOUS TASKS

Various tasks do not fit into the categories described previously, including adjusting seats and seatbelts, looking up reference data, retrieving checklists, checking fire extinguishers, etc. These tasks were derived from the checklists and procedures in reference 17.

6.4 TASK DURATION TIME DERIVATION

6.4.1 CONTROL- AND DISPLAY-RELATED TASKS

6.4.1.1 Ground Rules

Task duration times for all control- and display-related tasks were analytically calculated from geometric and human factors data. The following ground rules were observed for calculation of these task duration times:

1. Total task duration time was calculated from the sum of the time required to turn and look at the control or display (sec. 6.4.1.3) plus the time to reach to the control (sec. 6.4.1.4) plus the time to actuate the control or monitor the displayed information (sec. 6.4.1.5).

Table 4.—Display-Related Tasks

Display type	Number of tasks for this type	Examples	
		Task code	Task name/description
Discrete indicators			
On/off types	Two	7K 32	Monitor TANK NO. 1 FWD FUEL PUMP LO press LT ON.
		7K 33	Monitor TANK NO. 2 FWD FUEL PUMP LO press LT OFF.
Multicolored types	One task for each color	3V 08	Monitor GLIDE SLOPE ANNUN LT green
		3V 09	Monitor GLIDE SLOPE ANNUN LT amber.
		3V 10	Monitor GLIDE SLOPE ANNUN LT off.
Digital indicators	One	1A 01	Monitor VHF-1L FREQ INDIC.
Analog indicators	One task for each information element	7F 29	Monitor ENG NO. 1 EPR INDIC.
		7D 30	Monitor ENG NO. 1 EPR BUG.
CRT displays	One task for each information element	2J 01	Monitor ROLL ATT INDIC (EADI).
		2J 02	Monitor PITCH ATT INDIC.
		2J 03	Monitor ALTITUDE CALLOUT.
			o
			o
			o
Switch position	As required in checklists	7C 68	Check ENG NO. 2 FUEL HEAT SW OFF.

Table 5.—Auditory Tasks

Auditory task types	Examples	
	Task code	Task name/description
Monitor audible signals	1F 04	Monitor COCKPIT CALL CHIME.
	4D 31	Monitor LANDING GEAR NOT DOWN AND LOCKED WARNING HORN.
Monitor verbal communnications		
Incoming radio messages	1P 02	Monitor REQUEST.
	1A 09	Monitor VHF-1 COMM AUDIO.
Cockpit callouts	1P 02	Monitor REQUEST.
	1P 04	Monitor REPORT.
	1P 05	Monitor RESPONSE.

Table 6.—Verbal Tasks

Verbal task type	Examples	
	Task code	Task name/description
Internal cockpit callouts	1P010005	Callout: "SET EPR AT XXX"
	1P030004	Callout: "AFTER START CHECKLIST"
	1P040028	Callout: "BEFORE TAKEOFF CHECKLIST COMPLETE"
Radio communications	1P030002	Interphone comm: "STARTING NO. 2"
	1P030019	Radio comm: "ATLANTA GROUND CONTROL, NASA 515 READY TO TAXI, OVER"

2. The origin from which the task was initiated was always the location of the eyes and hands at the completion of the previous task.

3. Time required to return to the rest position was not included.

6.4.1.2 Derivation of Reach Distances and Eye Angles

All distance and angular measurements used to calculate turn and reach times were taken from the output of Link 3 of Boeing program TX-105, a program developed for control cabin design evaluations. (See ref. 25.) This program and the option compute, among other things, the straight line hand movement distance between points and the angular eye movement between points. (See fig. 23 for an example of the TX-105 Link 3 output report.)

The basic input data required to execute TX-105 Link 3 are (1) the X-Y-Z location (buttock line-water line-station line) of the controls and displays (fig. 24) and (2) the sequence in which they are used.

The X-Y-Z locations of the controls and displays for both the FFD and AFD were derived in two ways:

1. From control location data listed unpublished data inputs for TX-105 Link 3 used in the 737 certification program

2. From measurements extrapolated from the control location data using scale drawings of the control panels (from refs. 18 and 23)

The sequence of use of the controls and displays was taken from references 17 and 26.

6.4.1.3 Turn Time

Time required for eye and head deflection was computed from the following equation:

$$T = \frac{\text{eye angle change (in deg) x 0.66 sec}}{90^{\circ}}$$

This formula was derived from time and motion data (ref. 27) in which a flat 0.66 sec is allotted for all turning movements up to 90°. The rational multiplier (actual deflection divided by 90) was imposed to make the factor more sensitive to the minimal body turns used in the cockpit. The eye angle change data used in this calculation were those derived from TX-105 data (described in sec. 6.4.1.2). These data are shown in the column Angular Change, Eye in figure 23.

6.4.1.4 Reach Time

Time to reach from one location to another was assessed according to table 7 (also from ref. 27). These data were plotted on a time versus distance plot, and a sequence of polynominal equations was derived to define the reach time for intermediate distances

ISSION SEGMEN CRUISE CREW MEMBER CAPTAIN
CONDITION CONVENTIONAL 737 COCKPIT

	CHANGE IN DISTANCE FROM EYE POINT	CHANGE IN DISTANCE FROM LEFT SHOULDER	CHANGE IN DISTANCE FROM RIGHT SHOULDER	DISTANCE BETWEEN POINTS EYE POINT	DISTANCE BETWEEN POINTS LEFT HAND	DISTANCE BETWEEN POINTS RIGHT HAND	ANGULAR CHANGE EYE	ANGULAR CHANGE LEFT HAND	ANGULAR CHANGE RIGHT HAND	TOTAL ANGLE EYE
TASK ENGINE START LEVERS										
ENG NO. 1 EPR INDIC	6.2			40.7			72.3			32.5
CAPT RIGHT HAND RELAXED POS			3.3			32.9			136.0	
ENG NO.1 START LEVER CUT OFF	2.8		8.5	29.5		14.7	48.3		35.0	78.3
ENG NO.1 START LEVER RUN POS	2.4		2.4	3.8		3.8	5.0		7.2	74.8
ENG NO. 1 EPR INDIC	5.2			26.5			44.1			32.5
ENG NO.1 START LEVER RUN POS	5.2		.0	26.5		.0	44.1		.0	74.8
ENG NO.1 START LEVER CUT OFF	2.4		2.4	3.6		3.8	5.0		7.2	78.3
ENG NO. 1 EPR INDIC	2.8			29.5			48.3			32.5
TASK ENG OVRHT SYS SETUP										
CAPT VIEW THRU NO. 1 WINDOW	1193.9			1139.9			32.5			.0
CAPT RIGHT HAND RELAXED POS			8.5			14.7			35.0	
ENG NO.1 OVERHT DETECT SW	1196.7		8.9	1236.4		16.3	97.9		39.8	97.8
ENG NO.2 OVRHT DETECT SW	2.9		2.3	5.5		5.5	7.5		11.0	97.2
ENG OVRHT TEST SW	2.5		1.8	5.9		5.9	8.4		12.1	101.1
EXT TEST SW	4.3		3.4	6.3		6.3	11.0		15.9	98.4
EXT TEST LTS	.2			1.0			1.4			99.8
TASK ENG NO. 1 FIRE										
CAPT VIEW THRU NO. 1 WINDOW	1191.9			1238.5			99.9			.0
CAPT RIGHT HAND RELAXED POS			12.7			22.8			51.8	
CAPT ANNUN PNL	1207.0			1209.5			25.6			25.6
ENG NO 1 FIRE WARNING SW	9.6		8.0	36.9		16.9	77.2		44.3	99.7
L. BOTTLE DISCHARGE LT	4.4			6.3			7.2			96.3
R. BOTTLE DISCHARGE LT	.7			1.1			1.3			96.2
FIREBELL CUTOUT SW	3.4		1.2	3.8		3.8	2.9		8.4	96.8
CAPT VIEW THRU NO. 1 WINDOW	1195.8			1235.9			96.8			.0
CAPT RIGHT HAND RELAXED POS			9.2			18.5			46.9	
ENG NO 1 FIRE WARNING SW	1197.4		8.0	1237.4		16.9	99.7		44.3	99.7
ENG NO 1 FIRE WARNING SW	.0		.0	.0		.0	.0		.0	99.7
ENG NO 1 FIRE WARNING SW	.0		.0	.0		.0	.0		.0	99.7
TASK ENG. NO. 2 FIRE										
CAPT VIEW THRU NO. 1 WINDOW	1197.4			1237.4			99.7			.0
CAPT RIGHT HAND RELAXED POS			8.0			16.9			44.3	

Figure 23.—TXJ 105 Link 3 Output—Example

			Buttock line	Water line	Station line		
A1	737BASIC	0NI009	R009.4	0201.9	0223.2	OFF SCHEDULE DESCENT LT	
A1	737BASIC	0NC009	R006.7	0260.0	0218.6	LAND AUTO PRESS CONT	
A1	737BASIC	0NI010	R011.6	0261.9	0223.2	MAN PRESS SYS ENG LT	
A1	737BASIC	0NC010	R011.7	0259.8	0218.6	PRESS MODE SEL	
A1	737BASIC	0NC011	R010.3	0261.0	0221.2	STANDBY PRESS RATE CONT	
A1	737BASIC	0PI001	L011.0	0248.3	0209.5	CAPT ANNUN PNL	
A1	737BASIC	0PC003	L004.0	0223.4	0236.0	ENG NO.1 OVERHT DETECT SW	
A1	737BASIC	0PC004	L004.0	0223.4	0238.0	ENG OVRHT TEST SW	
A1	737BASIC	0PC005	L003.0	0225.0	0237.0	ENG NO 1 FIRE WARNING SW	
A1	737BASIC	0PI006	L002.7	0223.4	0235.5	WHEEL WELL FIRE WARNING LT	
A1	737BASIC	0PC008	L000.0	0225.0	0237.0	APU FIRE WARNING SW	
A1	737BASIC	0PC009	R001.5	0223.4	0236.0	ENG NO.2 OVRHT DETECT SW	
A1	737BASIC	0PI010	R001.5	0223.4	0237.0	ENG NO.2 OVRHT LT	
A1	737BASIC	0PC011	R002.7	0225.0	0237.0	ENG NO 2 FIRE WARNING SW	
A1	737BASIC	0PI012	R002.9	0223.4	0235.5	L. BOTTLE DISCHARGE LT	
A1	737BASIC	0PI013	R004.0	0223.4	0235.5	R. BOTTLE DISCHARGE LT	
A1	737BASIC	0PI014	L001.2	0223.4	0236.0	APU BOTTLE DISCHARGE LT	
A1	737BASIC	0PI020	L004.0	0223.4	0237.0	ENG NO. 1 OVRHT LT	
A1	737BASIC	0PI021	L001.2	0223.4	0237.0	APU DET INOP LT	
A1	737BASIC	0PC022	R000.5	0225.0	0235.5	FIREBELL CUTOUT SW	
A1	737BASIC	0PI022	R004.2	0223.4	0238.0	EXT TEST LTS	
A1	737BASIC	0PC023	R004.2	0223.4	0237.0	EXT TEST SW	
A1	737BASIC	0PI100	R010.2	0248.3	0209.5	F.O. ANNUN PNL	
A1	737BASIC	0QI002	R004.9	0265.7	0232.1	MON ENG 1 ANTI-ICE SW	*
A1	737BASIC	0QI003	R006.1	0265.7	0232.1	MON ENG 2 ANTI-ICE SW	*
A1	737BASIC	0QI017	R003.1	0266.8	0233.6	WING ANTI-ICE DUCT OVRHT LT	
A1	737BASIC	0AI001	L003.6	0242.1	0199.6	ENG NO. 1 EPR INDIC	
A1	737BASIC	0AI002	L008.3	0266.2	0236.6	STANDBY HYD LO PRESS LT	
A1	737BASIC	0AC003	L010.1	0266.6	0233.1	YAW DAMPER ON OFF SW	
A1	737BASIC	0AI004	L011.0	0266.6	0233.1	YAW DAMPER ANNUN LT	
A1	737BASIC	0AI005	[illegible]	0260.5	0220.0	APU LO OIL QTY LT	
A1	737BASIC	0AI006	L005.0	0260.5	0220.0	APU LO OIL PRESS LT	
A1	737BASIC	0AI007	L004.0	0260.5	0220.0	APU HI OIL TEMP LT	
A1	737BASIC	0AI008	L003.0	0260.5	0220.0	APU OVERSPD LT	
A1	737BASIC	0AI009	L002.2	0259.9	0218.7	APU AC AMPS METER	
A1	737BASIC	0AC010	L000.0	0267.1	0234.5	CIRCUIT BKR PANEL LTS BRIGHT CONT	
A1	737BASIC	0AC011	L000.0	0266.3	0232.5	PANEL LTS BRIGHT CONT	
A1	737BASIC	0AI012	L000.5	0264.3	0228.1	EQUIP COOLING LT	
A1	737BASIC	0AC013	R000.5	0264.3	0228.1	EQUIP COOLING ON OFF SW	
A1	737BASIC	0AI013	R000.5	0264.3	0228.1	MON EQUIP COOLING SW	*
A1	737BASIC	0AC014	L000.0	0263.5	0226.5	EMERG EXIT LTS SW	
A1	737BASIC	0AI014	L000.0	0263.5	0226.5	MON EMERG EXIT LT SW POS	*
A1	737BASIC	0AI015	L000.0	0263.0	0226.0	EMERG EXIT LTS NOT ARMED LT	
A1	737BASIC	0AC016	L000.7	0262.4	0224.0	NO SMOKING LT SW	
A1	737BASIC	0AI016	L000.7	0262.4	0224.0	MON NO SMOKING LT SW	*
A1	737BASIC	0AC017	R000.[illegible]	0262.4	0224.0	FASTEN SEATBELTS LT SW	
A1	737BASIC	0AI017	R000.7	0262.4	0224.0	MON SEAT BELT LT SW	*
A1	737BASIC	0AC018	L001.0	0261.5	0222.0	ATTENDENT CALL SW	
A1	737BASIC	0AC019	R001.0	0261.5	0222.0	GND CALL SW	
A1	737BASIC	0AI020	L000.9	0261.0	0221.0	CALL LT	*
A1	737BASIC	0AC021	L000.6	0260.4	0220.0	L RAIN REPELLANT SW	
A1	737BASIC	0AC022	R000.6	0260.4	0220.0	R RAIN REPELLANT SW	
A1	737BASIC	0AC023	L008.3	0259.0	0217.0	LANDING LTS SW	
A1	737BASIC	0EI023	L006.2	0237.6	0200.2	SPEED BARKE ARMED LT	*
A1	737BASIC	0AC024	L005.5	0259.0	0217.0	L RUNWAY TURNOFF LT SW	
A1	737BASIC	0AC025	L004.6	0259.0	0217.0	R RUNWAY TURNOFF LT SW	
A1	737BASIC	0AC026	R006.0	0259.0	0217.0	POSITION LT SW	

Figure 24.—TX-105 Input Data—Example

Table 7.—Time Required for Controlled Reach

Distance, in.	Time, sec	Distance, in.	Time, sec
1	0.324	12	0.570
2	0.372	14	0.574
3	0.402	16	0.624
4	0.432	18	0.648
5	0.456	20	0.672
6	0.474	22	0.696
7	0.492	24	0.720
8	0.510	26	0.744
9	0.522	28	0.768
10	0.540	30	0.792

not shown in the table. The time allotments of this table are those for visually directed movements, which are stopped by muscular control and which terminate in a grasping or placing motion.

The reach distance data used in these computations were those derived from TX-105 data (described in sec. 6.4.1.2). These data are shown under the column headings Distance Between Points, Left Hand/Right Hand shown in figure 23.

6.4.1.5 Operation Time

Control operation times and visual monitoring times for the various types of controls and displays were derived from human factors data (refs. 28 and 29). The times used for the various items and their sources are listed in table 8.

Operation times for other control and monitor tasks that do not fit into the types listed in table 8 were either estimated, simulated, or calculated.

6.4.2 COMMUNICATION TASKS

The task duration times for all verbal communications were based on the stop-watch timed duration of the verbal delivery of the exact text of the communication.

6.4.3 OTHER TASKS

For tasks that did not fit into the previous categories, the task duration times were based on stop-watch timed simulations of the task. Examples of these other tasks are seat adjustment, approach chart retrieval and review, data lookup, fire extinguisher check, etc.

6.5 TASK SITUATIONS

An entity called "task situation" was created as a mechanism for reducing the number of tasks to be listed in the task catalog.

Many controls and displays are used by both the pilot and the copilot and are located between the two crewmembers. Actuation of a control on one of the center panels is a right-hand task for the pilot and a left-hand task for the copilot. Rather than creating a separate task number and description to make this right-hand/left-hand distinction, a situation number is used with a single task number/task name. This type of situation will have associated with it a unique channel activity allocation that distinguishes it from another situation. The situation number will direct the program to select the appropriate channel activity data associated with this task as it is applied to the operator performing the task. Task 3H-01, shown in figure 25, is an example of a task where this type of left-hand/right-hand situation is used.

The second use of the situation number is to account for different task duration times for a task. For example, the time required to adjust the throttles a small amount is quite different from the time required to apply full thrust on takeoff. The situation

Table 8.—Operating Time for Various Control and Display Types

Control/display type	Average operation time, sec	Reference
Pushbutton	1.04	28
Two-position toggle switch	1.11	28
Three-position toggle switch	1.35	28
Covered toggle switch	1.50	28
Single rotary switch	1.58	28
Rotary switch in an array	1.64	28
Single thumbwheel	1.95	28
Thumbwheel in an array	2.00	28
Hand lever, 5° to 10° movement	1.65	29
Hand lever, 10° to 20° movement	1.85	29
Hand lever, 20° to 40° movement	2.05	29
Hand lever, 40° to 60° movement	2.25	29
Rotary knob	1.69	29
Hand wheel	2.39	29
Discrete indicator	0.25	29
Analog indicator	2.00	29
Digital indicator	0.75	29

BOEING
TLA-1
TASK DATA CODING FORM

PROGRAM | PAGE OF
PROGRAMMER | DATE

TASK CODE NO. (SUBSYS)		TASK NAME AND/OR DESCRIPTION		DURATION TIME (SECONDS)	CHANNEL ACTIVITY - PERCENT OF DURATION TIME: EV	IV	LH	RH	LF	RF	COG	AUD	VBL
3H	01	SET ALTIMETER SW TO	1	2.10		100	100				20		
		ON	2	2.10		100		100			20		
4C	05	MON ENG NO. 2 REVER-	1	.55		100					20		
		SER UNLOCKED LT ON	2	.76		100					20		
10	04	ADJ VHF-1L VOLUME	1	1.58		50		100			20		
			2	2.15		50		100			20		
			3	1.58		50	100				20		
			4	2.15		50	100				20		

Figure 25.—Example Tasks

number allows the analyst to use the same task number and title for both cases while the situation number directs the program to select the appropriate task duration time for the specific case. Task 4C-05, shown in figure 25, is an example of a task where this type of duration time situation is used.

Task 1Q-04, shown in figure 25, is an example of a single task where both types of situations are used.

6.6 CHANNEL ACTIVITY

In TLA-1, nine anatomical/physiological channels have been defined which the operator will use in performing tasks. These channels are: (1) internal vision, (2) external vision, (3) right hand, (4) left hand, (5) right foot, (6) left foot, (7) verbal, (8) auditory, and (9) cognition. Each task will require one or more of these channels to be used to perform the task.

For every task in TLA-1, an assessment was made as to which channel would be used in performing the task and what percentage of task duration time each channel would be used. For example, to turn the windshield wiper switch to ON, the pilot will use his eyes (internal vision) to look at the control plus his right hand to reach up and actuate the control and his cognition to think about what he is doing. Each of the first two channels will be involved 100% of the total time required to perform the task. However, he will use his cognitive channel only a small percentage of the time (estimated at 20%) since he can be aware of many things simultaneously.

The channel activity percentages assigned to each task and situation are estimates. In general, it was assumed that the appropriate channel was occupied 100% of the task duration time. The major exception to this was that a 20% cognitive channel activity was allocated for all tasks.

7.0 PHASE, EVENT, AND PROCEDURE DERIVATION

7.1 INTRODUCTION

Phases, events, and procedures are discussed in this section as a group because they are interrelated. Figure 26 shows the time-based relationship between these entities and their relationship to the scenarios and the tasks. As this figure shows, the mission (or flight) is a series of sequential flight phases (sec. 7.2). Each phase is a series of events (sec. 7.3.1) and of procedures (sec. 7.3.2). Each procedure is a sequence of tasks. The workload analysis worksheets (fig. 3) are used by the analyst to organize and define, these data prior to coding.

7.2 FLIGHT PHASES

Each flight phase is described by a code number, a descriptive name, a start time, and a listing of the events/procedures that compose the phase and when these events/procedures start. Section 8.2.1.2.2 shows how the phase data are coded. Section 8.2.1.2.1 shows how the sequence of phases and their respective start times are coded on the mission data coding form. All the phase data items are discussed in detail in the following sections. (See App. Nine, ref. 4, for a listing of the phases that were derived for the scenarios described in sec. 5.0.)

7.2.1 FLIGHT PHASE NAMES AND CODES

7.2.1.1 Normal Flight Phases

In TLA-1, the total mission (or flight) can be described by a sequence of normal flight phases. Table 9 lists 19 normal flight phase code numbers and titles from which the analyst can select those that pertain to the specific scenario being analyzed. Others can be added by the analyst if necessary. Each normal flight phase is given a four-character phase code number.[1] Figure 27 shows a typical sequence of normal flight phases that describe a scenario where no emergency or abnormality occurs.

7.2.1.2 Emergency Situations

The 19 flight phases listed in table 9 can be annotated to show that an emergency or abnormal event has occurred in or persisted through the various phases. This bookkeeping annotation is described in the following paragraphs and is used by the analyst to keep track of flight phases where emergencies or abnormal events have altered the normal procedures.

Table 10 lists all the emergency situations for the 737 as taken from reference 17. Each emergency is assigned a unique two-letter code that is used in the four-character flight phase code to show that an emergency event has occurred. This emergency code would be used in successive flight phase codes if the emergency situation persisted and/or if the procedures used during the successive flight phases were impacted by the earlier emergency.

[1] These phase names and code numbers have been borrowed from another Boeing computer program.

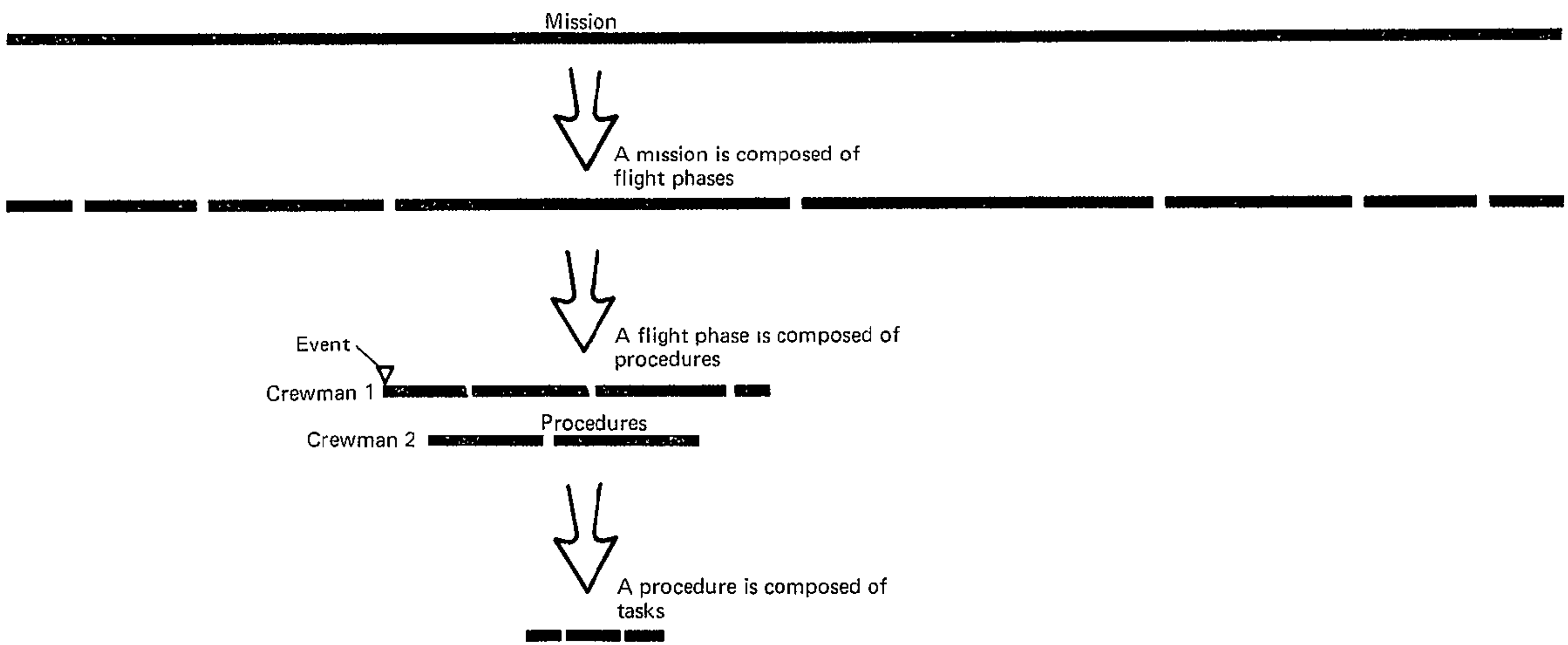


Figure 26.—Time-Based Relationship of Missions, Phases, Events, Procedures, and Tasks

Table 9.—Flight Phases

Phase code number	Phase name
0100	Prestart prep, FFD
0200	Prestart prep, AFD
0300	Start
0400	Taxi, before takeoff
0700	Takeoff, IFR
0900	Climb, noise abatement
1100	Cruise, normal airway
1200	Cruise, normal off airway
1300	Cruise, area navigation
1400	Descent, conventional procedures
1500	Descent, advanced procedures
1600	Approach/land, ILS procedural
1700	Approach/land, MLS procedural
1800	Approach/land, advanced procedures
1900	Approach/land, curved and segmented
2000	Park, visual
2100	Park, IFR (CAT III)
2200	Shutdown
2300	Taxi, after landing

Note: New flight phases can be added by the analyst as required.

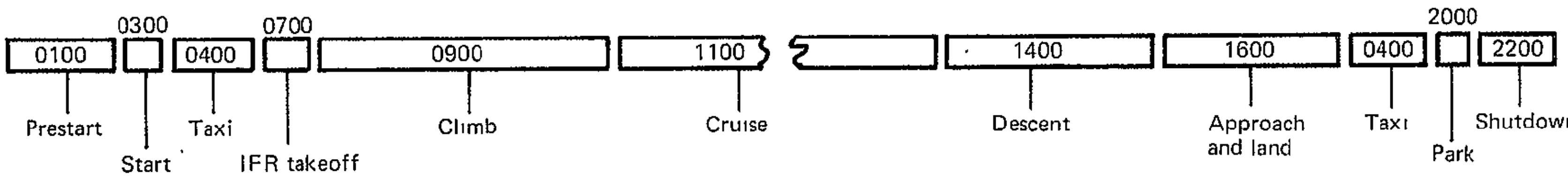


Figure 27.—Example of Typical Flight Phases Used To Define a Mission/Flight

Table 10—Emergency Situations

Name	Code
Engine fire, severe damage, or separation	XXEA
Engine overheat	XXEB
Electrical system smoke or fire	XXEC
Rapid depressurization	XXED
Emergency descent	XXEE
APU fire	XXEF
Wheel well fire	XXEG
Cockpit smoke	XXEH
Main cabin smoke	XXEI
Ditching	

Figure 28 shows a scenario where an engine overheat (code XXEB) occurred during the cruise phase (code 1100). The resulting flight phase code and description are

11EB Cruise–Engine Overheat

In this example, the overheat condition was taken care of and there was no subsequent impact on any other flight phase.

Figure 29 shows a scenario where a rapid depressurization (code XXED) occurred during normal airway cruise (code 1100). The resulting flight phase code and description are

11ED Normal Airway Cruise–Rapid Depressurization

In this example, the emergency had impact on the descent and the approach and land flight phases. Therefore, these flight phases are coded and described as

14ED Maximum Descent–Rapid Depressurization
16ED ILS Approach/Land–Rapid Depressurization

This coding system will not accommodate scenarios where multiple failures occur or persist through a flight phase. In such scenarios, the analyst is advised to stay with the normal flight phase coding or to adopt some other convention.

7.2.1.3 Abnormal Situations

Table 11 lists all the abnormal situations for the 737 as taken from reference 17. These abnormalities are coded and handled in a manner similar to the emergency situations described previously.

7.2.2 FLIGHT PHASE START TIME

The scenario will define the starting time of each flight phase relative to the total mission/flight start time. In some scenarios, the mission start time (T = 0) will start at the time the pilots enter the cockpit. The analyst may choose to start the mission at a specific time of day (for example, T = 09:15:00). Whichever time reference is used, the flight phase start times are always expressed as hours:minutes:seconds from the beginning time of the mission. See figure 30.

7.3 EVENTS AND PROCEDURES

As figure 26 shows, flight phases are made up of a series of events and procedures. Events are discussed in section 7.3.1 and procedures in section 7.3.2. Event and procedure start times are discussed in section 7.3.3. (See App. Eight, ref. 4, for a listing of the events and procedures that were derived for the scenarios described in sec. 5.0.)

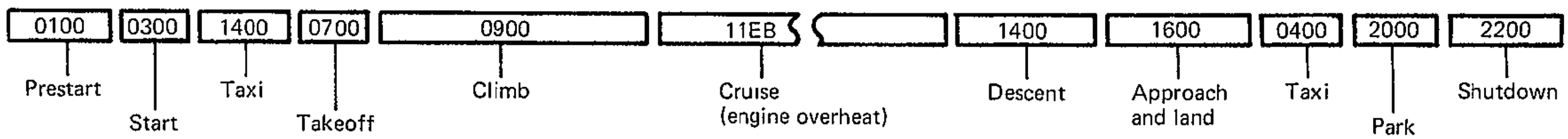


Figure 28.—Example of a Scenario That Includes an Emergency in a Phase That Does Not Impact Following Phases

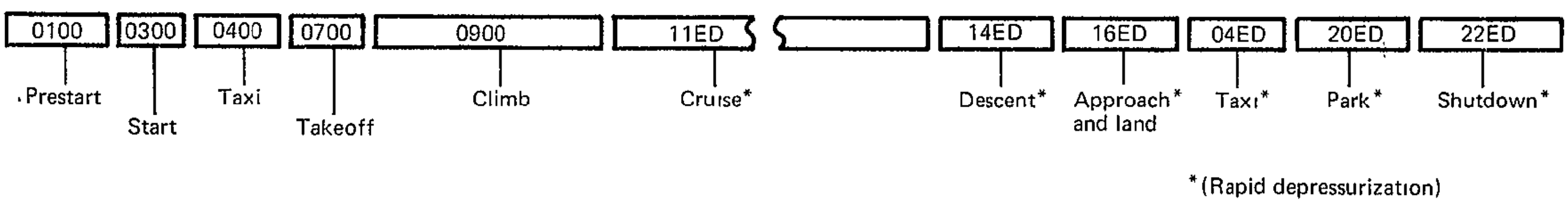
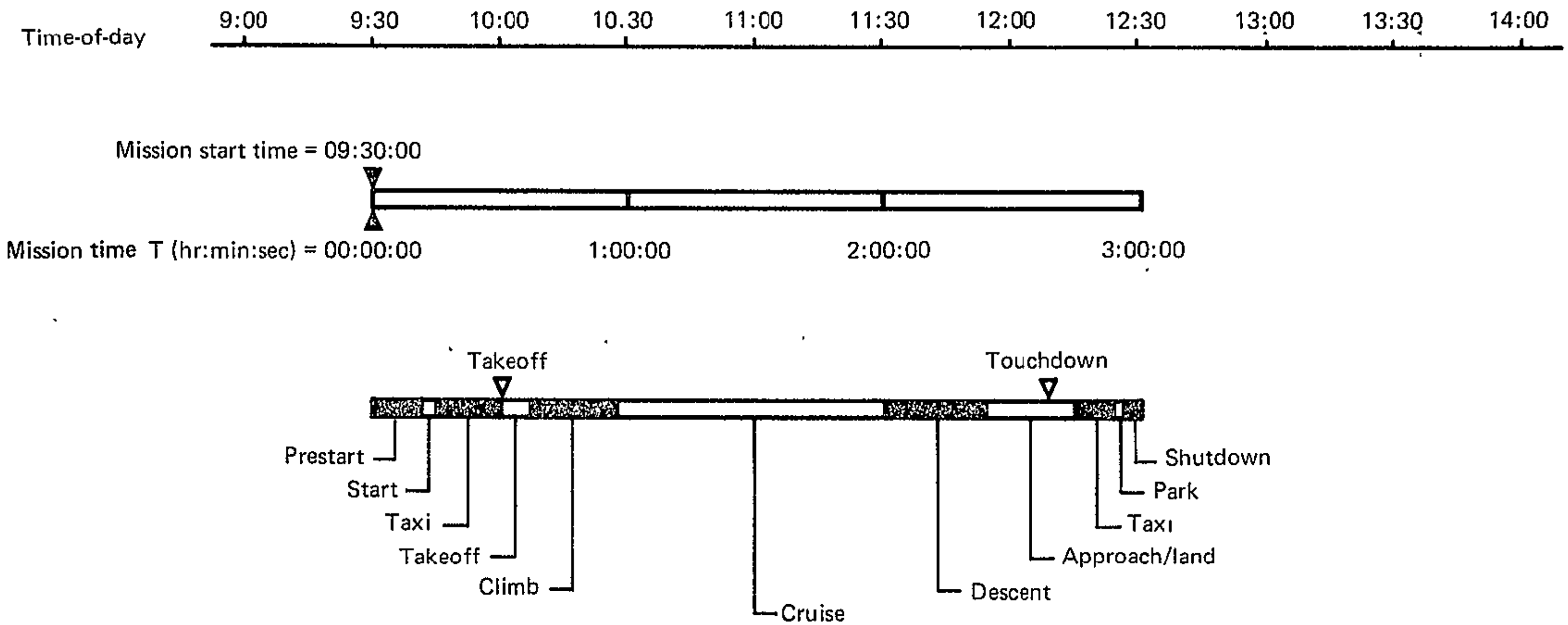


Figure 29.—Example of a Scenario That Includes an Emergency in a Phase That Impacts Following Phases

Table 11.—Abnormal Situations

Name	Code
Engine shutdown in flight	XXAA
Engine start in flight	XXAB
One engine inoperative	XXAC
Reverser unlocked	XXAD
Low oil pressure	XXAE
Oil filter bypass	XXAF
Fuel heat valve failure	XXBA
Minimum fuel go-around	XXBB
Fuel filter icing	XXBC
Inadvertent fuel transfer	XXBD
Circuit breaker trip	XXCA
CSD low oil pressure	XXCB
CSD high oil temperature	XXCC
Standby power off	XXCD
Bus off	XXCE
Transfer bus off	XXCF
Equipment cooling off	XXCG
Loss of system A	XXDA
Loss of system B	XXDB
Loss of both systems A and B	XXDC
Gear not sealed	XXFA
Gear unsafe	XXFB
Loss of system A or B hydraulic brake pressure	XXFC
Hydraulic pump low pressure	XXFD
System B pump overheat	XXFE
One or both antiskids inoperative	XXFG
Auto brake inoperative	XXFF
Duct overheat	XXGA
Pack trip off	XXGB
Wing-body overheat	XXGC
Bleed trip off	XXGD
Auto fail	XXGE
Off-schedule descent	XXGD
Engine anti-ice valve failure	XXHA
Cockpit window failure	XXJA
Window overheat	XXJB
Runaway stabilizer	XXKA
Abnormal flight controls	XXKB
Jammed stabilizer	XXKC
Unsymmetrical or no leading-edge devices	XXKD
Unsymmetrical trailing-edge devices	XXKL
Flag-up landing	XXKM
Flight control low pressure	XXKN
Yaw Damper	XXKP
Stabilizer out of trim	XXKQ
Speed brakes do not arm	XXKR
Mach trim fail	XXKS



Phase	Time-of-day	Flight phase start time relative to mission start time
Prestart	09:30:00	00:00:00
Start	09:43:00	00:13:00
Taxi	09:45:00	00:15:00
Takeoff	10:01:15	00:31:15
Climb	10:02:30	00:32:30
Cruise	10:28:00	00:58:00
Descent	11:30:00	02:00:00
App/land	11:51:30	02:21:30
Taxi	12:15:00	02:45:00
Park	12:25:00	02:55:00
Shutdown	12:28:00	02:58:00

Figure 30.—Flight Phase Start Time

7.3.1 EVENTS

In TLA-1, an event has an event code number and a description. In general, an event is used as a mechanism to insert descriptions of significant milestones into the mission scenario report (sec 8.4.2.1) and the mission timeline plot (sec. 8.4.2.4). An event is distinguished from a procedure becuase an event does not have a task series associated with it. The following are examples of events:

Event code number	Event description
060002	Rotate
060003	Liftoff
060001	Receive takeoff clearance
090003	Cross Stubbs intersection
160011	Cross outer marker
160013	Cross inner marker
160014	Touchdown
09FE05	System B pump overheat anomaly

The first four characters in the six-character event code number are the code number of the flight phase in which the event occurred. The last two numbers are the sequence number of the event during the phase. This coding convention is purely arbitrary, and the analyst is free to adopt any one- to six-character coding convention that assigns a unique number to each event.

It is emphasized that the events are used only for inserting some reference information or landmarks into timelines and scenario reports to aid readers in interpreting this information. Events do not have any effect or impact on the statistical computations. In general, the events are derived from the scenarios.

7.3.2 PROCEDURES

In TLA-1, a procedure has a code number, a description, and a listing of the sequential order of tasks required to perform the procedure. Each task in a procedure is given a start time relative to the procedure start time, a task slide time, a crewmember assignment, and a task-situation number. Figure 31 is a typical event/procedure data coding form showing how these entities are coded, and the following sections describe the entities.

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TLA-1
EVENT/PROCEDURE DATA CODING FORM

PROGRAM | PAGE OF
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EVENT/PROC CODE NO.	EVENT/PROCEDURE NAME OR DESCRIPTION	TASK CODE NO.	TASK START TIME HR	MIN	SEC	SLIDE (SEC) −	+	CREW MEMBER	S/T	TASK CODE NO.	TASK START TIME HR	MIN	SEC	SLIDE (SEC) −	+	CREW MEMBER	S/T
070004	CLEARED TØ TAXI ØNTØ	1B 14			0			CP	1	1B 15			0			CP	1
	RUNWAY 9L	1P070005			0			CP	1	1P070006			3.6			CP	1
		1B 18			6			*	2	1P070007			6			*	1
		1B 14			9			CP	2	1B 15			9			CP	2
		1P070008			9			CP	1	4D 52			13			P	1
		4B 03			14			P	2	4M 01			14			P	4
		4B 03			24			P	1	4D 28			27			P	1
		8A 04			10			P	3								
070005	RECEIVE TAKEØFF	1B 18			0			P	2	1P070009			0			*	1
	CLEARANCE	1B 14			3			P	3	1B 15			3			P	3
		1P070010			3			P	1								
070006	TAKEØFF RØLL	8A 02			0			P	1	4A 64			0		2	P	1
		4B 05			0			P	1	7F 29			3	1	2	P	2
		7F 34			3	1	2	P	3	4B 06			5	1	1	P	1
		7F 27			8	1	2	CP	2	7F 30			8	1	2	CP	3
		4B 07			10	2	2	CP	1	3A 01			12	4	4	CP	4
		8A 04			4	2	2	P	4	3A 01			20	4	4	P	1
		3A 09			20	2	2	CP	3	1P070001			20			CP	1
		1P 12			20			P	4	3A 03			25			CP	4
		1P070002			27			CP	1	1P 11			27			P	3
070007	RØTATIØN, FLARE, AND	3A 06			0			CP	4	1P070003			1			CP	1
	GEAR UP	1P 11			1			CP	3	4A 24			2	7	3	P	1
		3A 01			4	2	2	CP	2	4D 07			15		2	CP	2
		4D 09			16		2	CP	3								
070008	SET HEADING BUGS TØ	3S 11			0			P	1	3S 12			5			P	2
	090 DEG AND CØURSE	3S 11			5			CP	1	3S 12			10			CP	2
	BUGS TØ 105 DEG																

Figure 31.—Event/Procedure Data Coding Form—Example

7.3.2.1 Procedure Code Number and Description

Each procedure is given a name or description and a procedure code number with up to six characters.

In the scenarios analyzed in this report, a procedure coding convention was adopted that is similar to the one used for events. (See sec. 7.3.1.) In this convention, the first four characters are the code number for the flight phase in which the procedure was first used. The last two numbers are the sequence number of the procedure during the phase. This is an arbitrary convention, and the analyst is free to assign any unique alphanumeric code using from one to six characters.

Almost all tasks that need to be performed can be grouped into procedures. The analyst is free to create meaningful names or descriptions for these procedures. In the detailing of the scenarios analyzed in this report, a repertoire of over 600 procedures has been defined. (See fig. 31.) The reader is referred to Appendix Eight (ref. 4) for a complete catalog of the procedures that have been developed to date.

For those tasks or task sequences in which a procedure name is not necessary or applicable, the analyst can leave the procedure name blank.

The procedures, in general, have been derived from reference 17 as required to accomplish the flights detailed in the various scenarios.

7.3.2.2 Procedure Task Data

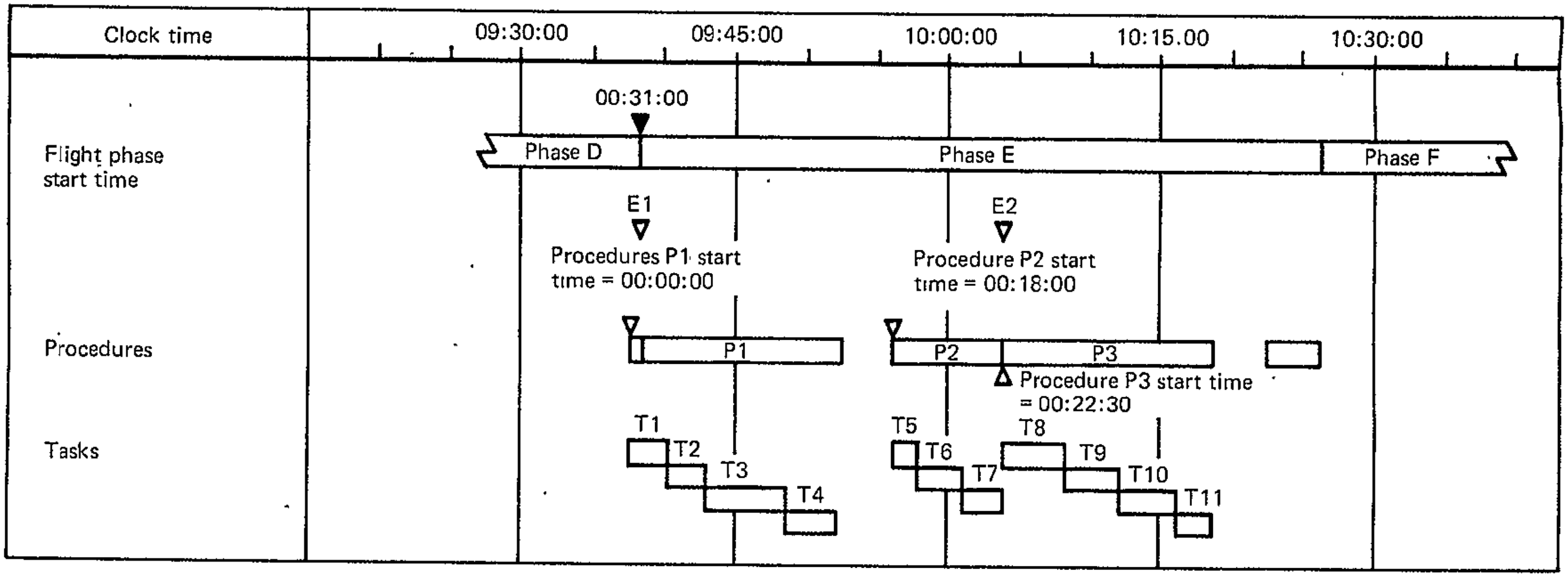
Each procedure is composed of one or more tasks. The analyst lists the task code number of each task to be performed.

The starting time for each task is specified relative to the procedure start time. (See fig. 32.) If a task can be started anytime within a time span, the analyst specifies a nominal task start time and then specifies the allowable time limits ahead and/or back in time. These limits are called the slide time limits. The TLA-1 program will attempt to move (slide) a task within these limitations, if there is a channel overload on a crewmember, in an attempt to relieve the overload. See section 8.3.3 for a detailed description of this process.

For each task in a procedure, the analyst specifies which crewmember performs the task. Each task in a procedure must have its situation number specified. (See sec. 6.5.)

7.3.3 EVENT AND PROCEDURE START TIMES

The start time for each event and procedure is specified relative to the phase start time. (See sec. 7.2.2.) As figure 32 shows, the start time of an event or procedure is expressed as hours:minutes:seconds after the start of the flight phase in which the procedure takes place.



Clock time	Phase	Phase start time	Procedure/ event	Procedure/event start time	Task	Task start time
09:38:00	E	00:31:00 = 31 min after start of mission	E1	00:00:00		
			P1	00:00:00	T1 T2 T3 T4	00:00.00 [a]00:02:00 00:04:00 00:11:00
09:56:00			P2	00:18:00 = 18 min after start of phase E	T5 T6 T7	00:00:00 [b]00:01:30 00:04:15
10:00:30			E2	00:22:30		
			P3	00:22:30	T8 T10 T9 T11	00:00:00 00:07:00 00:04:30 00:12:30

[a]2 min after start of P1

[b]1 min 30 sec after start of P2

Figure 32.—Task Start Time

8.0 DATA PROCESSING

This section contains abbreviated descriptions of the TLA-1 program organization, data input, processing computations, and output data formats. This section is not to be used as directions for coding. Users are referred to the TLA-1 User's Guide (ref. 2) for complete instructions on how to use the TLA-1 model. For detailed information concerning the TLA-1 code, refer to the TLA-1 Programmer's Guide (ref. 3), which contains program flow charts, the program code, etc.

8.1 PROGRAM STRUCTURE

The program is divided into four modules. (See fig. 33.)

1. Control

2. Input (sec. 8.2)

3. Processor (sec. 8.3)

4. Report generation (sec. 8.4)

The control module processes all control cards and initiates the other three modules.

All mission data is input through the input module and output to an external permanent file.

The processor performs all calculations and functions and outputs the results to an external file. The input to the processor comes from the data stored by the input module.

The report generation module receives inputs of report requests and acts to produce the requested reports by using the data from the two external files created by the input module and the processor module. There may be as many as three sets of external files (different configurations of the same mission) input to create some reports.

8.2 INPUTS

Inputs to TLA-1 are from two sources: card and tape. The following sections describe the card types and formats and the tape inputs.

8.2.1 CARD INPUT

Card inputs to TLA-1 are of three classes:

1. Control specification (sec. 8.2.1.1)

2. Mission data (sec. 8.2.1.2)

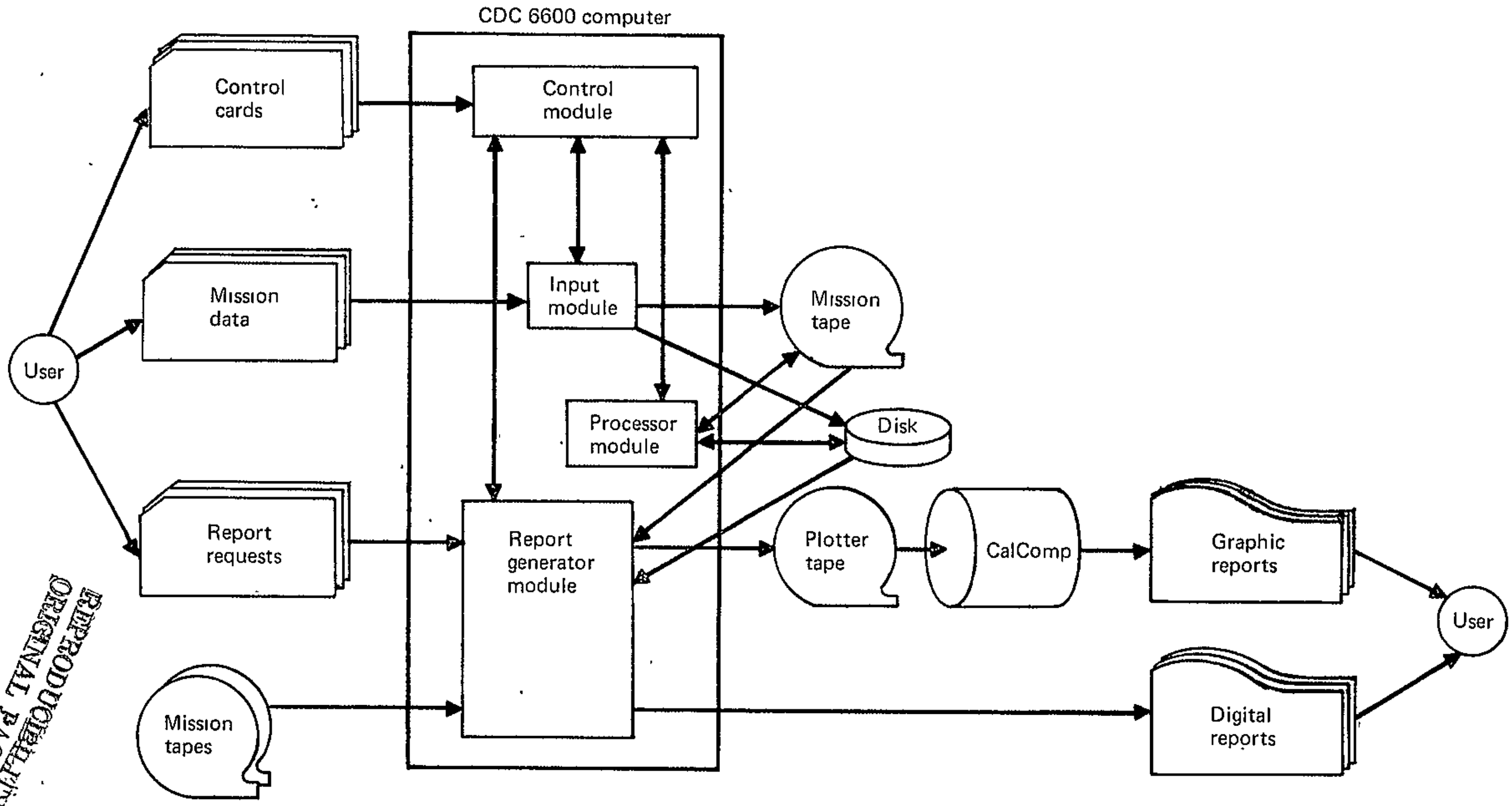


Figure 33.—TLA-1 System Diagram

3. Report request specification (sec. 8.2.1.3)

The control specifications cause the functions to be executed. The mission data prescribe in detail a mission timeline. The report request specification causes reports to be generated.

8.2.1.1 Control Card

Control card input is used to initiate four functions: (1) input, (2) process, (3) output, and (4) terminate.

The input function cuases the mission specification data to be input from cards, listed, and output to the mission tape.

The process function reads mission data from the mission tape, performs all functions specified in section 8.3, and outputs the processing results to a second file on the mission tape.

The output function inputs report request specification cards and one, two, or three mission tapes to create requested reports and plot tapes.

The terminate function causes all files to be closed and causes termination of program execution.

8.2.1.2 Mission Data Input

The mission data input is classified into five types: (1) mission specification, (2) phase specification, (3) event/procedure specification, (4) task specification, and (5) subsystem specification.

8.2.1.2.1 Mission Specification Input.–The mission specification will be given by three data types: (1) mission parameters, (2) mission profile, and (3) crewmember titles. Figure 34 is a sample of the mission data coding form that is used to specify the data types. Table 12 provides an explanation for the inputs.

8.2.1.2.2 Phase Specification Input.–As discussed in detail in section 7.2, the phase specification consists of phase identification, and even and procedure assignment. See figure 35.

The phase identification is a code of four characters and a name of up to 60 characters. The phase name can extend to 60 characters by continuing the name, 20 characters per card, for as many as three continuation cards. A card is a continuation of the phase if the first four columns are blank on succeeding cards.

Each event and procedure assigned to the phase is specified by an event or procedure number and the start time of the event or procedure relative to the phase start time. The start time is given in hours, minutes, and seconds.

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TLA-1
MISSION DATA CODING FORM

PROGRAM	PAGE OF
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MISSION PARAMETERS

RUN DATE	MISSION TITLE	TIME INTVL (SEC)	STRT TM HR	STRT TM MIN	SLIDE INTVL (SEC)	SLIDE THSHD %	RUN CODE	CONFIGURATION TITLE
NOV 1, 1975	SCENARIØ 1B - ILS WITH MALFUNCTIØNS	5	00	00	1	80	2	1454 515 - FFD

MISSION PROFILE

NO. 10

PHASE CODE NO.	HR	MIN	SEC	PHASE CODE NO.	HR	MIN	SEC	PHASE CODE NO.	HR	MIN	SEC	PHASE CODE NO.	HR	MIN	SEC	PHASE CODE NO.	HR	MIN	SEC	PHASE CODE NO.	HR	MIN	SEC	PHASE CODE NO.	HR	MIN	SEC
0100	0	0	0	0300		15	20	4900		18	50	4700		31	00	49FE		34	35	11XX	1	04	20	1400	1	17	55
16EK	1	57	35	23EK	2	20	50	20EK	2	23	40																

CREWMEMBERS

NO. 2

CODE	NAME	CODE	NAME	CODE	NAME
P	PILØT	K	PRCØ-PILØT		

Figure 34.—Mission Data Coding Form—Example

Table 12.—Mission Specification Input

Parameter	Description
RUN DATE	Date for the run, put on each report generated
MISSION TITLE	Title, put on each report generated
TIME INTVL	Time interval in seconds for the task processor· The entire mission is broken into intervals of this value. It is also the interval used for the statistics. This interval is the smallest interval for which channel workloading is considered. It is the total channel workload in this interval that is checked for exceeding of workload threshold.
STRT TM	Mission start time: The first two digits are hours, the second two digits are minutes.
SLIDE INTVL	Time step in seconds used for sliding a task if a channel threshold is exceeded
SLIDE THSHD	Channel threshold percentage criterion used to determine channel overload for task sliding
MISSION PROFILE	Number of phases specified for the mission
PHASE CODE NO.	A four-character phase designator
PHASE START TIME	Start time for the phase relative to mission start time: The first two digits are hours, the second two are minutes, and the last two are seconds.
NO. OF CREWMEMBERS	The number of crewmembers specified for the mission
CREWMEMBER CODE	A one- or two-character code to designate the crewmember
CREWMEMBER NAME	A 20-character label used on all report title blocks for a crewmember
RUN CODE	A two-digit integer to identify the run number
CONFIGURATION TITLE	Label used on all reports to designate the cockpit layout and manning

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TLA-1

PHASE DATA CODING FORM

PROGRAM	PAGE OF
PROGRAMMER	DATE

PHASE CODE NO.	PHASE NAME	EVENT/PROC CODE NO.	HR	MIN	SEC	EVENT/PROC CODE NO.	HR	MIN	SEC	EVENT/PROC CODE NO.	HR	MIN	SEC	EVENT/PROC CODE NO.	HR	MIN	SEC
A400	TAXI - BEFØRE TAKEØFF	040001			0	040002			18	030007		1	00	040003		2	48
	(EED)	040004		4	54	040005		6	24	040006		7	21	030007		2	00
		030007		3	00	030007		4	00	030007		5	00	030007		6	00
		030007		7	00	040007		8	21	040008		10	08				

Note: The EVENT/PROC start time column headings read "EVENT/PROC START TIME".

Figure 35.—Phase Specification—Example

8.2.1.2.3 Event/Procedure Specification Input.–As described in detail in sections 7.3.1 and 7.3.2, an event or procedure is specified by an identification code and a character name. A procedure is further specified by one or more associated task situations. Each task situation is specified by a task code, a start time, a slide time option, and the crewmember performing the task. Figure 36 is a sample coding form for the event/procedure specification.

The task code consists of two parts. The first part specifies the associated subsystem and is a two-digit alphanumeric code in the left of the task code field. The second part is an integer right-adjusted in the task code field.

The start time is relative to the procedure start time and is given in hours, minutes, and seconds.

The slide interval specifies the number of seconds the task may slide if a shift threshold is exceeded by a channel workload. (See sec. 8.3.3.) The first two columns specify the number of seconds that may be stepped backward; the second two columns specify the number of seconds that may be stepped forward.

The crewmember code is input for the crewmember or crewmembers responsible for the task.

If more than two task situations exist for a procedure, they may be added on succeeding cards, leaving the procedure number and procedure name description blank. In other words, succeeding cards are considered a continuation of the event/procedure specification if the first six columns are blank.

8.2.1.2.4 Task Specification Input.–As discussed in detail in section 5.0, a task is specified by a code number, a descriptive title, a set of situations, and the associated workload for each channel. Figure 37 is a sample of the task specification coding form.

The identification consists of a two-word code and a name of up to 60 characters. The first word of the identification code is two characters identifying the subsystem used in the task, and the second word is the integer that is the task number. The 60 characters are placed on consecutive cards, 20 per card, leaving the first eight columns blank on the continuation cards.

A situation within a task is identified by an integer (from 1 to 4) and the task-situation duration time in seconds. Situations are placed on successive cards, leaving the first eight columns blank on all cards except the first to denote a continuation.

The workload (percentage of channel use during task-situation duration) is specified for each of the following nine channels:

1. EV (external vision)

2. IV (internal vision)

3. LH (left hand)

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TLA-1
EVENT/PROCEDURE DATA CODING FORM

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EVENT/PROC CODE NO.	EVENT/PROCEDURE NAME OR DESCRIPTION	TASK CODE NO.	TASK START TIME HR	MIN	SEC	SLIDE (SEC) −	+	CREW MEMBER	TASK CODE NO.	TASK START TIME HR	MIN	SEC	SLIDE (SEC) −	+	CREW MEMBER
070004	CLEARED TØ TAXI ØNTØ	1B 14			0			CP1	1B 15			0			CP1
	RUNWAY 9L	1P070005			0			CP1	1P070006			3.6			CP1
		1B 18			6			*2	1P070007			6			*1
		1B 14			9			CP2	1B 15			9			CP2
		1P070008			9			CP1	4D 52			13			P1
		4B 03			14			P2	4M 01			14			P4
		4B 03			24			P1	4D 28			27			P1
		8A 04			10			P3							
070005	RECEIVE TAKEØFF	1B 18			0			P2	1P070009			0			*1
	CLEARANCE	1B 14			3			P3	1B 15			3			P3
		1P070010			3			P1							
070006	TAKEØFF RØLL	8A 02			0			P1	4A 64			0		2	P1
		4B 05			0			P1	7F 29			3	1	2	P2
		7F 34			3	1	2	P3	4B 06			5	1	1	P1
		7F 27			8	1	2	CP2	7F 30			8	1	2	CP3
		4B 07			10	2	2	CP1	3A 01			12	4	4	CP4
		8A 04			4	2	2	P4	3A 01			20	4	4	P1
		3A 09			20	2	2	CP3	1P070001			20			CP1
		1P 12			20			P4	3A 03			25			CP4
		1P070002			27			CP1	1P 11			27			P3
070007	RØTATIØN, FLARE, AND	3A 06			0			CP4	1P070003			1			CP1
	GEAR UP	1P 11			1			CP3	4A 24			2	7	3	P1
		3A 01			4	2	2	CP2	4D 07			15		2	CP2
		4D 09			16		2	CP3							
070008	SET HEADING BUGS TØ	3S 11			0			P1	3S 12			5			P2
	090 DEG AND CØURSE	3S 11			5			CP1	3S 12			10			CP2
	BUGS TØ 105 DEG														

Figure 36.—Event/Procedure Specification—Example

BOEING
TLA-1
TASK DATA CODING FORM

PROGRAM	PAGE OF
PROGRAMMER	DATE

TASK CODE NO. SUBSYS	TASK CODE NO.	TASK NAME AND/OR DESCRIPTION	STEP	DURATION TIME (SECONDS)	EV	IV	LH	RH	LF	RF	COG	AUD	VBL
7A	28	ACTUATE ANNUN PNL	1	2.28		10	100				20		
		RECALL SW	2	1.93		10	100				20		
7A	29	CHECK SYS B	1	.90		100					20		
		SW'S OFF	2	1.52		100					20		
7A	30	CHECK ENG NO. 1 SYS A HYD PUMP SW SET TO ON	1	1.36		100					20		
7A	31	CHECK ENG NO. 2 SYS A HYD PUMP SW SET TO ON	1	.75		100					20		
7A	32	MON HYD SYS SW'S	1	2.0		100					20		
7A	33	MON MASTER CAUTION	1	.70		100					20		
		AND ALL ANNUN PNL LTS ILLUMINATED	2	.54		100					20		
7A	34	SET GROUND INTER-	1	1.48		100	100				20		
		CONNECT SW TO OPEN	2	2.58		100		100			20		
7A	35	SET GROUND INTER-	1	1.48		100	100				20		
		CONNECT SW TO CLOSED	2	2.58		100		100			20		
7A	36	MON ALL ANNUN LTS OFF	1	.53		100					20		

Figure 37.—Task Specification—Example

4. RH (right hand)

5. LF (left foot)

6. RF (right foot)

7. COG (cognitive)

8. AUD (auditory)

9. VBL (verbal)

8.2.1.2.5 Subsystem Specification Input.–A subsystem is specified by a 2-character code and a 30-character name. In addition, eight columns are allotted for the ATA code number (ref. 30). Figure 38 is a sample coding form for preparation of this input.

8.2.1.3 Report Request Specifications

Fifteen different inputs are used to specify the reports to be generated. They are divided into three types:

1. Digital report request specifications (sec. 8.2.1.3.1)

2. Graphic report request specifications (sec. 8.2.1.3.2)

3. Class output specifications (sec. 8.2.1.3.3)

Samples of printer and plotter outputs are included in section 8.4.

A sample report request coding form is shown in figure 39. An explanation of required inputs or options is given in the section pertaining to the requested report.

A report is requested by a three-character code in the report field of the report request card. Table 13 is a cross reference for the report request codes. For each report, none, one, two, . . ., or five of the options in table 14 may be specified, or selected standard options may be requested by using SR1 through SR4.

8.2.1.3.1 Digital Report Request Specifications.–There are seven different line printer output reports: (1) mission scenario (MNS), (2) crewman workload profile (CWP), (3) crewman workload summary statistics (CWS), (4) task-channel activity (TCA), (5) subsystem activity (SSA), (6) subsystem activity summary (SAS), and (7) task list (TLS). Resulting reports are shown in section 8.4.

8.2.1.3.2 Graphic Report Request Specifications.–The following five plots will be available for request: (1) channel activity (CAS), (2) workload histogram (WLH), (3) workload summary (WLS), and (4) mission timeline (MTL). The resulting plots are shown in sec. 8.4.

BOEING
TLA-1
SUBSYSTEM CODING FORM

SUBSYS CODE	SUBSYSTEM NAME	ATA CODE NO.
1A	VHE-1 (FFD)	23-21-02
1B	VHF-2 (F.F.D)	23-21-02
1F	INTERPHØNE	23-42-03
1G	PUBLIC ADDRESS	23-31-00
1H	GRØUND CREW CALL	23-43-00
1J	VØICE RECØRDER	23-71-02
1M	SELCAL	23-28-00
1N	TRANSPØNDER	34-53-02
1P	VØICE	
1Q	VHF-1 (AED)	23-21-02
1R	VHF-2 (AFD)	23-21-02
1S	VHE-3 (AFD)	23-21-02
1T	LØUDSPEAKER	23-21-02

Figure 38.—Subsystem Specification—Example

BOEING
TLA-1
REPORT REQUEST CODING FORM

PROGRAM		PAGE OF
PROGRAMMER		DATE

REPORT PLOT CODE			PHASE	REPORT	SUBSYSTEM	AVE/AVE ± 1 SIG		COMPARISONS 1 RUN CODE	PHASE CODE	PLOTTER TYPE
CWP	**	*	****							
CWS	**	*	****							
MNS	**	*	****							
TCA	**	*	****	50						
SSA	**	*	****	50	1Q					
SSA	**	*	****	50	1R					
SSA	**	*	****	50	4A					
WLS	**	*				A+1		50	0200	
WLS	**	*				A+1		50	0300	
WLS	**	*				A+1		50	8400	
WLS	**	*				A+1		50	8700	
WLS	**	*				A+1		50	8900	
WLS	**	*				A+1		50	1300	
WLS	**	*				A+1		50	1500	
WLS	**	*				A+1		50	1800	
WLS	**	*				A+1		50	2300	
WLS	**	*				A+1		50	2000	
CAS	**	*	****			A+1				
WLH	**	*		75			AVC	50		
MTL	**	*	****							

Figure 39.—Report and Plot Request Specification—Example

Table 13.—Report Request Codes

Report/plot code	Report
MNS	Mission scenario
CWP	Creman workload profile
CWS	Crewman workload summary statistics
TCA	Task channel activity
SSA	Subsystem activity
SAS	Subsystem activity summary
TLS	Task list
CAS	Channel activity
WLH	Workload histogram
WLS	Workload summary
MTL	Mission timeline
SR1	Standard report set 1
SR2	Standard report set 2
SR3	Standard report set 3
SR4	Standard report set 4

Table 14.—Report Request Options

Option	Description
Crewmember (CRWMBR)	A two-character code that must be one of those input on the crewmember card of the mission data cards: If a report is to be generated for each crewmember, the two characters will be "**" (double astrisk).
Shift option (SHIFTED/UNSHIFTED)	A one-character code specifying the shift option as follows: S, report with task shifting U, report with no task shifting *, a report with task shifting and a report with no task shifting
Phase	A four-character code that must be one of the codes on the mission profile card in the mission data cards: If the four-character code is all asterisks ("****"), then a report is created for every phase.
Report threshold (RPT THSHD)	An integer specifying the percent workload governing the output of the report: It is an exclusion parameter that causes only workloads exceeding its value to be considered for the report.
Subsystem (SUB SYST)	A two-character code that identifies the subsystem to be considered for certain outputs: This must be one of the subsystems in the subsystem input.
Average + 1 or average (AVE/AVE + 1 SIG)	A three-character code that controls bar plots and is used to specify the average plus 1σ bars ("A+1") or the average-only bars ("AVE").
Channel or channel group (CHNL/TOT)	A three-character field used to specify a specific channel, channel group, or average channel. The following are valid codes. Channels EV External vision — RF Right foot IV Internal vision — COG Cognitive LH Left hand — AUD Auditory RH Right hand — VBL Verbal LF Left foot Channel Groups VIS Visual — COG Cognitive MOT Motor — COM Communicative Average Channel AVC Weighted average channel
COMPARISONS	A set of three fields that identifies up to three sets of runs-phases to be compared in the comparison bar charts
PLOTTER TYPE	A six-character code that identifies the type of plotting machine to be used: CALCMP CALCOMP PLOTTER SC4020 SC4020 PLOTTER

8.2.1.3.3 Class Output Specifications.–Four classes of output cause sets of reports to be generated as requested by the SR1, SR2, SR3, or SR4 request codes. Table 15 specifies the reports for each class.

8.2.2 MISSION DATA TAPE INPUT

This tape consists of two files: one for the mission data card input and the other for the processor module output, which will be used to generate the reports. The use of tape inputs is discussed in detail in the User's Guide (ref. 2).

8.3 PROCESSING FUNCTIONS

This section describes the following functions to be performed to produce data for the output reports: (1) task processing, (2) phase statistics, (3) task-situation time shift, (4) task-channel activity calculations, and (5) subsystem activity calculations.

8.3.1 TASK PROCESSING

The task processing function uses the task-situation channel workloads and performs the following:

1. Calculates the time intervals spanned by the task situation

2. Calculates the workload contributions to study-time intervals

3. Updates the study-time interval workload sums

4. Calculates the channel group workload

5. Calculates the weighted average channel workload

8.3.1.1 Time Intervals Spanned by a Task

The equations giving the time intervals spanned by a task are presented in this section.

If a task starts at time t_{TS} (fig. 40) and is of duration t_T, the first interval within a phase in which the task contributes to workload is T_{ISF} to $(T_{ISF} + \Delta t)$. T_{ISF} is given by

$$T_{ISF} = \left[t_{TS}/\Delta t\right] \Delta t$$

where

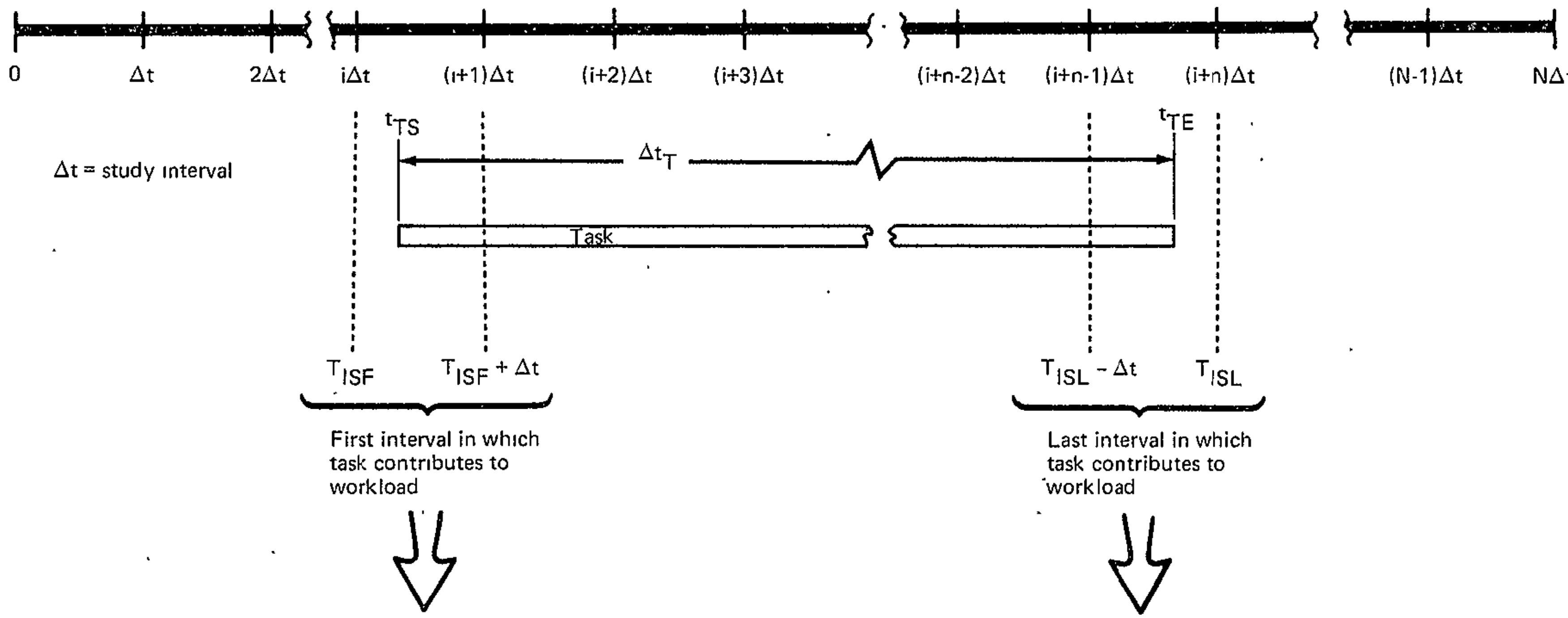
$[\ ]$ indicates the greatest integer less than or equal to the expression in the bracket

Δt is the study-time interval

Table 15.—Standard Report Requests

Standard report request number	Description
1 (SR1)	The following reports are for all crewmembers, are nonshifted, and are for all phases with an option for subsystem and task channel activity reports. Crewman workload profile report Crewman workload summary statistics report Mission scenario report The following two types of reports are selected with the subsystem option and with a threshold of 75%. Subsystem activity reports Task channel activity report
2 (SR2)	This report set is the same as SR1 but with shifting.
3 (SR3)	This report set is the same as SR1 plus the following plots: Workload summary plot with average plus 1σ and standard configuration Channel activity plots with average plus 1σ Workload histograms with standard configuration and average channel Mission timeline plot
4 (SR4)	This report set is the same as SR3 but with shifting. When comparative data plots are to be output (workload summary plot, workload histogram), it is necessary to load the mission tapes (two maximum) of the runs that will be compared with the data from the run being processed. Mission tape input: The mission tape will consist of two files. The first will be the mission data card input and the second will be a file of the process module output that will be used to generate the reports.

Note: These calculations are performed for each task.



$T_{ISF} = [t_{TS}/\Delta t]\ \Delta t$

$$T_{ISL} = \begin{cases} [t_{TE}/\Delta t]\ \Delta t & \text{if } t_{TE} \text{ is a multiple of } \Delta t \\ [t_{TE}/\Delta t]\ \Delta t + \Delta t & \text{if } t_{TE} \text{ is not a multiple of } \Delta t \end{cases}$$

where [ ] = greatest integer ≤ to value in brackets

Figure 40.—Time Intervals Spanned by a Task

The last interval in which the task contributes is $(T_{ISL} - \Delta t)$ to T_{ISL}, and

$$T_{ISL} = \begin{cases} [t_{TE}/\Delta t]\,\Delta t, \text{ if } t_{TE} \text{ is a multiple of } \Delta t \\ [t_{TE}/\Delta t]\,\Delta t + \Delta t, \text{ if } t_{TE} \text{ is not a multiple of } \Delta t \end{cases}$$

The square brackets [ ] indicate the greatest integer less than or equal to the value in the brackets.

The task end time t_{TE} is given by

$$t_{TE} = t_{TS} + \Delta t_T$$

Examples of this computation are shown in figures 41 and 42.

8.3.1.2 Channel Workload for Study-Time Interval

If a study-time interval is from t_{IS} to t_{IE} (fig. 43) the associated percent channel workload W_A is calculated from

$$W_A = \frac{[\min(t_{IE}, t_{TE}) - \max(t_{IS}, t_{TS})]\, W_{CT}}{\Delta t}$$

where

t_{IS} = interval start time

t_{IE} = interval end time

Δt = time interval between t_{IS} and t_{IE}

t_{TS} = task start time

t_{TE} = task end time

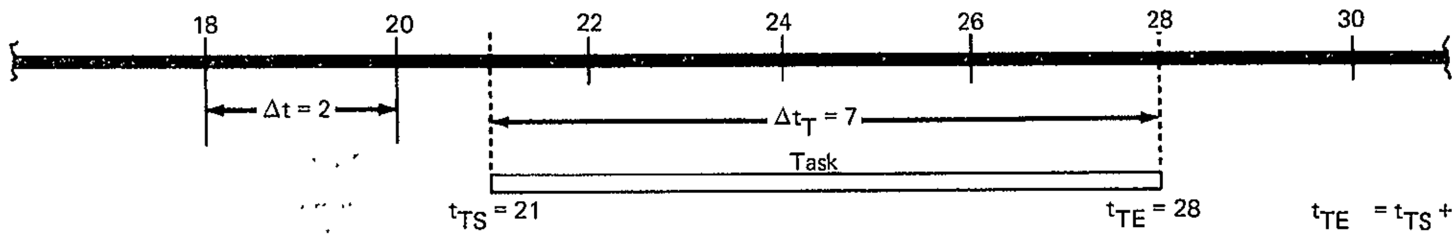
W_{CT} = percent channel workload for the task situation

Figure 44 shows an example of this computation.

8.3.1.3 Update of Study-Time Interval Workload Adders

A sum exists for each channel, channel group, and the weighted average channel for every study-time interval.

Using the equation in section 8.3.1.2, the contribution of each of the sums is calculated and accumulated into the appropriate study-time interval sums.



$$t_{TE} = t_{TS} + \Delta t_T = 21 + 7 = 28$$

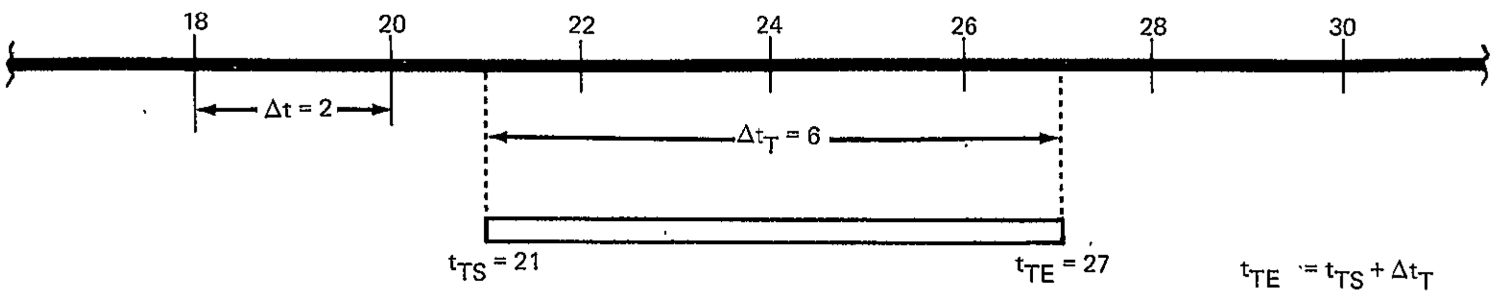
$$T_{ISF} = [t_{TS}/\Delta t]\ \Delta t = \frac{21}{2}\ 2 = [10.5]\ 2 = (10)\ (2)$$

$$T_{ISF} = 20$$

$$T_{ISL} = [t_{TE}/\Delta t]\ \Delta t = \frac{28}{2}\ 2 = (14)\ (2)$$

$$T_{ISL} = 28$$

Figure 41.—Sample Calculation of Time Intervals Spanned by a Task—Example A

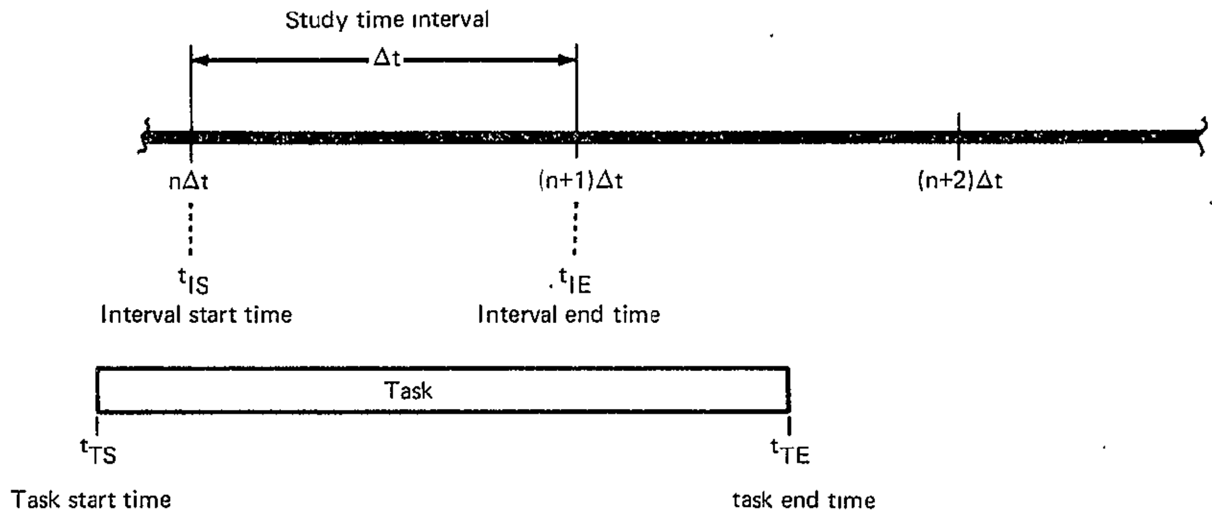


$$t_{TE} = t_{TS} + \Delta t_T$$
$$= 21 + 6$$
$$= 27$$

$$T_{ISF} = [t_{TS}/\Delta t]\ \Delta t$$
$$= \frac{21}{2}\ 2$$
$$= [10.5]\ 2$$
$$= (10)\ (2)$$
$$T_{ISF} = 20$$

$$T_{ISL} = [t_{TE}/\Delta t]\ \Delta t + \Delta t$$
$$= \frac{27}{2}\ 2 + 2$$
$$= [13.5]\ 2 + 2$$
$$= (13)\ (2) + 2$$
$$= 26 + 2$$
$$T_{ISL} = 28$$

Figure 42.—Sample Calculation of Time Intervals Spanned by a Task—Example B



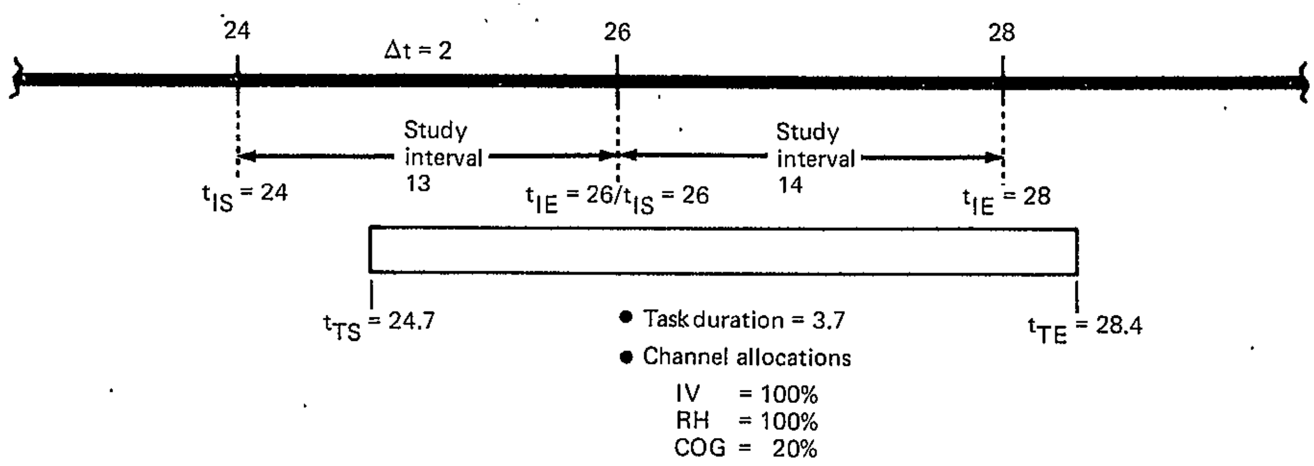
Workload for channel N during study time interval $= W_{A,N} = \dfrac{[\min (t_{IE}, t_{TE}0 - \max (t_{IS}, t_{TS})]}{\Delta t} W_{CT,N}$

where $W_{CT,N}$ = the allocated channel N activity

Note:
This calculation is performed for each channel, channel group, and weighted average for each study time interval for every task that occurs within the study time interval.

The results of this computation for each channel, channel group, and weighted average are accumulated into the appropriate study time interval sums.

Figure 43.—Channel Workload for Study-Time Interval Calculation



Workload for IV channel
during study interval 13

$$W_{A,IV} = \frac{[\min(t_{IE}, t_{TE}0 - \max(t_{IS}, t_{TS})]}{\Delta t} W_{CT,IV}$$

$$= \frac{[\min(26,28.4) - \max(24,24.7)]\ (100)}{2}$$

$$= \frac{(26 - 24.7)\ (100)}{2}$$

$$= 26\%$$

Workload for IV channel
during study interval 14

$$= \frac{[\min(28,28.4) - \max(26,24.7)]\ (100)}{2}$$

$$= \frac{(28 - 26)\ (100)}{2}$$

$$= 100\%$$

Figure 44.—Example of the Channel Workload for Study-Time Interval Calculation

8.3.1.4 Channel Group Workload Calculation

For each task situation, the visual, motor, communication, and cognitive channel group workloads are calculated from the following equations:

$$W_{G,VIS} = W_{C,IV} + W_{C,EV}$$

$$W_{G,MOT} = \frac{(W_{C,LH} + W_{C,RH} + W_{C,LF} + W_{C,RF})}{4}$$

$$W_{G,COM} = W_{C,VBL} + W_{C,AUD}$$

$$W_{G,COG} = W_{C,COG}$$

where

$W_{C,IV}$ = internal vision workload

$W_{C,EV}$ = external vision workload

$W_{C,LH}$ = left-hand workload

$W_{C,RH}$ = right-hand workload

$W_{C,LF}$ = left-foot workload

$W_{C,RF}$ = right-foot workload

$W_{C,VBL}$ = verbal workload

$W_{C,AUD}$ = auditory workload

$W_{C,COG}$ = cognitive workload

8.3.1.5 Weighted Average Channel Calculation

The weighted average channel $\overline{W}$ is the average of the channel group workloads.

$$\overline{W} = \frac{(W_{G,VIS} + W_{G,MOT} + W_{G,COM} + W_{G,COG})}{4}$$

8.3.2 PHASE STATISTICS

The following statistics are calculated across all time intervals in a phase for each channel, each channel group, and the weighted average channel:

1. Workload sum S_W

2. Sum of the squares of workload S_{W2}

3. Mean workload $\overline{W}$

4. Workload variance σ^2

5. Standard deviation of the workload σ

The equations for the five calculations are:

$$S_W = \sum_{i=1}^{N_I} W_i$$

$$S_{W2} = \sum_{i=1}^{N_I} W_i^2$$

$$\overline{W} = S_W/N_I$$

$$\sigma^2 = S_{W2}/(N_I - 1) - \overline{W}^2$$

$$\sigma = \sqrt{\sigma^2}$$

where

N_I = the number of time intervals

W_i = the workload for time interval i

8.3.3 TASK-SITUATION TIME SHIFT FUNCTION

After all task processing has been completed, the shift function will be performed if the option is specified. The shift function checks each time interval in turn to determine if any channel workload exceeds a specified shift threshold criterion. If a channel workload exceeds the shift threshold, an attempt is made to slide start times of those task situations contributing to the workload excess. Only those task situations that have the slide option specified are used to attempt reduction of the excess workload.

Priority for shifting to be done is given to those channel workloads with the highest values, which will be the first for which an attempt is made to reduce workload. Further, those task situations that make the highest contribution to the workloads exceeded will be the ones for which the slide is first attempted, if a slide is permissible.

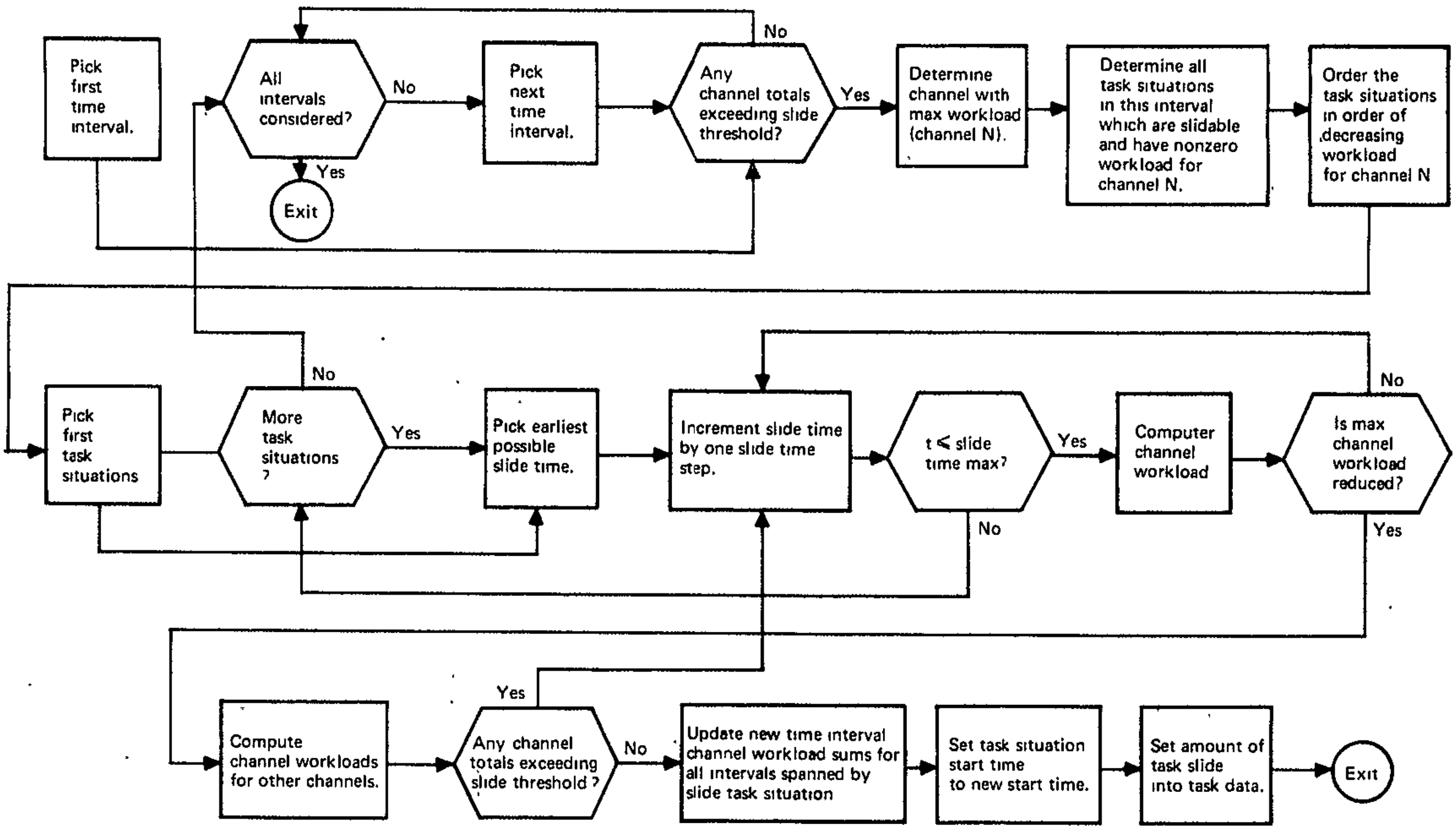
A task situation is permitted to slide only if no other time intervals will have a channel workload exceeding the slide threshold criterion as a result of the slide. A task situation slides back in time to the earliest start time possible without causing other channel workloads to be exceeded in other time intervals.

After all time intervals have been checked and all shifting is performed, the statistics for the shifted timeline are performed by the following procedure (refer to fig. 45):

- Step 1: Pick the first time interval and go to step 3.
- Step 2: Pick the next time interval and go to step 3 unless all time intervals have been considered. If all time intervals have been considered, the sliding process is finished.
- Step 3: If any channel totals in the time interval exceed the slide threshold criterion, go to step 4. Otherwise, go back to step 2.
- Step 4: Determine the channel with the maximum workload. Perform steps 5 through 12 to attempt reduction of this maximum channel workload.
- Step 5: Determine all task situations that are associated with this interval, that are slidable, and that have a nonzero workload for the channel to be reduced. List the task situations in the order of decreasing workload for the channel to be reduced.
- Step 6: Pick the first task situation and go to step 8.
- Step 7: Pick the next task situation if there are more task situations to be considered and go to step 8. Otherwise, go back to step 2.
- Step 8: Pick the earliest possible slide time for the task situation and go to step 9.
- Step 9: Increment slide time by one slide time step and go to step 10 if the resulting slide time is less than or equal to the slide maximum. Otherwise, go back to step 7.
- Step 10: If the maximum channel workload total from step 4 is reduced as a result of the slide, go to step 11. Otherwise, go back to step 9.
- Step 11: If the time intervals spanned by the task situation after sliding do not have a channel total exceeding the slide threshold as a result of the slide, the slide is permitted and step 12 is next. Otherwise, go back to step 9.
- Step 12: Update the new interval channel workload sums as a result of sliding for all intervals spanned by the slide task situation. Set the task-situation start time to the new start time and set the amount of the slide into the task information. Go back to step 3.

8.3.4 TASK-CHANNEL ACTIVITY CALCULATIONS

This set of calculations gives the percent of interval time that a task-situation channel workload contributes to an interval total channel workload if the interval total channel workload exceeds a report threshold.



[a]Performed after all task processing has been completed if this option is specified.

Figure 45.—Task-Situation Time Shift Function[a]

The time intervals are first scanned to determine if any channel workload exceeds the report threshold. If an overload occurs, the task situations contributing to the workload are tagged with the time interval and channel of the overload. The workload for each task-situation channel is calculated by using the equation for W_A in section 8.3.1.2. These workloads are put into the task-channel activity report.

The analytical procedure is shown in figure 46. An example of the calculations is shown in figure 47.

8.3.5 SUBSYSTEM ACTIVITY CALCULATIONS

The purpose of the subsystem activity calculations is to measure how much of the time the subsystems are involved in workloads exceeding given thresholds. Figure 48 shows the analytical procedure used to derive three different measures of the subsystem activity.

For a given subsystem, all related task situations that contribute to a channel workload exceeding a threshold are obtained for each time interval within a phase. As a task situation is tagged, the associated channel workload contributing to the excessive workload is tagged as well. These tagged channel workloads will be referred to as channel overload contributors.

The next step is to add all channel overload contributors for a given channel and count the number N_{COC}. This sum is called the total channel overload contribution W_{OVLD}.

The next step is to ascertain the number of time intervals $N_{\Delta T}$ for each phase channel in which there are channel overload contributors and then to calculate the total interval time for a channel in which an overload occurs by using the equation

$$\Delta T_{INT} = N_{\Delta T}\ \Delta t$$

where Δt is the time interval.

The ratio of total channel overload contributions to total interval time is given by

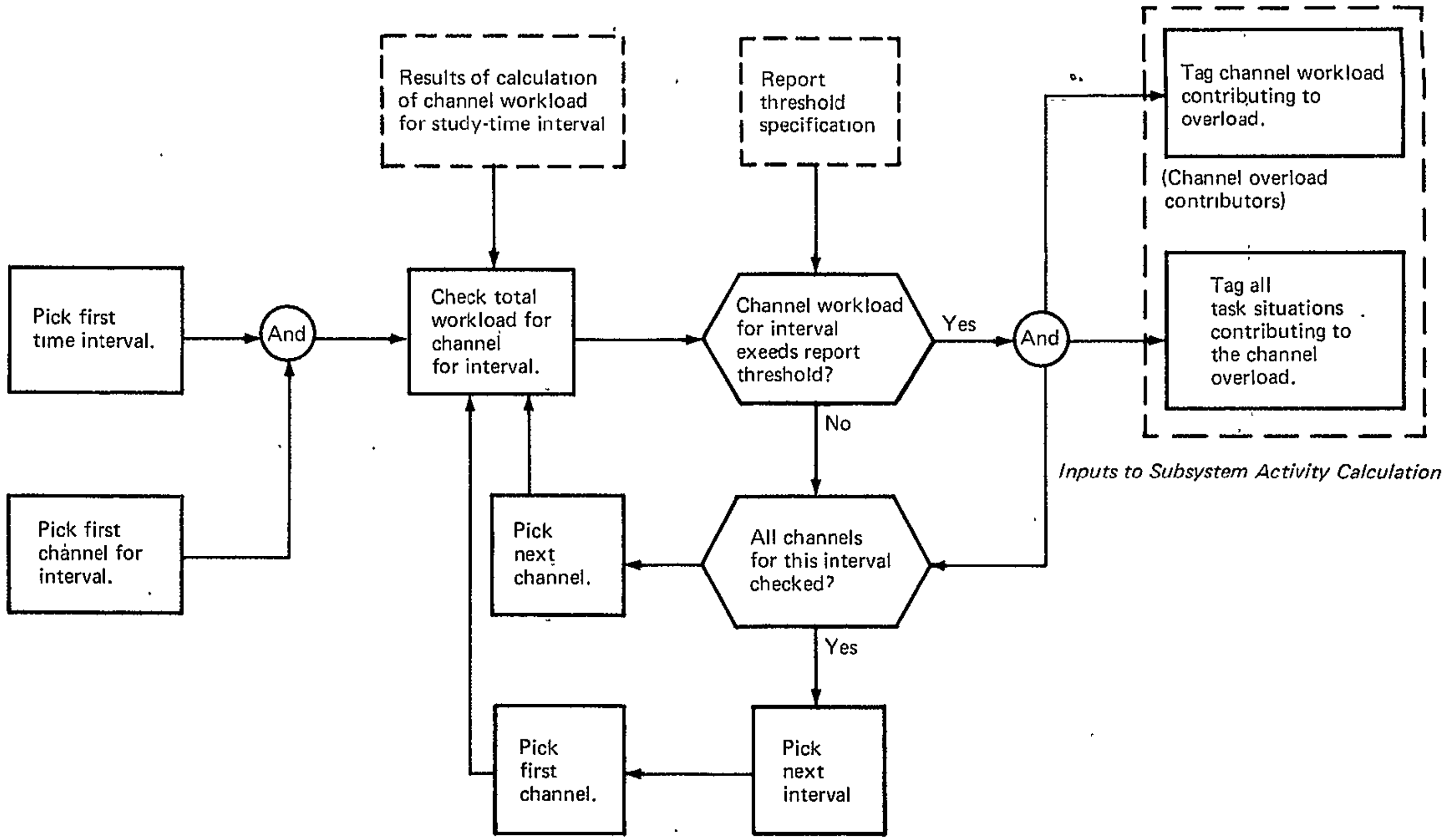
$$R_{INT} = \frac{W_{OVLD}}{\Delta T_{INT}}$$

See figure 49 for an example of interval time calculation.

The ratio of total channel overload contribution to phase total time is given by

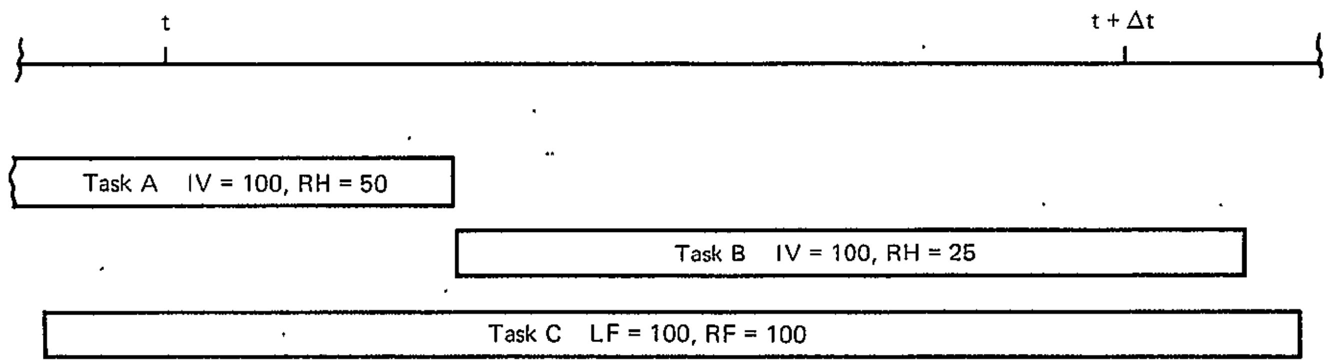
$$R_{PHS} = \frac{W_{OVLD}}{\Delta T_{PHS}}$$

where ΔT_{PHS} is the time between the phase start and the start of the next phase. See figure 50 for an example of phase time calculation.



[a]This computation is performed for each phase.

Figure 46.—Task-Channel Activity Calculations[a]



Note: For the study interval t to (t + Δ), the IV channels for task A and task B would be tagged for any report threshold < 100%.

Figure 47.—Example of the Task-Channel Activity Calculation

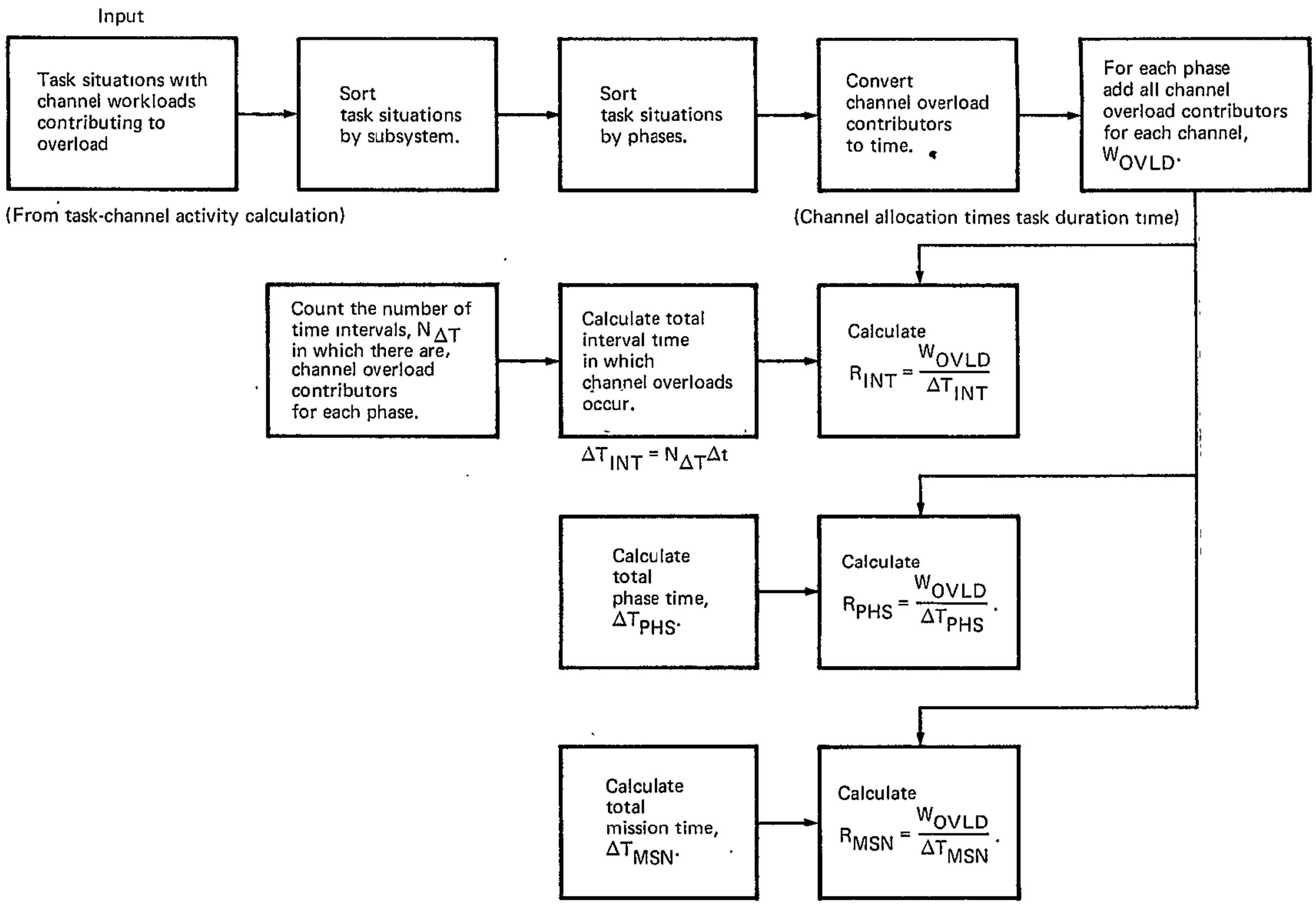
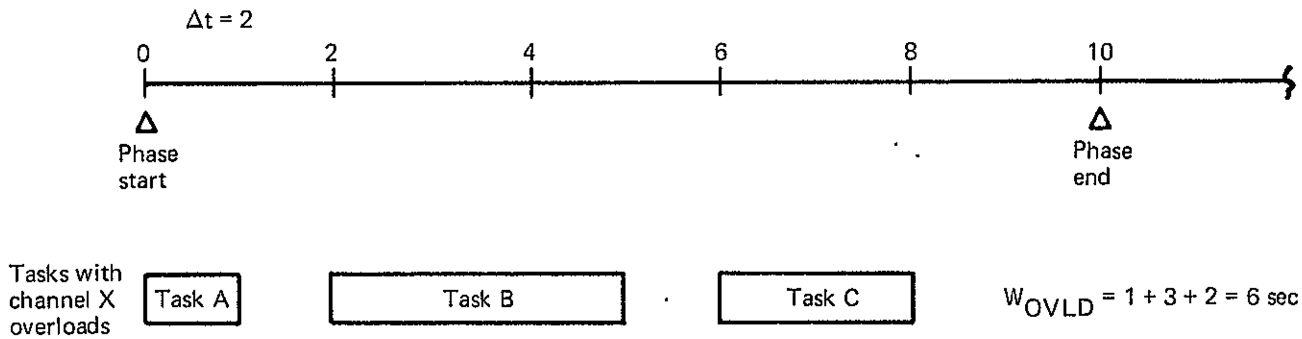


Figure 48.—Subsystem Activity Calculations



$$N_{\Delta T} = \Sigma \text{ intervals occupied by channel overloads}$$

$$= \underset{(\text{task A})}{1} + \underset{(\text{task B})}{2} + \underset{(\text{task C})}{1}$$

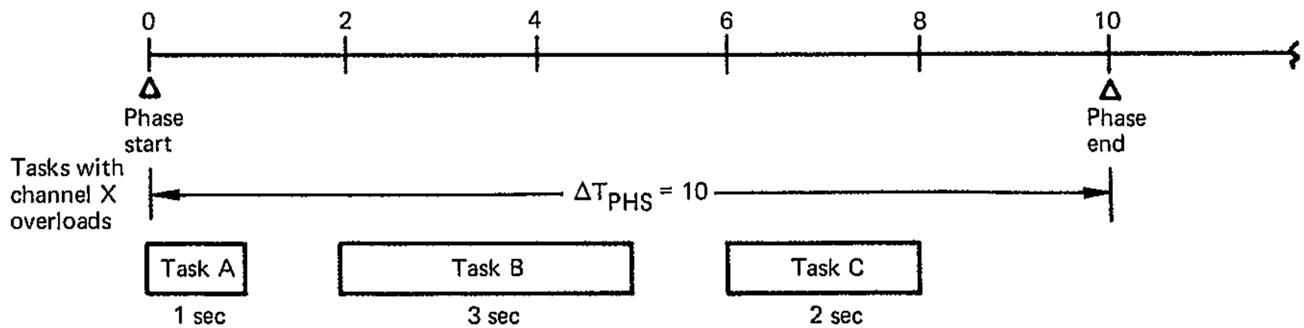
$$= 4 \text{ intervals}$$

$$\Delta T_{INT} = N_{\Delta T}\,\Delta t = 4(2) = 8 \text{ sec}$$

$$R_{INT} = \frac{W_{OVLD}}{\Delta T_{INT}} = \frac{6}{8} = 0.75 = 75\%$$

Note: R_{INT} is the ratio of the total length of time that there is a channel overload during a phase, compared to the total time occupied by the study-time intervals in which the overloads occur.

Figure 49.—Percent Active Time of Interval Time Calculation—Example



$$R_{PHS} = \frac{W_{OVLD}}{\Delta T_{PHS}}$$

$$= \frac{6}{10}$$

$$= 60\%$$

Note: R_{PHS} is the ratio of the total length of time that there is a channel overload during a phase, compared to the total time duration of the phase.

Figure 50.—Percent Active Time of Phase Time Calculation—Example

The ratio of total channel overload contribution to mission total time is given by

$$R_{MSN} = \frac{W_{OVLD}}{\Delta T_{MSN}}$$

where ΔT_{MSN} is the time interval between mission start and mission end. See figure 51 for an example of mission time calculation.

Refer to section 8.4.2.6 for a description of how these statistical subsystem activity measures are used.

8.4 OUTPUTS

Program outputs are to tape, printer, and plotter. The tape output will contain the mission data input and the timeline analysis data generated by the task processing function of the computer program.Two classes of report outputs are specified for the TLA-1 program: digital printer and graphical plotter.

8.4.1 MISSION DATA TAPE OUTPUT

A tape will be used to store the mission data input and the processed data for later use by the report generation function. The tape will consist of two files, one containing the mission data input and the other containing the processor output used by the report generator function.

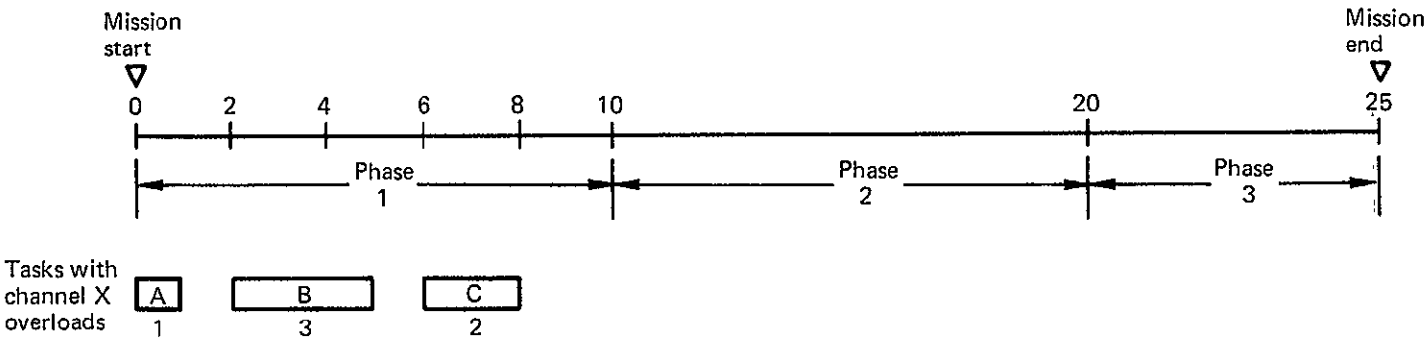
8.4.2 DIGITAL PRINTER OUTPUT

1. Mission scenario
2. Crewman workload profile
3. Crewman workload summary statistics
4. Task channel activity
5. Subsystem activity
6. Subsystem activity summary
7. Task list

The following sections describe these reports, which are generated as a result of the report requests described in section 8.2.1.3.1.

8.4.2.1 Mission Scenario Report

The mission scenario report presents a listing of specified phases and associated events, procedures, and tasks. Relative to the mission start time, the start times of the phases,



$W_{OVLD} = 6$ sec

$\Delta T_{MSN} = 25$ sec

$$R_{MSN} = \frac{W_{OVLD}}{\Delta T_{MSN}} = \frac{6}{25} = 0.24 = 24\%$$

Note: R_{MSN} is the ratio of the total length of time that there is a channel overload during a phase, compared to the total time duration of a mission.

Figure 51.—Percent Active Time of Mission Time Calculation—Example

procedures, and events are output. The start and end time and the activity time are output for each task in the specified phases. In addition, the amount of task shifting is output if the shifting option is specified.

The report is generated for a selected crewmember. Figure 52 is an example of the unshifted format for this report, and figure 53 is an example of the shifted format. The block in the upper left-hand corner contains the word "SHIFTED" or "UNSHIFTED" to denote whether the report contains the shifted tasks. The title block contains three labels of identification: a 40-character mission name, a 20-character configuration name, and a 20-character crewmember name. The run date is listed in the upper right-hand corner.

The report has two purposes:

1. The mission scenario report is used as final documentation to describe the tasks and procedures performed by the operators to accomplish a mission scenario. This report contains the same data as the mission timeline plot (sec. 8.4.3.4); however, it is less expensive to obtain.

2. The mission scenario report is used during the data analysis process to determine all tasks that are being performed during the various study-time intervals.[1]

This report lists the tasks in the exact order that they were specified on the event/procedure coding form; therefore, if procedures and/or tasks were specified out of time sequence, they will not be listed in sequence on this report. The report must be scanned to check if the time intervals are out of sequence.

The mission scenario lists all phase event and procedure titles for each crewmember, even if the crewmember has no tasks associated with these entities. This report only indirectly shows interaction between crewmembers. The only place where crew interaction is clearly visible is on the workload analysis worksheets. (See sec. 4.1.3.)

8.4.2.2 Crewman Workload Profile Report

The crewman workload profile report gives the channel, channel groups and average channel workload for each time interval within a specified phase. The workload is in percent, and the time interval start and end times are relative to the mission start time.

Each report is identified by an indication of whether the shifted or unshifted option was used and by the run date. The report is also identified by the mission name and configuration (cockpit layout and manning), the crewmember, and the flight phase.

A sample of the report is shown in figure 54. The block in the upper left-hand corner is for printing the specified option, shifted or unshifted. The block in the upper right-hand corner is for the run date.

[1]The task-channel activity report (sec. 8.4.2.4) lists only those tasks that occur during the study-time intervals that exceed the report threshold. If the report threshold was specified as 0%, these two listings would show the same tasks.

* UNSHIFTED *

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MISSION SCENARIO REPORT

MISSION - SCENARIO 3A - ILS

CONFIGURATION - NASA 515 - AFD (737)

CREWMEMBER - PILOT

TIME INTERVAL SINCE MISSION START BEGINNING	END	TOTAL ACTIVITY TIME	FLIGHT PHASE EVENT/PROCEDURE TASK		
.00			0200 PRE-START PREP - AFD		
.00			010001 COCKPIT SAFETY INSPECTION		
3.00	3.90	.90		7B	84 CHECK BATT SW ON
4.00	6.18	2.18		7B	57 SET DC METER SEL SW TO BATT
6.00	8.06	2.06		7B	53 MON DC VOLTS INDIC
8.00	10.04	2.04		7B	52 MON DC AMPS INDIC
12.00	12.90	.90		7A	29 CHECK SYS B HYD PUMP SWSS OFF
14.00	14.90	.90		4D	47 CHECK LANDING GEAR LEVER IN DOWN POS.
15.00	15.54	.54		4D	05 MONITOR NOSE GEAR DOWN AND LOCKED LT ON
15.50	16.04	.54		4D	09 MONITOR LEFT/RT GEAR DOWN AND LOCKED LT ON
18.00	20.17	2.17		6A	17 CHECK W/R OFF
22.00	24.50	2.50		4E	16 CHECK FLAP LEVER AND POSITION INDIC AGREE
26.00	26.90	.90		7P	48 MON ENG NO.1 OVRHT DETECT SW ON NORMAL
26.90	27.80	.90		7P	49 MON ENG NO.2 OVRHT DETECT SW ON NORMAL

Figure 52.—Mission Scenario Report, Unshifted—Example

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* SHIFTED *
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MISSION SCENARIO REPORT

MISSION - SCENARIO 3A - ILS

CONFIGURATION - NASA 515 - AFD (737)

CREWMEMBER - PILOT

TIME INTERVAL SINCE MISSION BEGINNING	START END	TOTAL ACTIVITY TIME	AMOUNT SHIFTED	FLIGHT PHASE EVENT/PROCEDURE TASK	
.00				0200 PRE-START PREP - AFD	
.00				010001 COCKPIT SAFETY INSPECTION	
3.00	3.90	.90	.00	7B	84 CHECK BATT SW ON
4.00	6.18	2.18	.00	7B	57 SET DC METER SEL SW TO BATT
6.00	8.06	2.06	.00	7B	53 MON DC VOLTS INDIC
8.00	10.04	2.04	.00	7B	52 MON DC AMPS INDIC
12.00	12.90	.90	.00	7A	29 CHECK SYS B HYD PUMP SWS OFF
14.00	14.90	.90	.00	4D	47 CHECK LANDING GEAR LEVER IN DOWN POS.
15.00	15.54	.54	.00	4D	05 MONITOR NOSE GEAR DOWN AND LOCKED LT ON
15.50	16.04	.54	.00	4D	09 MONITOR LEFT/RT GEAR DOWN AND LOCKED LT ON
18.00	20.17	2.17	.00	6A	17 CHECK W/R OFF
22.00	24.50	2.50	.00	4E	16 CHECK FLAP LEVER AND POSITION INDIC AGREE
26.00	26.90	.90	.00	7P	48 MON ENG NO.1 OVRHT DETECT SW ON NORMAL
26.90	27.80	.90	.00	7P	49 MON ENG NO.2 OVRHT DETECT SW ON NORMAL

Figure 53.—Mission Scenario Report, Shifted—Example

****
* UNSHIFTED *
****

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* CREWMAN WORKLOAD PROFILE REPORT
* MISSION - SCENARIO 3A - ILS
* CONFIGURATION - NASA 515 - AFD (737)
* CREWMEMBER - PILOT
* FLIGHT PHASE - PRE-START PREP - AFD

TIME INTERVAL START	END	EXTERNAL VISION	INTERNAL VISION	LEFT HAND	RIGHT HAND	LEFT FOOT	RIGHT FOOT	COGNITION	AUDIO	VERBAL	TOTAL VISION	TOTAL MOTOR	TOTAL COMM	AVERAGE
0	5	.00	38.00	.00	20.00	.00	.00	4.00	.00	.00	38.00	5.00	.00	11.75
5	10	.00	104.80	.00	23.60	.00	.00	20.96	.00	.00	104.80	5.90	.00	32.91
10	15	.00	36.80	.00	.00	.00	.00	7.36	.00	.00	36.80	.00	.00	11.04
15	20	.00	61.60	.00	.00	.00	.00	12.32	.00	.00	61.60	.00	.00	18.48
20	25	.00	53.40	.00	.00	.00	.00	10.68	.00	.00	53.40	.00	.00	16.02
25	30	.00	100.80	.00	32.40	.00	.00	20.16	.00	.00	100.80	8.10	.00	32.26
30	35	.00	98.40	.00	50.00	.00	.00	19.68	10.80	.00	98.40	12.50	10.80	35.34
35	40	.00	16.25	.00	32.60	.00	.00	8.68	.00	.00	16.25	8.15	.00	8.27
40	45	.00	100.00	.00	100.00	.00	.00	20.00	.00	.00	100.00	25.00	.00	36.25
45	50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
50	55	.00	71.80	.00	71.80	.00	.00	14.36	.00	.00	71.80	17.95	.00	26.03
55	60	.00	94.80	.00	69.60	.00	.00	18.96	.00	.00	94.80	17.40	.00	32.79
60	65	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
65	70	.00	100.00	100.00	100.00	.00	.00	20.00	.00	.00	100.00	50.00	.00	42.50
70	75	.00	100.00	100.00	100.00	.00	.00	20.00	.00	.00	100.00	50.00	.00	42.50
75	80	.00	100.00	100.00	100.00	.00	.00	20.00	.00	.00	100.00	50.00	.00	42.50
80	85	.00	40.00	40.00	40.00	.00	.00	8.00	.00	.00	40.00	20.00	.00	17.00

Figure 54.—Crewman Workload Profile Report—Example

This report is used in conjunction with the workload histogram plot (sec. 8.4.3.2) and the mission scenario report (sec. 8.4.2.1) to diagnose the cause of high workload situations. By looking at the histogram, the analyst determines the approximate time intervals in which unusually high workloads exist and then refers to the crewman workload profile report for the time intervals in question. The analyst scans the various workload values to isolate the channels that contribute to the high workload.

If the channel workload value for any study-time interval is in excess of 100%, one of the following two situations exists:

1. Most likely, an input data error has occurred.
   a. Tasks have been inadvertently overlapped.
   b. Most likely, a channel allocation specified for a task exceeds 100% because of keypunch errors where a channel allocation value for the task is not right-adjusted in the appropriate field on the task data specification. (Refer to the task list.)

2. A true work overload condition exists because of too many tasks to be performed during a time interval.

The analyst refers to the mission scenario report to determine the tasks that are to be performed during each time interval.

8.4.2.3 Crewman Workload Summary Statistics Report

The crewman workload summary statistics report presents the average workload, the workload variance, and the standard deviation of the workload for all channels, all channel groups, and the weighted average channel over a phase. In addition, the sum of the workloads and the sum of the squares of the workloads are given.

Figure 55 is a sample of this report. In the upper left-hand corner of the report is a block for printing whether the report is for the task shifted or unshifted option. In the upper right-hand corner is a block to print the run date. Each report is identified by the mission name and configuration, the crewmember, and the flight phase.

The crewman workload summary statistics report lists the data that are plotted on the workload summary plot (sec. 8.4.3.3) and the channel activity summary plot (sec. 8.4.3.1). In addition to these data, the intermediate calculation results are listed. Since the graphical plots of the data are more easily interpreted, they are recommended; however, this report can be used to determine how the plotted average and 1σ values were obtained.

8.4.2.4 Task-Channel Activity Report

The task-channel activity report gives a listing of all tasks that contribute to a channel workload exceeding a specified threshold. The channel workloads that cause the threshold to be exceeded are called channel overload contributors and will be offset by a

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```
**************************************************
* CREWMAN WORKLOAD SUMMARY STATISTICS REPORT     *
*                                                *
* MISSION - SCENARIO 3A - ILS                    *
*                                                *
*                                                *
* CONFIGURATION - NASA 515 - AFD (737)           *
*                                                *
* CREWMEMBER - PILOT                             *
*                                                *
* FLIGHT PHASE - PRE-START PREP - AFD            *
*                                                *
*                                                *
*                                                *
**************************************************
```

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CHANNEL	SUM X	SUM X SQUARED	AVERAGE LOAD	VARIANCE	STANDARD DEVIATION
EXTERNAL VISION	52.00	480.0	.25	2.235	1.495
INTERNAL VISION	11070.55	1261801.9	52.72	3244.961	56.965
LEFT HAND	2038.00	148114.0	9.56	616.812	24.836
RIGHT HAND	6695.60	501780.5	31.88	1379.422	37.141
LEFT FOOT	430.00	35300.0	2.05	164.687	12.833
RIGHT FOOT	430.00	35300.0	2.05	164.687	12.833
COGNITION	2904.40	75183.4	13.83	167.532	12.943
AUDITORY	1252.80	52592.6	5.97	215.879	14.693
VERBAL	648.00	18534.3	3.09	79.114	8.895
TOTAL VISION	11122.55	1266422.7	52.96	3240.777	56.928
TOTAL MOTOR	2390.90	85337.6	11.39	278.070	16.675
TOTAL COMMUNICATIONS	1900.80	87959.8	9.05	338.540	18.399
AVERAGE	4579.66	172089.6	21.81	345.534	18.589

Figure 55.—Crewman Workload Summary Statistics Report—Example

symbol "*" on each side of the value. In addition, the study-time segment number, task code, task name, task start time relative to the mission start time, task duration time, and situation number are printed.

A sample of the report is shown in figure 56. The report is identified by a block in the upper left-hand corner stating whether the report is for shifted or unshifted task, by a run date in the upper right-hand corner, and by a title block. The title block contains the mission name and configuration, the crewmember, the flight phase, the study-time interval, and the threshold value (in percent) for the report.

The task-channel activity report is used to report the results of using the report threshold, which can be thought of as an adjustable "filter" that screens out only those tasks that contribute to workloads in excess of a specified value. The analyst could use this format on a first iteration to screen out the tasks that cause workload in excess of 100% (sec. 8.4.2.2) and that are caused by input data errors. This would eliminate using the workload histogram and mission scenario report (as described in sec. 8.4.2.2) to accomplish the same screening process.

On successive iterations, the task-channel activity report would be used as the report threshold adjusted by the analyst as he explores how sensitive a particular scenario or scenario segment is to various overload criteria. If 0% were specified for the report threshold, all tasks would be listed.

This report is used with the subsystem activity report (sec. 8.4.2.5) and subsystem activity summary report (sec. 8.4.2.6) to determine which subsystem contributes to work overload. Prior to requesting the subsystem reports, the analyst could use the task-channel activity report for an indication of which subsystems seem to be involved most often in work overloading. (The analyst will usually have a good idea which subsystems will be involved when he is laying out the data on the workload analysis worksheets.) The report is also used in conjunction with the subsystem activity reports to determine how the various subsystems interact during periods of high workload.

8.4.2.5 Subsystem Activity Report

The subsystem activity report provides the same information for tasks as the task-channel activity report (sec. 8.4.2.4) but reorders the task under the subsystems used in performing the task. In addition, a measure of the channel overload contributors is output for each channel and for each subsystem specified. The channel measures are the total of the channel overload contributors in seconds during the phase, the total study-interval time containing the tasks that exceed the report threshold, the percent of total study-interval time that the channel workload exceeds the threshold, the percent of mission time that the channel workload exceeds the threshold, and the percent of phase time that the channel workload exceeds the threshold. Figure 57 is a sample of this output.

The subsystem activity report is used with the subsystem activity summary report (sec. 8.4.2.6) and the task-channel activity report (sec. 8.4.2.4) to isolate and study

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NOV 5 1975

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***************************************
*                                     *
*     TASK CHANNEL ACTIVITY REPORT    *
*                                     *
* MISSION - ENGINE FIRE-NOISE         *
*           ABATEMENT CLIMB           *
*                                     *
* CONFIGURATION - NASA-515 AFD COCKPIT*
*                                     *
* CREW MEMBER - PILOT                 *
*                                     *
* FLIGHT PHASE - ENGINE FIRE - NOISE  *
*                ABATE CLB            *
*                                     *
*                                     *
* TIME INTERVAL - 5                   *
*                                     *
* REPORT THRESHOLD - 70               *
*                                     *
***************************************
```

TIME SEGMENT	MISSION TIME (MINUTES)	TASK CODE SUBSYS.	TASK CODE NO.	TASK NAME	SITUATION	TASK DURATION TIME SECONDS)	EV	IV	LH	RH	LF	RF	COG	AUD	VBL
6	619	1P	16	MONITOR REPORT	3	3	0	0	0	0	0	0	1 *	3*	0
	619	1P	16	MONITOR REPORT	4	2	0	0	0	0	0	0	0 *	1*	0
10	619	1R	25	ACT PUSH-TO-TALK SW ON CONTROL HANDGRIP	1	7	0	0	0 *	5*	0	0	1	0	0
	619	1PB9EA	13	RADIO COMM (ALT DEP CONTROL-NASA 515-ENGINE FIRE-EXT.-	1	7	0	0	0	0	0	0	1	0 *	5*
15	620	1R	42	ACT PUSH-TO-TALK SW ON CONTROL HANDGRIP	1	11	0	0	0 *	5*	0	0	1	0	0
	620	1PB9EA	15	RADIO COMM(ALT.D.C.-515 TURN LEFT 360DEG MAINTAIN A/S+HDG	1	11	0	0	0	0	0	0	1	0 *	5*

Figure 56.—Task-Channel Activity Report—Example

TIME SEGMENT	MISSION TIME (MINUTES)	TASK CODE SUBSYS.	TASK CODE NO.	TASK NAME	SITUATIONS	TASK DURATION TIME (SECONDS)	FV	IV	LH	RH	LF	RF	COG	AUD	VBL
18	620	2H	20	READ TKA SEL VALUE ON DIGITAL INDIC	1	1	0 *	1*	0	0	0	0	0	0	0
	620	2H	17	MON TKA SEL MODE LT BLUE - TKA SEL MODE PRESELECTED	1	1	0 *	1*	0	0	0	0	0	0	0
	620	2H	14	PRESS TKA SEL MODE SW	1	1	0 *	1*	0	1	0	0	0	0	0
	620	2H	15	MON TKA SEL MODE LT GREEN - TKA SEL MODE ENGAGED	1	1	0 *	1*	0	0	0	0	0	0	0
	620	2H	42	MON VERT PATH MODE LT DARK - VERT PATH MODE DISENGAGED	1	1	0 *	1*	0	0	0	0	0	0	0
	620	2H	28	PRESS ALT ENG MODE S SW	1	1	0 *	1*	0	1	0	0	0	0	0
19	620	2H	28	PRESS ALT ENG MODE S SW	1	1	0 *	1*	0	1	0	0	0	0	0
	620	2H	29	MONITOR ALT ENG MODE LT GREEN - ALT ENG MODE ENGAGED	1	1	0 *	1*	0	0	0	0	0	0	0
	620	2K	17	MON 32 NM MAP VIDEO	1	2	0 *	2*	0	0	0	0	0	0	0
27	621	1P	15	MONITOR CALL-OUT	3	4	0	0	0	0	0	0	1 *	4*	0

Figure 56.—(Concluded)

```
*************
* UNSHIFTED *
*************
                ****************************************
                *                                      *
                *   SUBSYSTEM ACTIVITY REPORT          *     NOV 5 1975
                *                                      *
                * MISSION - ENGINE FIRE-NOISE          *
                *           ABATEMENT CLIMB            *
                *                                      *
                * CONFIGURATION - NASA-515 AFD COCKPIT *
                *                                      *
                * CREW MEMBER -   CO-PILOT             *
                *                                      *
                * FLIGHT PHASE - ENGINE FIRE - NOISE   *
                *                ABATE CLB.            *
                *                                      *
                * PHASE TIME - 2325 TO 2465            *
                *              ( 2 MIN   20 SEC)       *
                *                                      *
                *TOTAL MISSION TIME -  41 MIN          *
                *                       5 SEC          *
                *                                      *
                * TIME INTERVAL -  5                   *
                *                                      *
                * REPORT THRESHOLD -  70               *
                *                                      *
                ****************************************
```

TIME SEGMENT	MISSION TIME (MINUTES)	TASK CODE SUBSYS.	TASK CODE NO.	TASK NAME	SITUATION	TASK DURATION TIME (SECONDS)	EV	IV	LH	RH	LF	RF	COG	AUD	VBL
**********															
* SUBSYSTEM - FIRE/OVERHEAT/SMOKE DETEC *															
**********															
6	619	7P	15	MON ENG NO.1 FIRE WARNING LT ON	4	5	0 *	2*	0	0	0	0	0	0	0
	619	7P	18	ROTATE ENG NO.1 FIRE WARNING SW HANDLE TO LEFT	2	2	0 *	2*	2	0	0	0	0	0	0
	619	7P	27	MON L BOTTLE DISCHARGE LT ON	2	0	0 *	0*	0	0	0	0	0	0	0

(Header of the channel columns: CHANNEL ACTIVITY - SECS)

Figure 57.—Subsystem Activity Report—Example

TIME SEGMENT	MISSION TIME (MINUTES)	TASK CODE SUBSYS.	TASK CODE NO.	TASK NAME	SITUATION	TASK DURATION TIME (SECONDS)	EV	IV	LH	RH	LF	RF	COG	AUD	VBL
10	619	7P	16	MON ENG NO.1 FIRE WARNING LT OFF	3	15	0 *	5*	0	0	0	0	1	0	0
11	620	7P	16	MON ENG NO.1 FIRE WARNING LT OFF	3	15	0 *	5*	0	0	0	0	1	0	0
				TOTAL ACTIVE TIME IN THIS PHASE WHERE THRESHOLD IS EXCEEDED (SEC)			0	14	0	0	0	0	0	0	0
				TOTAL INTERVAL TIME IN THIS PHASE WHERE THRESHOLD IS EXCEEDED (SEC)			0	15	0	0	0	0	0	0	0
				PERCENT ACTIVE TIME OF INTERVAL TIME			0	95	0	0	0	0	0	0	0
				PERCENT ACTIVE TIME OF MISSION TIME			0	1	0	0	0	0	0	0	0
				PERCENT ACTIVE TIME OF PHASE TIME			0	10	0	0	0	0	0	0	0

Figure 57.—(Concluded)

specified subsystem involvement in work overloads. The subsystem activity report is referred to after the subsystem activity summary report is studied to determine the exact tasks that are associated with a specified subsystem and that are being performed at a specific time interval during selected phases. The stars (*) flag the channels that contribute to the overload.

The tabulations at the end of each subsystem activity report show the intermediary and final computations that are listed on the subsystem activity summary report for the specified places and subsystems. (Refer to secs. 8.3.5 and 8.4.2.6 for discussions of the derivation and use of these subsystem activity computations.)

The data shown in the report title block list the parameters that are used in the various computations.

8.4.2.6 Subsystem Activity Summary Report

The subsystem activity summary report summarizes the results from the subsystem activity report. For all channel activity exceeding the report threshold, the report restates the percent of phase time and the percent of mission time that the channel is active. The active time is the sum of the time that the specific channel workload exceeds the specified report threshold. The interval time is the sum of the study intervals containing the tasks that have a specific channel workload exceeding the report threshold.

In addition, the report summarizes across all phases and gives the percent of active time to interval time, and the percent of active time to mission time.

Each report will be identified by the mission and configuration, the crewmember, the report threshold, the date, and an indication of whether the report is with the task shifting option. Figure 58 is a sample of this report.

The subsystem activity summary report is used as a means of scanning an entire mission to quickly spot the subsystems/phases/channels that merit closer inspection because they are involved in high workloading. To request this report, the analyst has to judge which subsystems are most likely to be involved in high workload and also has to specify a work overload threshold criterion, which narrows his attention to candidate subsystems. The next problem is to isolate the various subsystems, phases, and channels that require more detailed inspection and analysis. Each analyst will develop his own logical scanning process to home in on these levels of indenture. (This report was created during the development of TLA-1 and, subsequently, has been used enough to determine all the ways in which it could be used.) The following logic has been used:

1. Which subsystems are involved?

    a. Scan each page.
    b. Set aside any page that has all zeros. (No further analysis is required.)

```
*************
* SHIFTED   *
*************
```

A - ACTIVE TIME PERCENTAGE OF INTERVAL TIME

B - ACTIVE TIME PERCENTAGE OF PHASE TIME

C - ACTIVE TIME PERCENTAGE OF MISSION TIME

SUBSYSTEM ACTIVITY SUMMARY REPORT

MISSION - SCENARIO 3A - ILS

CONFIGURATION - NASA 515 - AFD (737)

CREWMEMBER - PILOT

REPORT THRESHOLD - 50

XXXX

SUBSYSTEM - PRIMARY ATTITUDE CONTROLS

PHASE	INT. VISION A	B	C	EXT. VISION A	B	C	LEFT HAND A	B	C	RIGHT HAND A	B	C	LEFT FOOT A	B	C	RIGHT FOOT A	B	C	COGNITIVE A	B	C	AUDITORY A	B	C	VERBAL A	B	C
PRE-START PREP - AFD	0	0	0	72	2	0	50	0	0	59	1	0	40	0	0	40	0	0	0	0	0	0	0	0	0	0	0
ENGINE START	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TAXI -BEFORE TAKEOFF (AFD)	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	30	0	0	7	0	0	0	0	0	0	0	0
TAKEOFF (AFD)	0	0	0	0	0	0	115	5	0	115	5	0	90	4	0	90	4	0	33	2	0	0	0	0	0	0	0
NOISE ABATEMENT LIMB - AREA NAV (AFD)	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0
CRUISE - AREA NAV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DESCENT - AFD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
APPROACH AND LANDING -ILS (AFD)	0	0	0	0	0	0	150	2	0	100	1	0	100	1	0	100	1	0	0	0	0	0	0	0	0	0	0
TAXI - AFTER LANDING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHUTDOWN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0		0	72		0	111		0	76		0	72		0	72		0	19		0	0		0	0		0

Figure 58.—Subsystem Activity Summary Report—Example

2. Which phases are involved for this subsystem?

   a. Select the page(s) that seem to have the most nonzero values.
   b. Set the others aside for later analysis.

3. For this subsystem and these phases, which channels are involved?

   a. Focus attention on those phases where there are nonzero values.
      (1) The A values show the relative ranking of how much the channels are involved in work overloading.

      (2) For a given phase, the B values give a relative ranking of how much time during the phase the various channels are involved in overloading.

      (3) For a given phase, the C values give a relative ranking of how much time the various channels are involved in overloading during the total mission. (Note: A zero in the C columns indicates that this value is less than 1%.)

   b. Ignore phases with all zeros.

4. From the preceding relative measures, rank the subsystem, phases, and channels in the order in which they should be investigated.

5. Go to the subsystem activity reports to determine which tasks and time intervals are involved for the subsystem during the phases to be studied.

6. Go to the task-channel activity report to determine the other tasks that contribute to the work overload during the time intervals in question.

7. To relieve the overload, do one of the following:

   a. Change the procedure.
   b. Give task(s) to another crewmember.
   c. Change the design of the hardware/software.

8.4.2.7 Task List Report

The task list report lists all tasks for a mission by task number and gives the task name, situations, duration times, and channel workloads. The sole purpose of this report is to provide the analyst with an easy-to-read task catalog. Figure 59 is a sample of this report. The only data analysis involved is that the analyst uses this report to scan for keypunch errors on the task data specification.

SUBSYS	TASK CODE NO.	TASK NAME/DESCRIPTION	SIT	DUR TIME (SEC)	EV	IV	LH	RH	LF	RF	COG	AUD	VBL
					CHANNEL ACTIVITY - PERCENT OF DUR TIME								
18	01	MON VHF-2L FREQ IND	1	.75	0	100	0	0	0	0	20	0	0
			2	4.83	0	100	0	0	0	0	20	0	0
			3	5.08	0	100	0	0	0	0	20	0	0
18	02	SET VHF-2L FREQ-WHOLE NO.S	1	2.20	0	10	100	0	0	0	20	0	0
			2	2.90	0	10	100	0	0	0	20	0	0
			3	2.40	0	10	0	100	0	0	20	0	0
			4	3.10	0	10	0	100	0	0	20	0	0
18	03	SET VHF-2L FREQ - FRACTIONS	1	1.98	0	10	100	0	0	0	20	0	0
			2	1.98	0	10	0	100	0	0	20	0	0
18	04	ADJ VHF-2 VOLUME	1	2.00	0	10	100	0	0	0	20	0	0
			2	2.09	0	10	100	0	0	0	20	0	0
			3	2.09	0	10	0	100	0	0	20	0	0
			4	2.17	0	10	0	100	0	0	20	0	0
18	05	SET VHF-2 COMM TFR SW TO LEFT	1	1.45	0	100	100	0	0	0	20	0	0
			2	2.39	0	100	0	100	0	0	20	0	0
			3	1.45	0	100	100	0	0	0	20	0	0
			4	2.30	0	100	100	0	0	0	20	0	0
18	06	SET VHF-2 COMM TFR SW TO RIGHT	1	1.45	0	100	100	0	0	0	20	0	0
			2	2.39	0	100	0	100	0	0	20	0	0
			3	1.45	0	100	100	0	0	0	20	0	0
			4	2.39	0	100	100	0	0	0	20	0	0
18	07	MON VHF-2R FREQ IND	1	.76	0	100	0	0	0	0	20	0	0
			2	4.01	0	100	0	0	0	0	20	0	0
			3	4.86	0	100	0	0	0	0	20	0	0
			3	4.86	0	0	0	0	0	0	0	0	0
18	08	SET VHF-2R FREQ - WHOLE NO.S	1	2.03	0	10	100	0	0	0	20	0	0
			2	2.88	0	10	100	0	0	0	20	0	0
			3	2.03	0	10	0	100	0	0	20	0	0
			4	2.98	0	10	0	100	0	0	20	0	0
18	09	SET VHF-2R FREQ - FRACTIONS	1	1.98	0	10	100	0	0	0	20	0	0
			2	1.98	0	10	0	100	0	0	20	0	0
18	10	SET COMM 2 MIC SEL SW TO VHF-2	1	2.86	0	100	100	0	0	0	20	0	0
			2	1.99	0	100	0	100	0	0	20	0	0
			3	2.92	0	100	0	100	0	0	20	0	0
18	11	SET COMM 2 VHF-2 COMM RECVR SW TO ON	1	2.09	0	100	0	100	0	0	20	0	0
			2	1.52	0	100	0	100	0	0	20	0	0
			3	2.39	0	100	100	0	0	0	20	0	0
			4	1.44	0	100	100	0	0	0	20	0	0
18	12	SET COMM 2 VHF-2 COMM RECVR SW TO OFF	1	2.09	0	100	0	100	0	0	20	0	0
			2	1.52	0	100	0	100	0	0	20	0	0
			3	2.39	0	0	100	100	0	0	20	0	0
			4	1.44	0	100	100	0	0	0	20	0	0

Figure 59.—Task List Report—Example

8.4.3 GRAPHICAL PLOTTER OUTPUT

The graphic output consists of the following plots: (1) channel activity summary bargraph, (2) workload histogram, (3) workload summary bargraph, and (4) mission timeline chart. The plots are generated by input requests, which are specified in section 8.2.1.3.2. The following sections describe the plots.

8.4.3.1 Channel Activity Summary Plot

This bargraph presents either the average and standard deviation or only the average of the channel workload for each channel as well as for the weighted channel average. The bargraph is for a specified phase within a mission and configuration, for a specified crewman, and for either the shifted or unshifted option. Figure 60 is a sample of the channel activity summary bargraph, which is identified by the mission name and configuration, the flight phase, a specified crewmember, the data, and a label denoting whether the bargraph is with optional shifted or unshifted tasks.

If the plotted bar exceeds the margin of 150%, the value of the average + 1σ (if optionally selected) is printed on the plot in place of the bar.

The channel activity summary plot shows the average load and standard deviation data that are found on the crewman workload summary statistics report (sec. 8.4.2.3). This data format would be used primarily as final documentation.

8.4.3.2 Workload Historgram Plot

The workload histogram is a plot of a channel, channel group, or weighted average workload as a function of elapsed mission time. The histogram provides for one or more configurations of a mission, is associated with a specified crewman, and is for a specified shifted or unshifted option.

Figure 61 is a sample of this type of plot for a single mission, and figure 62 is an example showing multiple missions. The plot is identified by the shifted or unshifted option, the run date, the mission name, the crewmember, and the configurations. A specified threshold line is also plotted. Under the histogram, the plot will also have a block that can later be used to draw an altitude profile.

The workload histogram plot is one of the most useful data formats and is used during all iterations. Early iterations quickly and clearly show high workload periods. Task data input errors will show up as unusually high spikes. On successive iterations. the histogram would be plotted for various channels as the analyst homes in on the specific nature of overloads.

Extremely busy periods can be expanded on some iterations by dropping all noncritical phases. The program will treat the remaining phase(s) as the whole mission and will therefore change the histogram time scale accordingly.

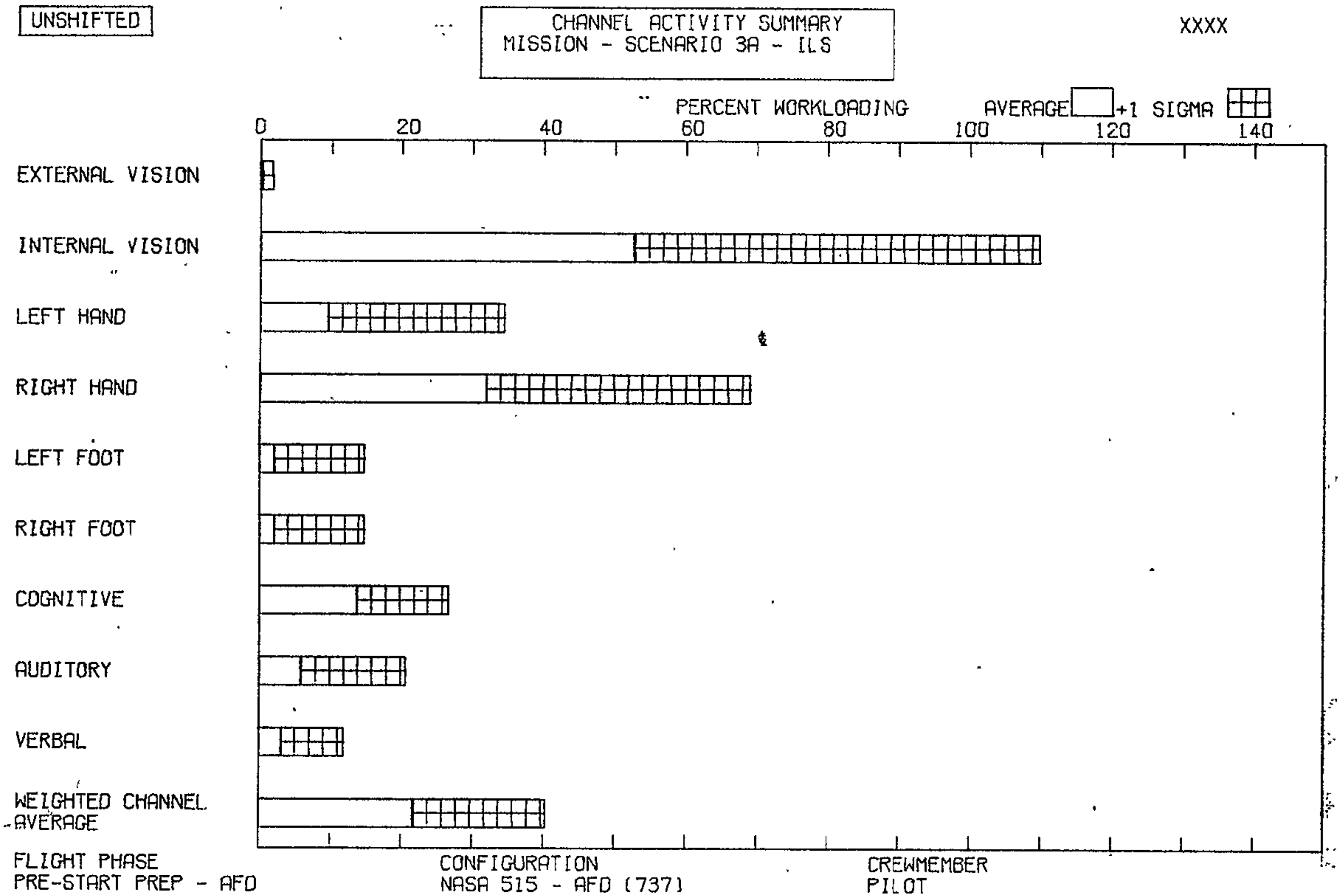

Figure 60.—Channel Activity Summary Plot—Example

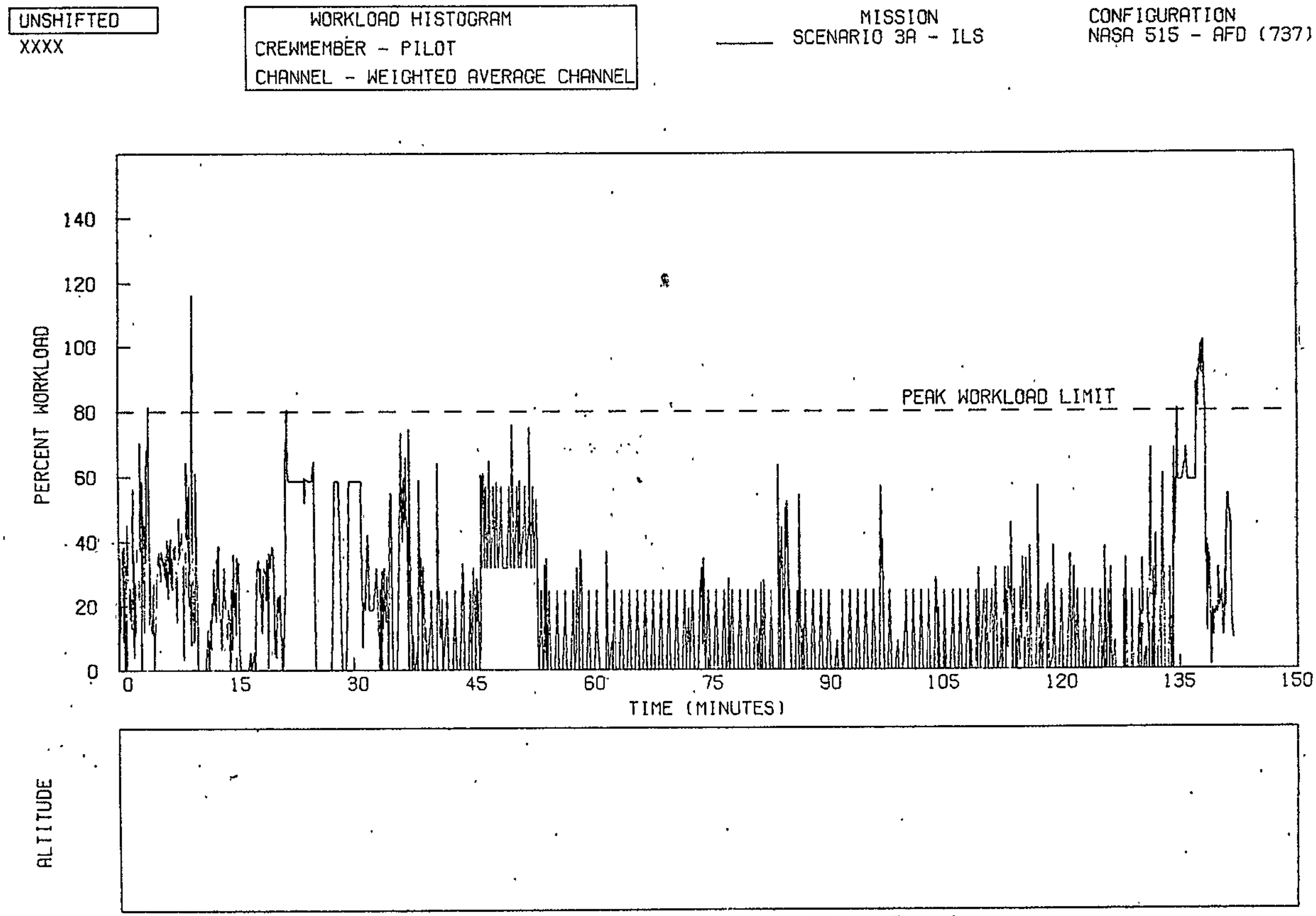

Figure 61.—Workload Histogram Plot, Single Mission—Example

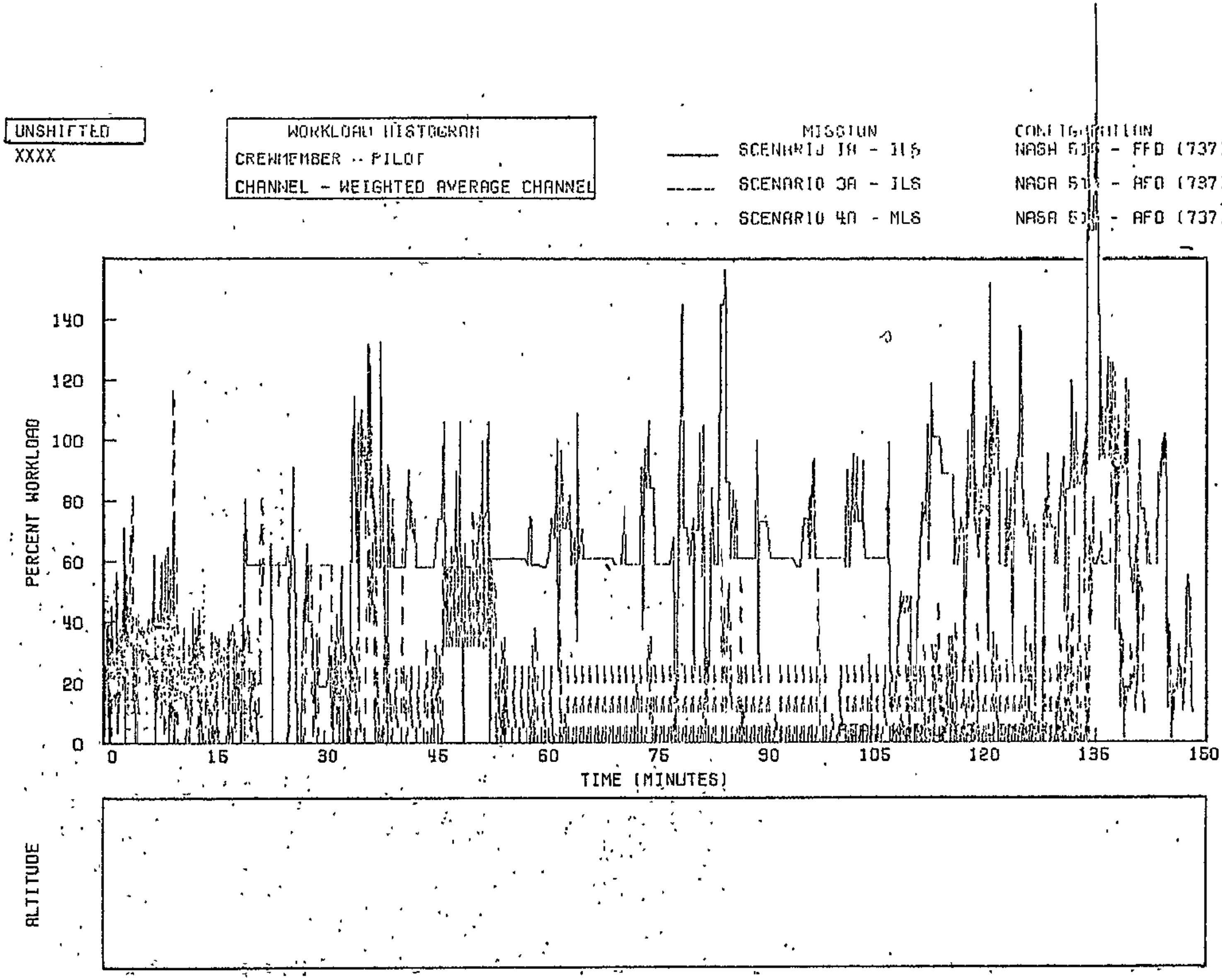

Figure 62.—Workload Histogram Plot Multiple Missions—Example

Using the comparative plot option, the analyst can plot as many as three crewmembers for one mission and as many as three different missions for any channel, channel total, or average. This format is ideal for final documentation, because the plotted data can be readily interpreted.

8.4.3.3 Workload Summary Plot

This bargraph gives either a summary of the average workload and workload standard deviation or only the average workload for each channel group (vision, motor, communication, and cognitive) and for the weighted average channel. The bargraph is for a specified crewmember and phase and for as many as three configurations of a mission.

Figure 63 is a sample of the bargraph showing a single mission, and figure 64 shows data from two missions. The bargraph is further identified by specifying in the upper left-hand corner whether the graph is for shifted or unshifted tasks. The run date is placed in the upper right-hand corner.

If the plotted bar exceeds the margin of 150%, the value of the average + 1σ (if optionally selected) is printed on the plot in place of the bar.

The workload summary plot is used for final documentation to plot some of the results listed in the crewman workload summary statistics report. This format offers a way to show how up to three different crewmembers, missions, or configurations compare. It is of little value early in the workload analysis.

8.4.3.4 Mission Timeline Plot

This chart presents an interval bar along a timeline to show when a task situation is in effect. The chart is for a specified phase and crewmember within a given mission and configuration and for an optional shifted or unshifted task catalog. Each event and procedure start time within the phase is indicated by a pointer "∇." Tasks are listed from the top to the bottom of the chart in their order of occurrence within the mission.

Figure 65 is a sample of this plot. The run date will be put in the upper right-hand corner of the plot. Due to the large number of expected tasks, there will be no blank lines between task/procedure/event descriptions.

The mission timeline plot is provided as a means to show the sequence of tasks. The same data as found in the mission scenario report (sec. 8.4.2.1) are shown in a graphical format, which would be used only for final documentation and then with discretion. Only 15 to 30 tasks will be listed per page, and a long mission will require many of these plots. This data output is therefore relatively expensive.

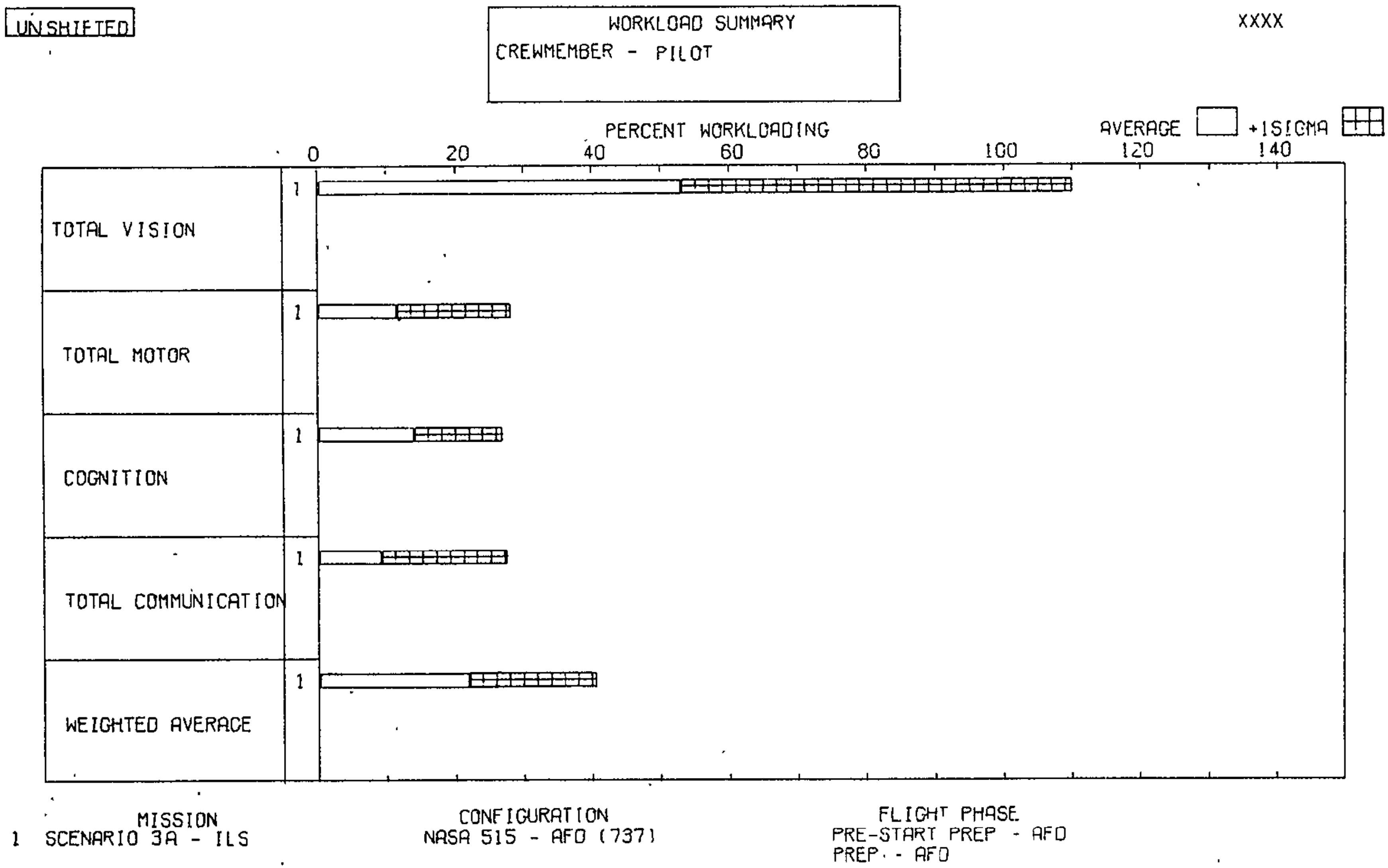

Figure 63.—Workload Summary Plot, Single Mission—Example

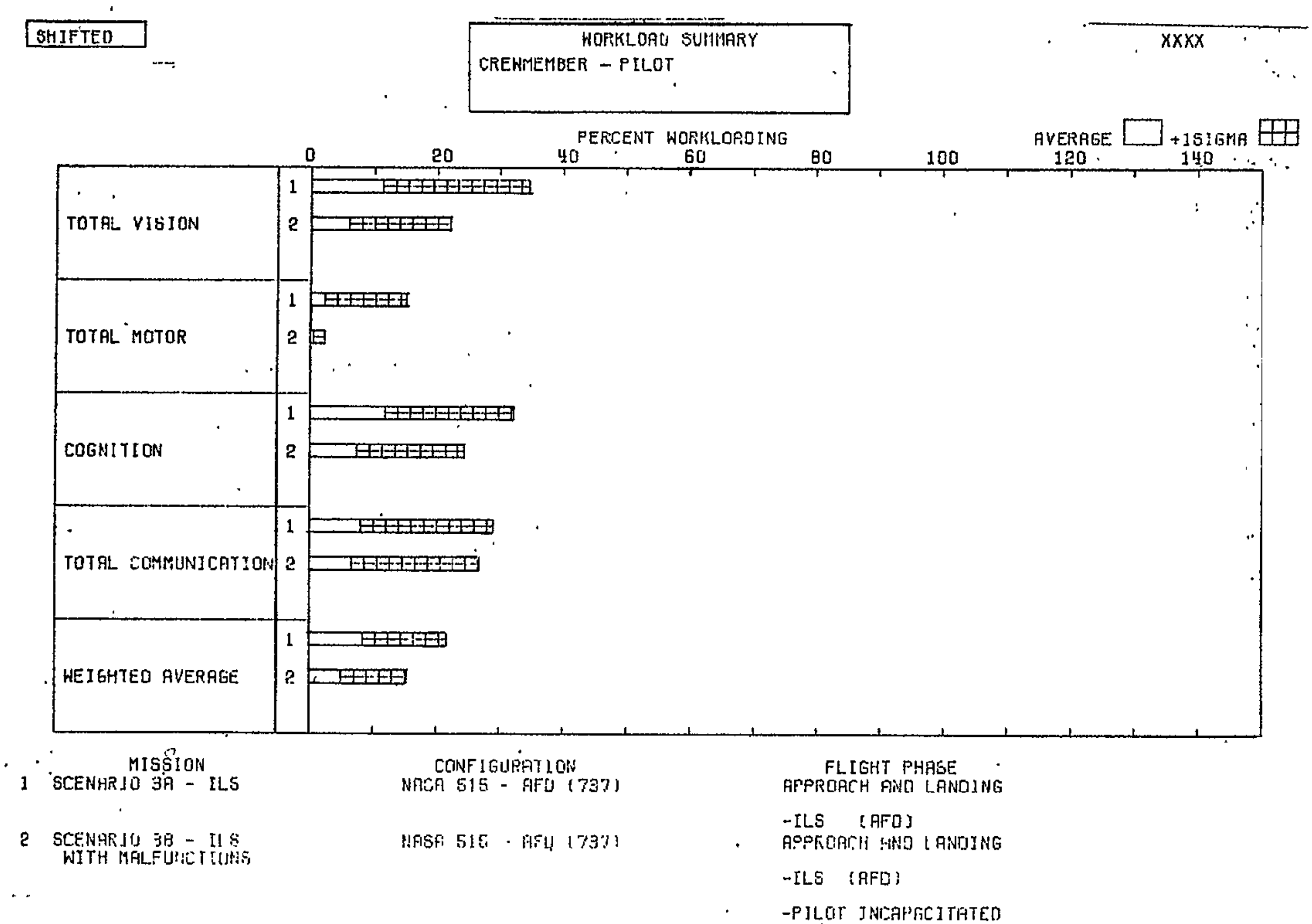

Figure 64.—Workload Summary Plot, Multiple Missions—Example

UNSHIFTED

MISSION TIMELINE
MISSION - SCENARIO 3A - ILS

CONFIGURATION - NASA 515 - ATD (737)
FLIGHT PHASE - ENGINE START

CREWMEMBER - PILOT

XXXX

CODE	EVENT/PROCEDURE OR TASK DESCRIPTION	TASK DUR (SEC)
030001	ENGINE NO.2 START-UP	
1A 25	ACTUATE COMM 2 PUSH-TO-TALK SW	2.35
1F 11	INTPHN COMM	1.30
1P030002	INTPHN COMM - [STARTING NO.2]	1.30
1P030001	MON INTPHN COMM - [CALL CLEAR]	.90
1F 09	MON INT COMM AUDIO	.90
7M 05	SET ENG NO.2 START SW TO GRD	3.64
7F 24	MON NO 2 ENG N2 IND	10.00
7F 22	MON NO 2 ENG N1 IND	2.52
7M 08	SET ENG NO.2 START LEVER TO START	2.51
7F 17	MON NO 2 ENG OIL PRESS INDIC	2.25
7F 32	MON ENG NO 2 EXH GAS TEMP IND	2.02
7F 34	MON ENG NO 2 FUEL FLOW INDIC	2.02
7M 16	MON ENG 2 START LVR AUTOMATICALLY MOVED TO OFF	1.30
7F 24	MON NO 2 ENG N2 IND	2.52
7F 32	MON ENG NO 2 EXH GAS TEMP IND	2.02
7F 34	MON ENG NO 2 FUEL FLOW INDIC	2.02
7F 30	MON ENG NO 2 EPR IND	2.24
7F 22	MON NO 2 ENG N1 IND	2.02
7F 17	MON NO 2 ENG OIL PRESS INDIC	2.06
1A 25	ACTUATE COMM 2 PUSH-TO-TALK SW	[illegible]
030002	ENGINE NO.1 START-UP	
1F 11	INTPHN COMM	1.30

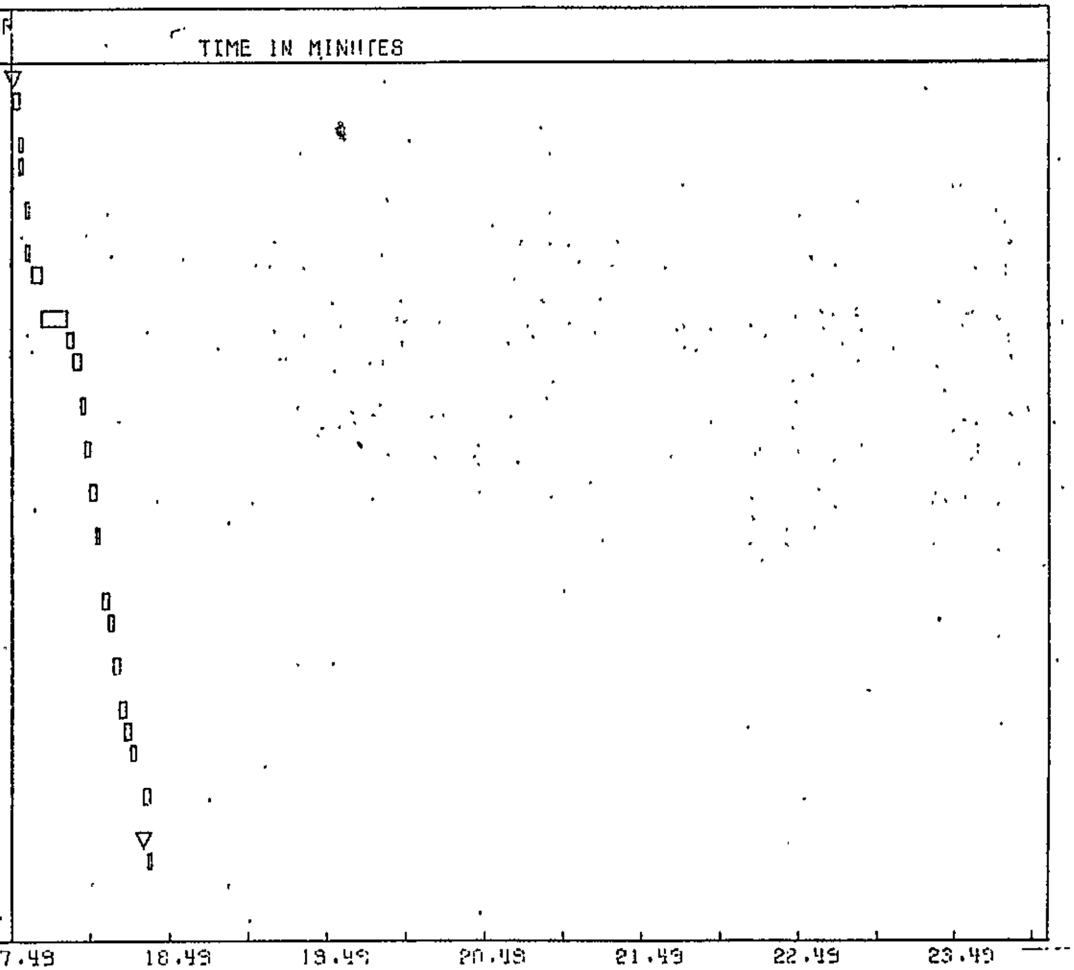

Figure 65.—Mission Timeline Plot—Example

CODE		EVENT/PROCEDURE OR TASK DESCRIPTION	TASK DUR (SEC)
7J	34	MON F/O PITOT HTR LT ON	1.14
7J	36	MON F/O STATIC 2 AUX P/S HTR LT ON	1.14
7J	38	MON R ELEV HTR LT ON	1.14
7Q	10	MON FWD ENTRY LT OFF	1.55
7Q	13	MON AFT ENTRY LT OFF	1.12
7Q	16	MON AIR STAIRS LT OFF	1.12
7Q	19	MON EQUIP / TIRE BURST LT OFF	1.12
7Q	22	MON FWD CARGO LT OFF	1.12
7Q	25	MON AFT CARGO LT OFF	1.12
7Q	28	MON FWD SERVICE LT OFF	1.12
7Q	31	MON AFT SERVICE LT OFF	1.12
7D	06	SET LEFT PACK SW TO ON	2.69
7D	19	SET RIGHT PACK SW TO ON	1.52
7D	18	SET APU ENG BLEED SW TO OFF	1.53
7D	34	MON DUAL BLEED LT OFF	.28
7L	11	SET APU SW TO OFF	2.57
7E	15	SET FLT/GRD SW TO FLT	3.06
7M	03	SET ENG NO.1 START SW TO FLT	1.74
7M	06	SET ENG NO.2 START SW TO FLT	1.74
7M	08	SET ENG NO.1 START LEVER TO CUTOFF	3.00
7M	10	SET ENG NO.2 START LEVER TO CUTOFF	2.51
1P030004		CALL OUT -(AFTER START CHECKLIST)	1.50
030004		AFTER START CHECK-LIST - 1	
1P	11	MONITOR CALL-OUT	.80
7B	31	MON GEN NO.1 GEN OFF BUS LT OFF	.52
7B	41	MON GEN NO.2 GEN OFF BUSS LT OFF	.59

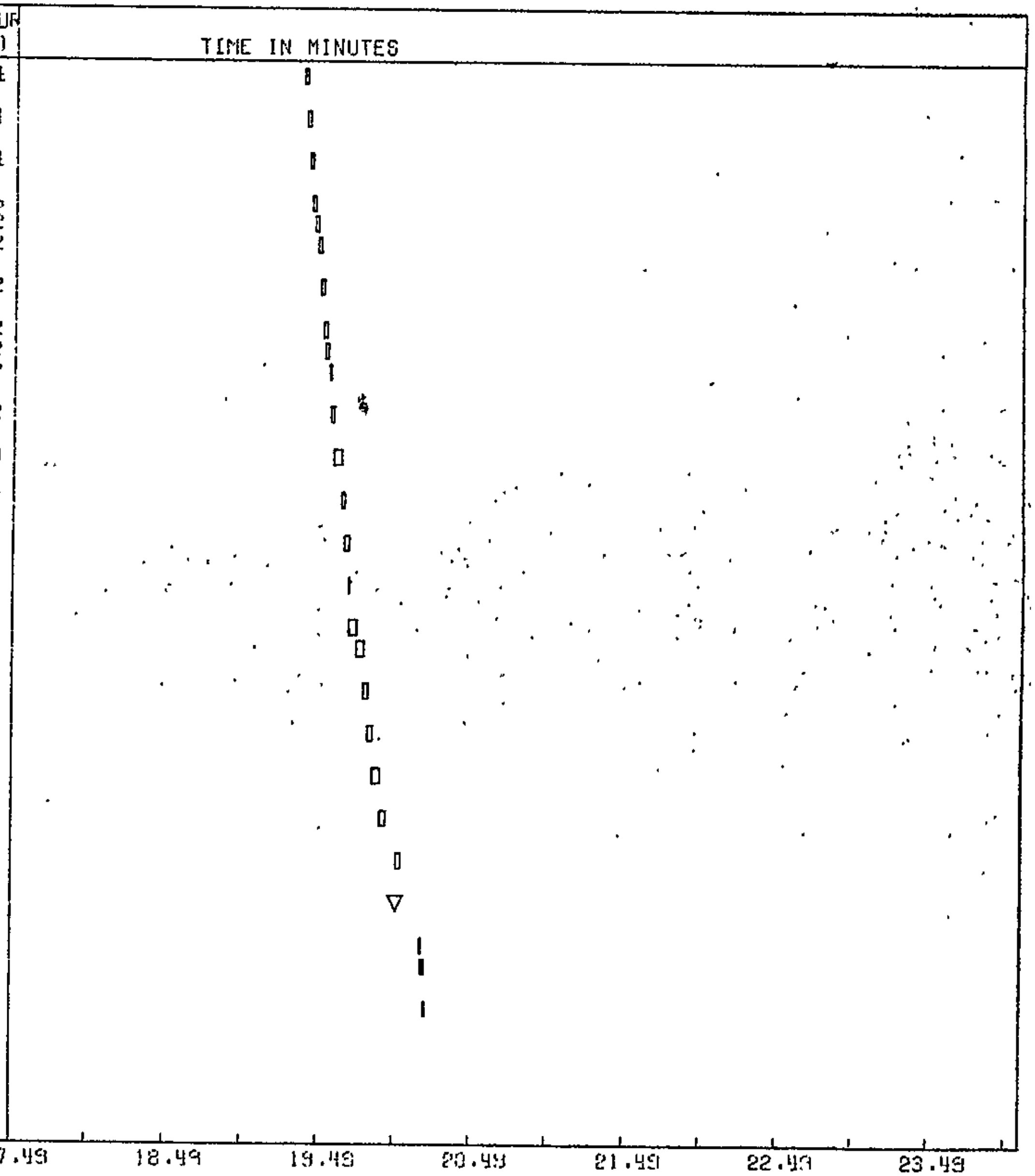

Figure 65.—(Continued)

CODE	EVENT/PROCEDURE OR TASK DESCRIPTION	TASK DUR (SEC)
1P030006	CALL OUT- CGENERATORS ON]	1.20
1P 11	MONITOR CALL-OUT	.90
7J 45	MON PITOT STATIC SYS A HT SW SET TO ON	1.47
7J 46	MON PITOT STATIC SYS B HT SW SET TO ON	.75
1P010018	CALL OUT - CON]	.50
1P030008	CALL OUT- CANTI-ICE]	.90
1P 11	MONITOR CALL-OUT	.90
1P030009	CALL OUT -CNOT REQD]	1.00
030005	AFTER START CHECK-LIST - 2	
1P 10	MONITOR CALL-OUT	1.20
7D 10	MON LEFT PACK OFF LT OFF	1.00
7D 22	MON RT PACK TRIP OFF LT OFF	1.00
7E 35	MON FLT/GRD SW SET TO FLIGHT	.54
1P030011	CALL OUT-CPACKS ON, FLT]	1.30
1P 11	MONITOR CALL-OUT	.90
7M 11	MON ENG START SW≤S IN FLT POS	.62
1P030013	CALL OUT -CFLT]	.60
030006	AFTER START CHECK-LIST - 3	
1P 11	MONITOR CALL-OUT	.80
7M 14	CHECK THAT ENG START LEVERS IN OFF POS	1.30
7L 20	MON APU START SW SET TO OFF	.75
1P030015	CALL OUT -COFF]	.60
1P 10	MONITOR CALL-OUT	1.00
1P030017	CALL OUT -COFF]	.60
1P 12	MONITOR CALL-OUT	1.40

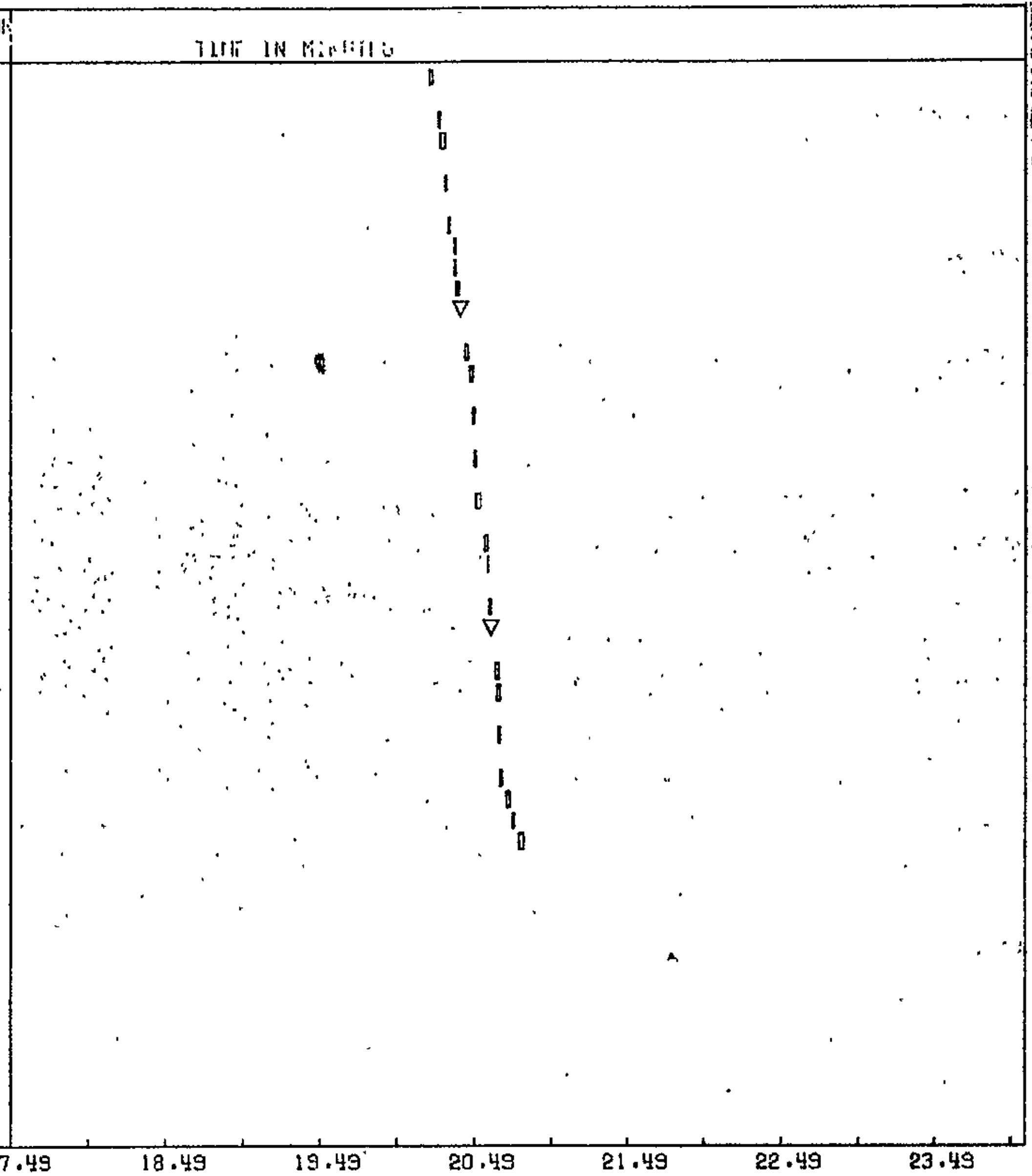

Figure 65.—(Concluded)

8.5 REPORT REQUEST STRATEGY

The decision logic diagram shown in figure 66 presents the recommended strategy for studying crew workload by using the TLA-1 model. This guide was developed as an aid for new analysts to guide them through the analytical process. The guide will help to keep the analyst from being swamped with nonusable data during the early stages of analysis.

The overall strategy can be summarized as follows:

1. Before requesting output data, the input data are debugged.

2. On the first pass, only those reports and plots are requested that allow the analyst to "home in" on the phases and subsystems involved in high workload. These first reports also allow the analyst to spot other heretofore hidden data errors.

3. The second pass is used to process the corrected data as well as to exercise the shift option.

4. The fine detail analysis runs are used to expose the nature of the high workload problems in fine detail. At this stage, the analyst will study alternatives as required to try to reduce the workload.

5. The final documentation run is used to generate summary data appropriate for coordination memos or final reports.

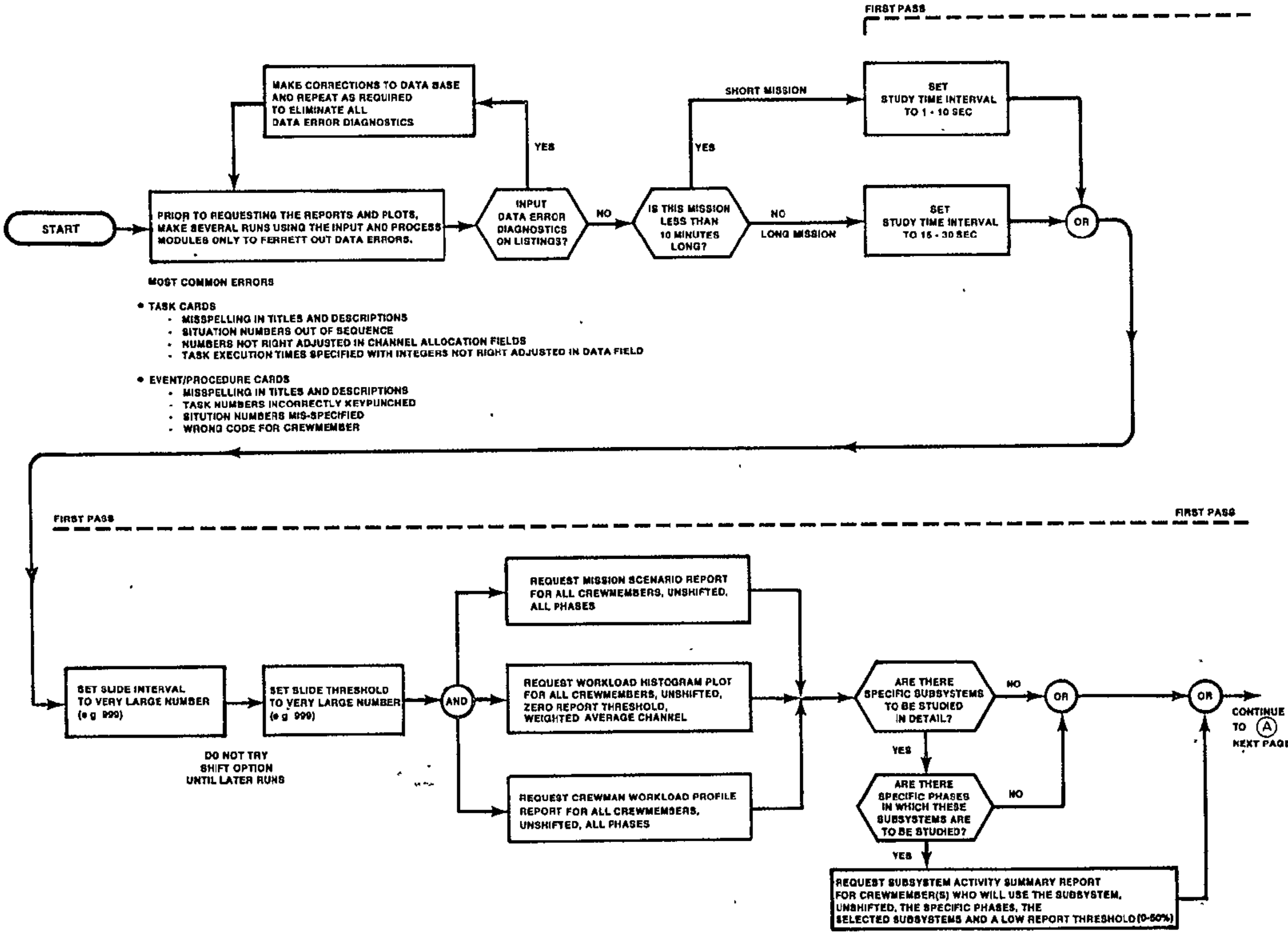

Figure 66.—Strategy for Using TLA-1 for Workload Analysis

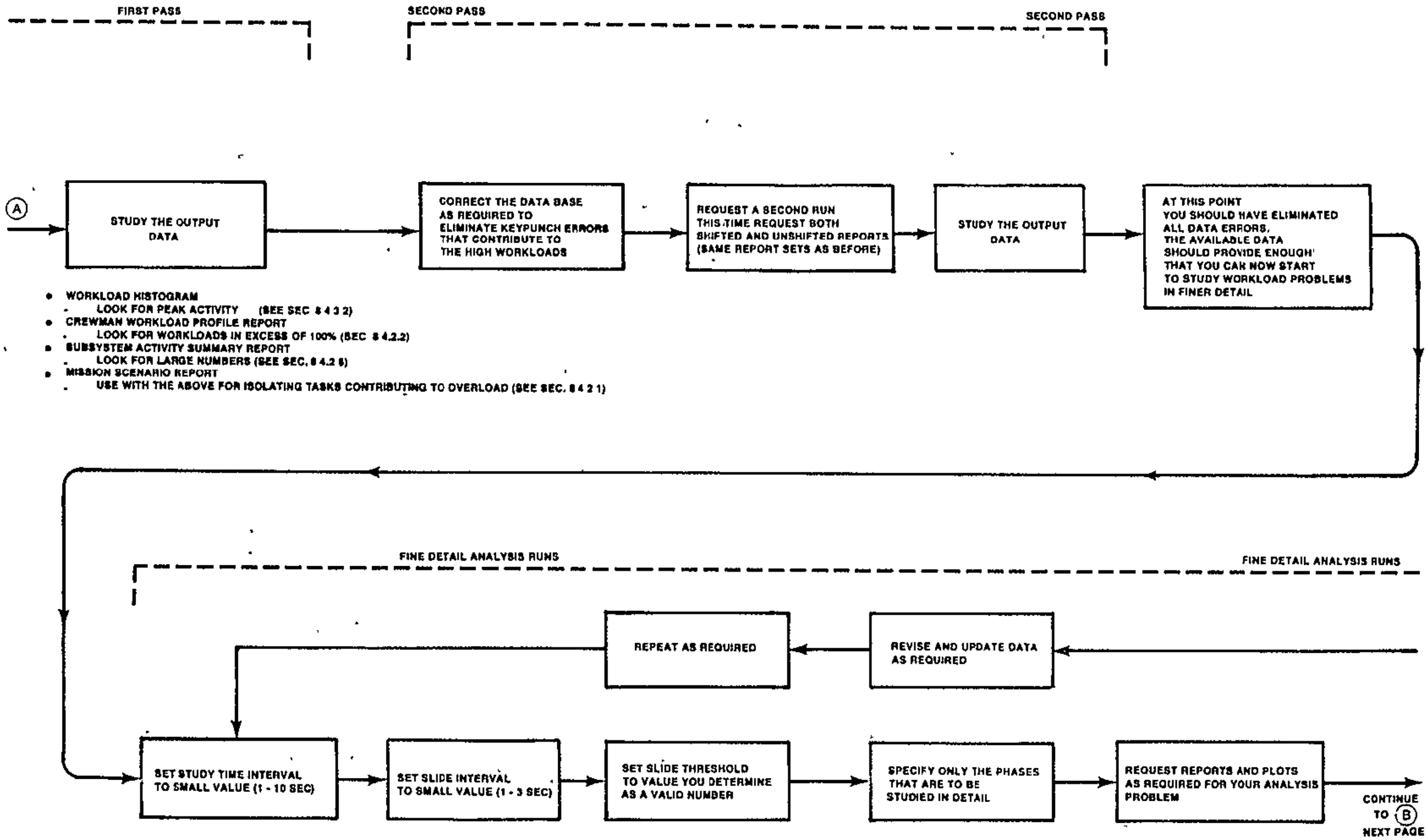

Figure 66.—(Continued)

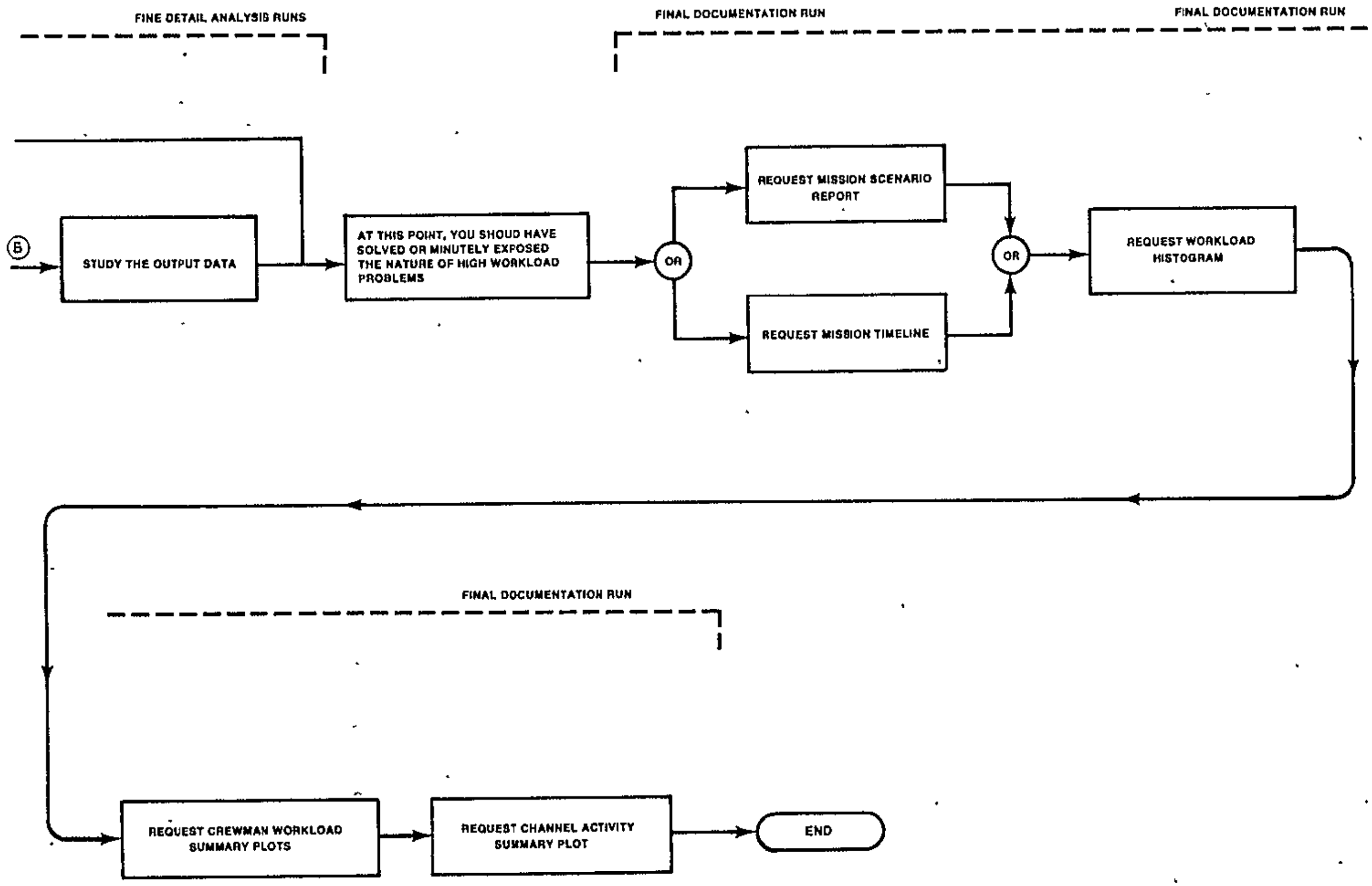

Figure 66.—(Concluded)

9.0 RECOMMENDATIONS FOR FUTURE DEVELOPMENT

This section lists and discusses the software modifications that are recommended for future development when TLA-2 is evolved. These recommendations range from minor corrections to some major fundamental, design changes.

During the development of the TLA-1 software, some limitations to the software design were accepted because of the press of time and budget, but they should be taken care of in the future. Some features designed into the program seemed at the time to be good ideas but, after using the program, it is obvious that these features should be modified.

The following software modifications are recommended:

1. Create a means for sliding entire procedures.

2. Create a means for specifying and requesting subsystem groups when requesting subsystem activity reports.

3. Find a more efficient way of doeing the mission timeline plot than on the CalComp plotter.

   a. Using the 4020 plotter is an improvement.
   b. Another option that could be explored is to have the title and descriptive lettering done by the line printer and to have the borders and time block plotted on a transparent overlay that would be mated with the line printer data.

4. Add a subsystem title to each page of the task list.

5. Provide a means for the program to scan the output request cards for format errors by either the input or the process modules so that errors on these cards can be diagnosed at the same time that input data errors are isolated.

6. Reformat the time scales on the report and plot formats as required so that all formats use the same time scaling.

7. For the mission scenario report, change the logic so that the tasks and procedures are listed in sequential time of initiation. (Currently, the tasks and procedures are listed in the sequence in which they are entered on the event/procedure coding form.)

8. For the crewmember summary statistics report and the workload summary plot, add the option of requesting statistics for the entire mission.

9. For the mission timeline plot, change the logic so that all tasks associated with a procedure are listed sequentially after the procedure title. (Currently, tasks from different procedures sometimes get listed under inappropriate procedure titles.)

10. Change the logic to allow the analyst to specify situation numbers for a task in any sequence.

11. Create some notation on the event/procedure coding form to show tasks that are performed simultaneously. Then, allow these simultaneous tasks to be shifted as a group.

12. Create some means to take away from the analyst the burden of calculating the start times of the tasks. This could be done by creating some code to indicate the sequence of tasks and the tasks to be performed simultaneously. (See item 11.)

13. Put in a diagnostic check to ensure that a zero slide time step and a zero report threshold are detected; or revise the code to allow the analyst to leave these parameters blank.

14. Reduce the number of files.

15. Create a means to extract from the date base and put into files only the phase, event/procedure, task, and subsystem data that are applicable to the scenario.

16. Redo the mission timeline plot subroutine to reduce reads and writes.

17. Provide for selective editing of phases, events/procedures, tasks, and subsystems. Then, alter process module data only to the extent of the edit changes.

18. Revise the code to include TX-105 Link 3 inputs, processing, and output format.

19. Change the code for weighted average channel to AVE on the report request form.

20. Improve the arithmetic subroutine in the timeline plot option to eliminate the time scale numbers that end in fractional 9's.

21. Revise the mission data coding form to restrict the crewmember specification fields to four crewmembers.

Boeing Commercial Airplane Company
P.O. Box 3707
Seattle, Washington 98124
April 16, 1976

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