CREW PROCEDURES DEVELOPMENT TECHNIQUES

FINAL REPORT

3 JANUARY 1975 MDC E1196

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COPY NO. 8

This report was prepared by McDonnell Douglas Astronautics Company-East, under contract NAS 9-13660, "Crew Procedures Development Techniques" for the Johnson Space Center of the National Aeronautics and Space Administration. The work was administered under the technical direction of the Crew Training and Procedures Division, Flight Operations Directorate of the Johnson Space Center with Don W. Lewis acting as Technical Manager.

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ABSTRACT

The Crew Procedures Development Techniques (CPDT) study developed requirements, designed, developed, checked out and demonstrated the Procedures Generation Program (PGP).

The PGP is a digital computer program which provides a computerized means of developing flight crew procedures based on crew action in the Shuttle Procedures Simulator. In addition, it provides a real-time display of procedures, difference procedures (actual vs. reference), performance data and performance evaluation data. Reconstruction of displays are possible post-run. Data may be hardcopied, stored on magnetic tape and transferred to the Generalized Document Processor for editing and documentation distribution.

SECTION 1

INTRODUCTION

This report presents the final results of the Crew Procedures Development Techniques Study conducted for the Johnson Space Center of the National Aeronautics and Space Administration under contract NAS 9-13660. This study was performed by the McDonnell Douglas Astronautics Company - East at the Houston Operations facility with subcontract support from United Airlines, Denver, Colorado.

A technical synopsis of the tasks performed and documents published is in Section 2. Conclusions and recommendations are in Section 3. An annotated bibliography is in Section 4.

SECTION 2

TECHNICAL SYNOPSIS

The purpose of this study was to develop a crew procedures development and evaluation digital program to be utilized in conjunction with the Shuttle Procedures Simulator (SPS). To accomplish this, a baseline system was established utilizing hardware available which related the interface between the SPS and the digital program "Procedures Generation Program" (PGP). This baseline system included the necessary PGP user interface hardware.

A comprehensive set of detailed software requirements were then written defining the eventual operational capability of the PGP. Detailed software and hardware requirements were also written for the PGP user console and related SPS interface. Top-level design of the PGP was developed taking into consideration all requirements. A traceability matrix was developed to assure all requirements were accounted for. Software design then progressed to math flow development for each subroutine making up the modules. This activity was directed toward achieving a program suitable for demonstrating the feasibility of automating the process of crew procedures development and providing data for the evaluation of vehicle and crew performance from SPS runs, and as such did not strive for satisfying all requirements documented.

Coding was performed from the developed math flows and minimal checkout performed on the subroutine level. Module checkout was performed in a non-real-time mode.

From the beginning of the study, it was recognized that the majority of the checkout verification would have to be accomplished in a real-time

SPS mode. Software was developed to record SPS output and to play back to the PGP in a pseudo real-time mode. This proved to be a very useful tool and minimized the requirements for real-time SPS support. Some SPS support was required and not available; therefore, a stop work order was placed on the contract for a period of 90 days starting 5 August 1974. Further complications were encountered when the SPS crew station was reconfigured and when the CDC 6400 computer operating system was changed from SCOPE 3.3 to SCOPE 3.4.1 prior to the demonstration of the PGP. The net result of these changes was insufficient SPS support time to completely checkout the PGP prior to demonstration. PGP demonstrations were successfully held on schedule and the study contract successfully concluded with an update to the math flow charts to reflect changes which took place during PGP checkout and verification.

2.1 DEVELOPMENT OF PGP

The following paragraphs contain a summary of each task performed in the study contract.

2.1.1 Baseline System Concept

The purpose of this task was to define a baseline system for developing Shuttle crew procedures and training the Shuttle flight crews. Hardware and software components of the baseline system were identified, and several attractive alternatives to the baseline that involve procuring additional hardware and/or software were identified. Crew Procedures Development Techniques Design Note No. 1 (The Crew Procedures Development Baseline System and Alternates) documents the results of this task.

The baseline system was designed to (1) automate crew procedures generation using the Shuttle Procedures Simulator (SPS) as the procedures basis and (2) provide a tool for instructor monitoring and evaluation of pilot/vehicle performance for crew training. The system was constrained to utilize existing hardware in the Building 35 computer complex of the Johnson Space Center.

Figure 2-1 shows the resulting components of the baseline system and their functional connections. Table 2-1 describes each of the components.

Operational scenarios for a procedures developer and an SPS instructor were developed to test and verify that the baseline system would satisfy the applications and needs of the different PGP users. As a result of this and the examination of alternatives to the baseline system components, it was concluded that the baseline system (utilizing

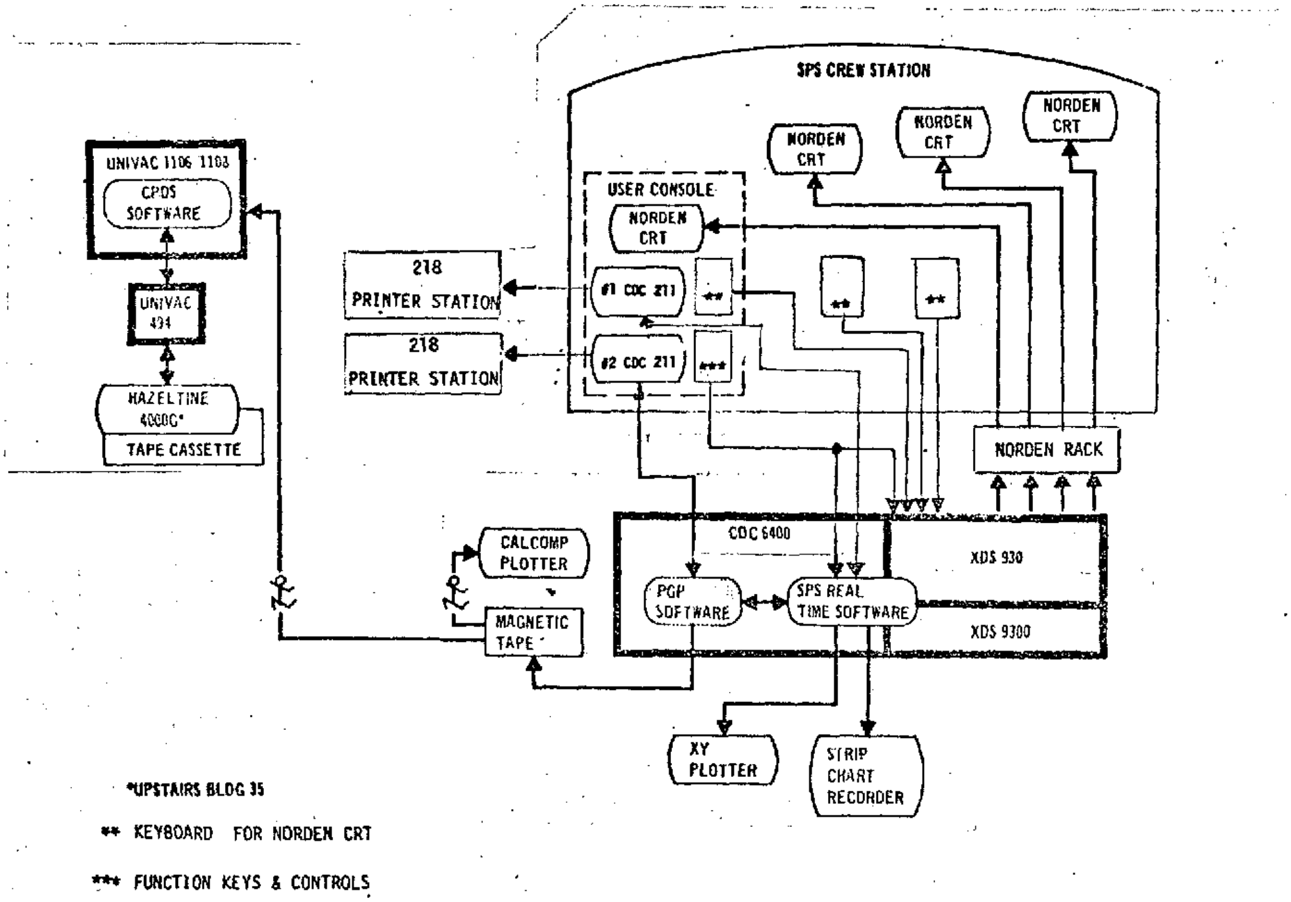

Figure 2-1 - Baseline System

TABLE 2-1 - BASELINE SYSTEM COMPONENTS

SYSTEM COMPONENTS	FUNCTIONS
USER CONSOLE	
#1 CDC 211	DISPLAY AND KEYBOARD PROVIDES INTERFACE WITH SPS REAL-TIME SOFTWARE. INTIATES SIMULATION, DISPLAYS SELECTION OF SPS PARAMETERS.
#2 CDC 211	DISPLAY AND KEYBOARD PROVIDES USER INTERFACE WITH THE PGP. DISPLAYS PROCEDURES AND PERFORMANCE DATA. ACCEPTS USER COMMAND INSTRUCTIONS. REAL-TIME LINK TO PGP SOFTWARE IN CDC 6400 COMPUTER.
NORDEN CRT	TWO MODES ARE TO BE PROVIDED. MODE 1 SLAVES (VIA A ROTARY SWITCH) THIS CRT TO ONE OF THE THREE CREW STATION CRTs. MODE 2 PROVIDES, VIA KEYBOARD ENTRIES, ACCESS TO ANY OF THE DISPLAYS CONTAINED IN THE XDS 930 SOFTWARE. THESE DISPLAYS INCLUDE THE SIMULATED ONBOARD DISPLAY AND GRAPHICAL PERFORMANCE DATA DISPLAYS.
FUNCTION KEYS & CONTROLS	CONTROL OF SPS SIMULATED SYSTEM FAILURES, SELECTION OF ATMOSPHERIC CONDITIONS AND SELECTION OF MODE OF DISPLAY ON NORDEN CRT.
KEYBOARD FOR NORDEN CRT	PROVIDES SAME FUNCTION CAPABILITY AS KEYBOARDS IN CREW STATION. IN ADDITION IT PROVIDES AN INDICATION, VIA LIGHTED KEYS, OF KEYBOARD ACTIVITY IN THE CREW STATION.
SPS CREW STATION	
NORDEN CRT	CREW STATION DISPLAY DEVICE. SIMULATES SHUTTLE ONBOARD CRT. ALL NORDEN CRT's ARE INDEPENDENT WITH RESPECT TO DISPLAY DATA.
KEYBOARD	SIMULATION OF INTERFACE WITH ONBOARD COMPUTER. EACH KEYBOARD HAS THE CAPABILITY TO ADDRESS ANY NORDEN CRT.
EQUIPMENT EXTERNAL TO CREW STATION	
NORDEN RACK	PROVIDES INTERFACE FROM XDS 930 TO THE NORDEN CRT's.
218 PRINTER STATION	IBM SELECTRIC TYPEWRITER PROVIDES HARDCOPY PRINT OF CDC 211 DISPLAY.
COMPUTERS-CDC 6400, XDS 930, XDS 9300	COMPUTERS CONTAINING PGP AND SPS REAL-TIME SOFTWARE.
CALCOMP PLOTTER	PROVIDES HIGH QUALITY GRAPHICAL HARDCOPY FROM AN INPUT MAGNETIC TAPE.
MAGNETIC TAPE	CDC 6400 PERIPHERAL EQUIPMENT. STORES DATA FOR TRANSFER TO CPDS OR DATA INPUT TO CALCOMP PLOTTER.
XY PLOTTER	PROVIDES XY PLOT OF SPS VARIABLES WITHOUT PGP INTERFACE.
STRIP CHART RECORDER	PROVIDES PLOT OF SPS VARIABLE WITH RESPECT TO TIME WITHOUT PGP INTERFACE.
UNIVAC 1106/1108	COMPUTER CONTAINING CPDS SOFTWARE. UNIVAC 1110 IS TO BE PHASED IN LATE 1973.
UNIVAC 494	PROVIDES MESSAGE ROUTING BETWEEN CPDS TERMINAL AND CPDS SOFTWARE.
HAZELTINE 4000G	TERMINAL THAT PROVIDES INTERFACE WITH THE CREW PROCEDURES DOCUMENTATION SYSTEM (CPDS)

existing equipment) was adequate for developing and demonstrating the Procedures Generation Program objectives. However, the baseline user terminal (CDC 211) appeared inadequate for the operational phase of the PGP and it was recommended that NASA pursue obtaining a Crew Procedures Documentation System (CPDS) terminal (Hazeltine 4000G) and the necessary hardware and software to interface it with the CDC 6400 computer. Also, an interactive graphics terminal appeared to provide many of the features desirable for performance monitoring and therefore was recommended for consideration by the NASA. Figure 2-2 represents the components and functional layout of the advanced version of PGP which resulted from these recommendations and NASA approval.

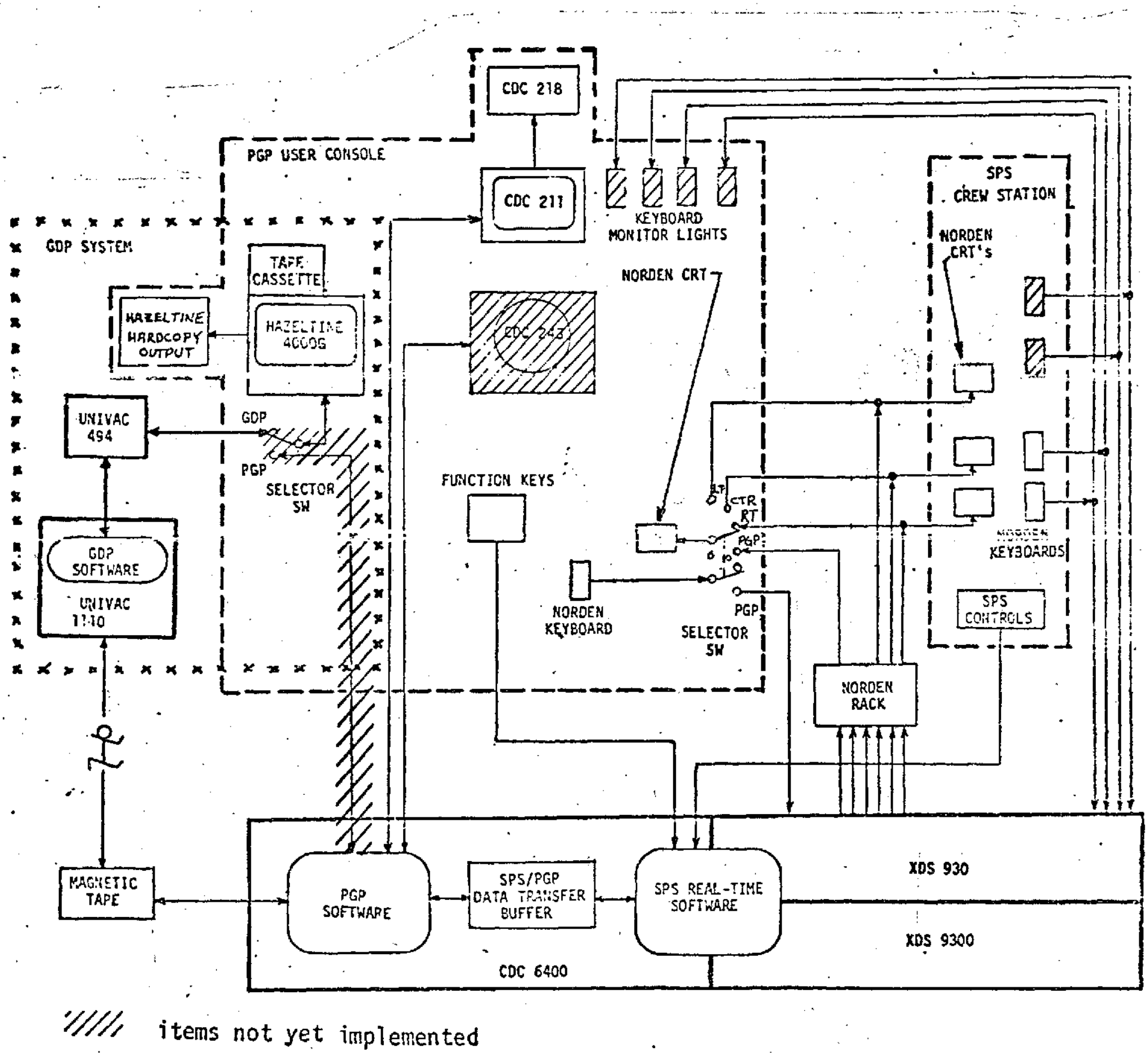

FIGURE 2-2 - ADVANCED PGP FUNCTIONAL DIAGRAM

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2.1.2 Define Computer Program Requirements

The purpose of this task was to (1) generate a PGP Requirements Document, (2) prepare a PGP data base, and (3) define PGP check cases.

PGP Requirements

The scope of the requirements document was such that it defined all the requirements for a digital computer program to automate the procedures development and performance data recording process in conjunction with a real time man-in-the-loop simulator, the Shuttle Procedures Simulator (SPS). The results (estimated at more than 500 requirements) of the requirements generation are documented in McDonnell Douglas Report No. MDC E1006 (Procedures Generation Program Requirements Document). The requirements for the PGP software, and the related requirements for the SPS are included.

Section 2 of the PGP Requirements Document, Procedures Requirements, identifies data which is the immediate result of crew action (e.g., switch settings, keyboard entries, and control deflections) which form the basis for documentation of crew procedures for flight plans, detailed procedures documents, and Flight Data File (FDF) checklists. The associated CRT display formats for these data are discussed in Section 3, Procedures Format Requirements. Section 4, Difference Procedures Requirements, identifies the requirements to establish the difference between the state of the crew station controls and displays on a standard state stored as reference procedures data. The associated display formats are presented in Section 5, Difference Procedures Format Requirements. The PGP is defined to process crew and vehicle system data and to output performance data as described in Section 6, Performance

Data Requirements. The CRT formats for these data are discussed in Section 7, Performance Format Requirements. Display Definition and User Interface Requirements are presented in Section 8. Section 9, Miscellaneous Requirements, present those requirements that do not logically fall in previous sections. Requirements for Training Scripts and Training Syllabus data are discussed. Finally, Section 10, SPS Requirements, details the software and hardware requirements to be implemented on the SPS in conjunction with the SPS.

The PGP requirements for user operation, control and monitoring of the automated system were specified to minimize the user interface. Figure 2-3 presents the revised version of the PGP display tree which was specified for display selection. Table 2-2 presents a revised list of the valid PGP user interface commands developed during the performance of the requirements generation task.

PGP Data Base

Crew Procedures Development Techniques Design Note No. 3 (Pre-Simulation Data Requirements for the PGP Data Base) documents the results of the PGP data base generation. This design note describes the data to be included in the data base and contains, as appendices, FORTRAN coding forms detailing the data base data required. The data presented represents that required for initial PGP activation and support of the PGP demonstration on the SPS for the Shuttle return sequence starting at entry interface (altitude of approximately 400,000 ft.) and continuing thru landing and rollout.

The PGP data base as defined in the design note is divided into four sections. The following describes the contents of each of these sections.

(1) Hollerith Statement Data - This section contains the English

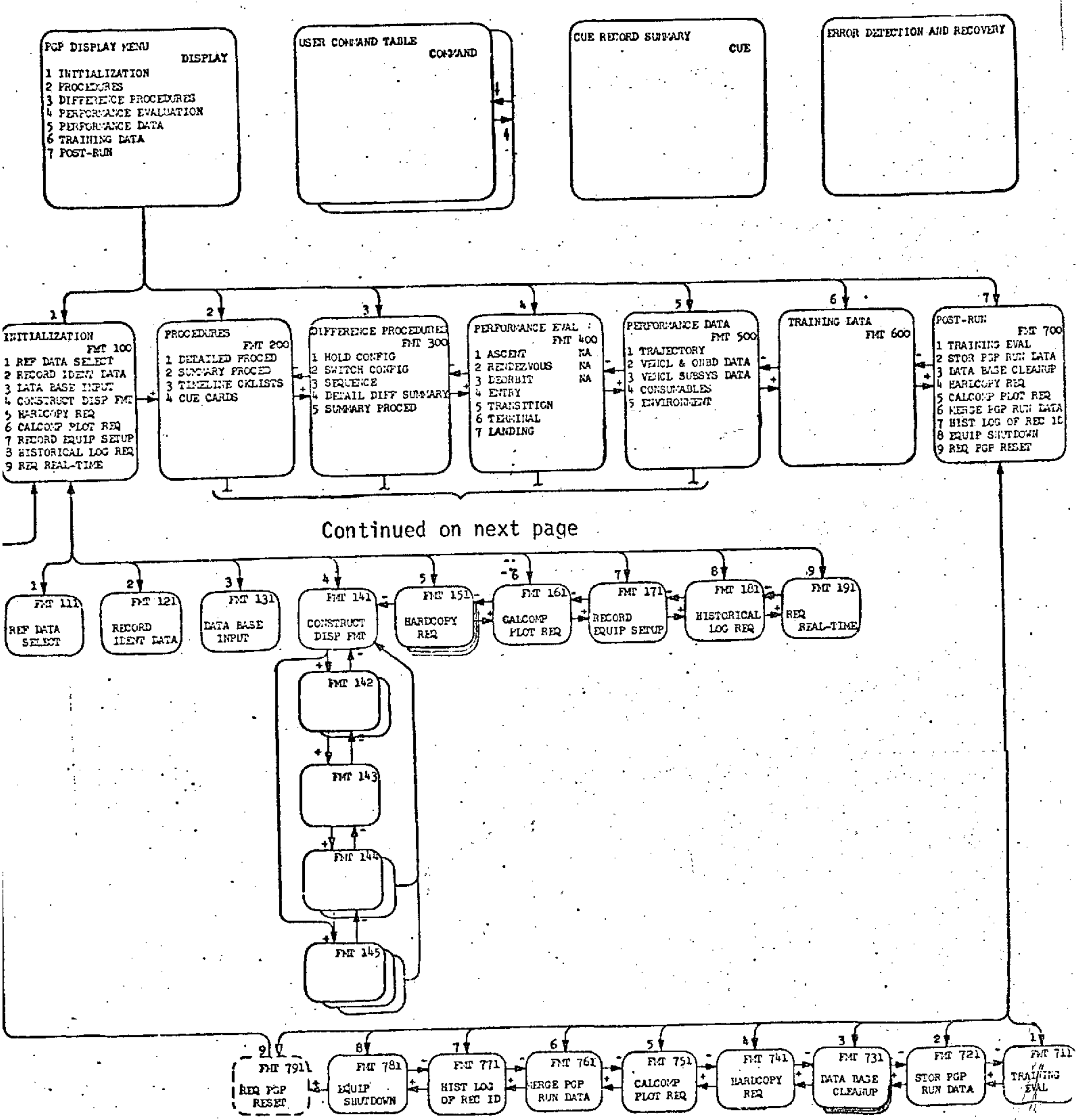

FIGURE 2-3 PGP DISPLAY TREE

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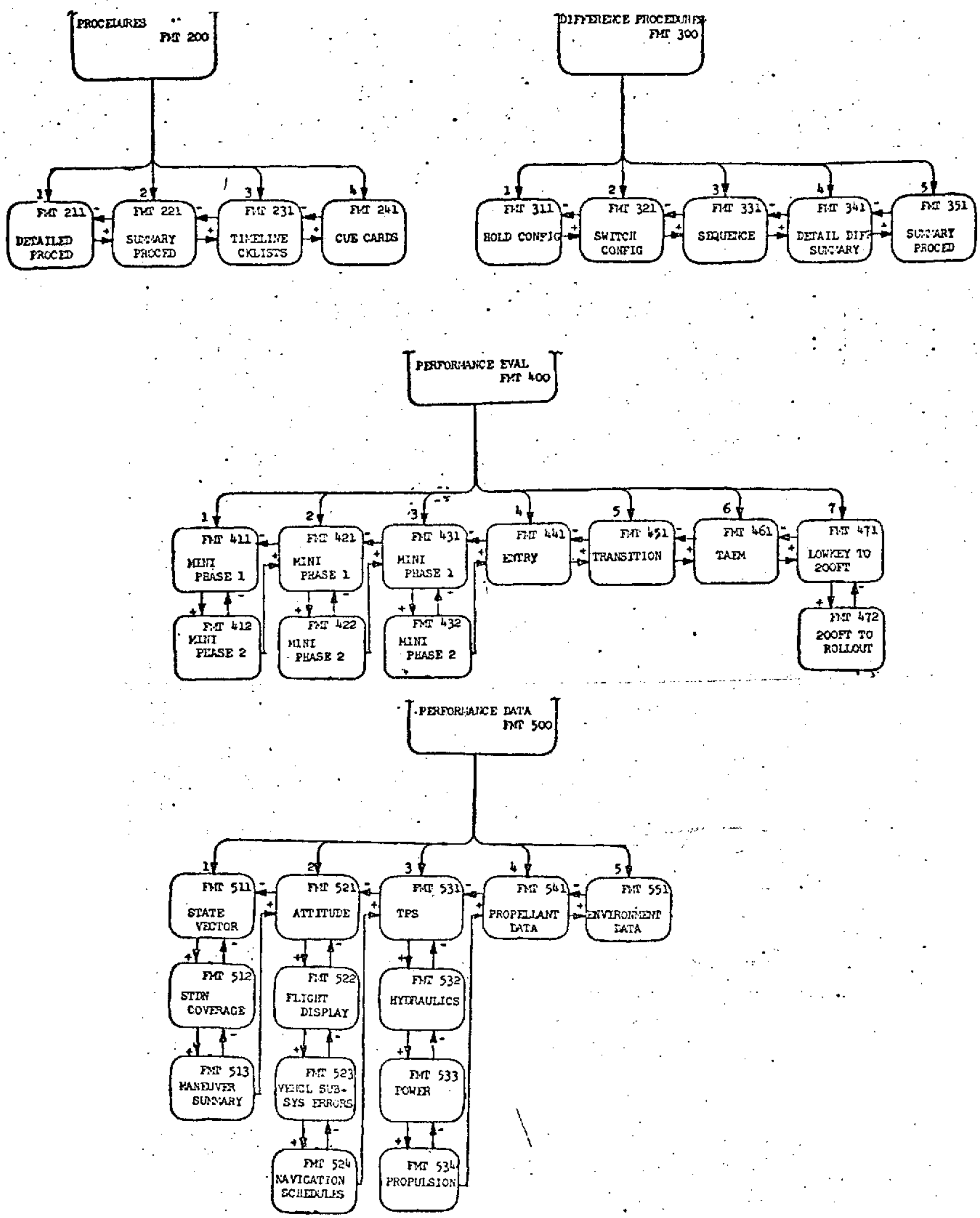

FIGURE 2-3 PGP DISPLAY TREE (CONT'D)

TABLE 2-2 REPERTOIRE OF VALID PGP COMMANDS

COMMAND	DESCRIPTION
COMMAND	PROVIDES DISPLAY COMMAND REPETORIE
CUE	PRESENTS CUE RECORD SUMMARY
DISPLAY	PRESENTS DISPLAY OF PGP DISPLAY MENU AND INITIATES CALLING SEQUENCE
N	REQUESTS DISPLAY OF THE N-TH FORMAT AT THE NEXT DISPLAY LEVEL
DISPLAY=L, M, N	REQUESTS SPECIFIC DISPLAY FORMAT L= LEVEL 1, M= LEVEL 2, N= LEVEL 3
+	ADVANCE ONE DISPLAY FORMAT
-	MOVE BACK ONE DISPLAY FORMAT
↑	ADVANCE ONE DISPLAY PAGE
↓	MOVE BACK ONE DISPLAY PAGE
^	ADVANCE ONE DISPLAY LINE
v	MOVE BACK ONE DISPLAY LINE
CLEAR	CLEAR DISPLAY ROTATION ARRAY
*	SELECT NEXT DISPLAY FROM ROTATION ARRAY ARRAY CONTAINS UP TO 5 FORMATS
REPEAT=L,M	CONSTRUCT CURRENT DISPLAY AT INPUT TIME L=TIME REF CODE OR MANEUVER EVENT M=TIME,HHH/MM/SS OR DELTA TIME,MM/SS
CONTINUE	RETURN DISPLAY TIME TO CURRENT TIME
/	CHANGE DATA SOURCE BETWEEN ACTUAL DATA AND REFERENCE DATA
COPY=L	COPY DISPLAY TO< L=LP PRINTER L=MT MAGNETIC TAPE
COMPARE	REQUEST COMPARISON OF CREW STATION
SWITCH	CHANGE CARD/211 INPUT SOURCE
RUN	BEGIN SPS/PGP REAL-TIME
BATCH	DISENGAGE SPS/PGP OPS.-BEGIN BATCH
TERMINATE	END OF INTERACTIVE RUN-DO HARDCOPY

language data used by the PGP to translate SPS data to procedures and difference procedures.

(2) Difference Procedures Data - This section contains the criteria data which determines when the PGP is to perform configuration difference and sequential difference tests and the switch groups and events included in the automatic difference tests. These data are made up of blocks of 10 parameters each. Switch groups are defined, pre-established times data with the appropriate switch groups are defined, and sequential test times data with the appropriate switch groups and events are defined.

(3) Format Descriptor Data - This section contains the data necessary to support the procedures, difference procedures, performance evaluation and performance data CRT formats displayed on the CDC 211 terminal.

(4) Reference Procedures Data - This section contains the detailed procedures data which provides the basis for difference procedures generation.

PGP Check Cases

Crew Procedures Development Techniques Design Note No. 5 (Program Verification Plan and Check Case Definition) documents the check cases required to checkout and verify the real time PGP operations and SPS/PGP interface on an integrated basis. These check cases assume that each PGP module has completed modular checkout and that the PGP checkout in the batch mode is complete. The check cases cover the Shuttle return sequence starting at entry interface and continuing thru landing and rollout. Various changes to the PGP and SPS system occurred following the publication of CPDT DN NO. 5, therefore, PGP Working Paper No. 11 (Program Verification Plan and Check Case Definition) was prepared to incorporate the necessary changes, such that, checkout of the PGP and SPS configurations was complete by the scheduled mid November demonstration.

The PGP functions and operations verified by the check cases are described below:

Check Case No. 1: PGP CRT DISPLAY CHECKOUT - The objective of this check case is to verify the display format structure and to exercise display callup and manipulation by all possible methods.

Check Cases No. 2 & 3: CREW INPUTS TO SPS SWITCHES, KEYBOARDS, AND CONTROLS - This check case exercises all active SPS controls to verify PGP recognition, transfer, and display capability; and verifies the PGP data base and detailed procedures generation.

Check Case No. 4: PERFORMANCE EVALUATION CHECK (LOW KEY TO ROLLOUT) - The purpose of this check case is to verify generation and auto sequencing of the performance evaluation formats (low key to rollout), summary procedures generation, hardcopy capability, cue capability, and to obtain reference data for subsequent runs.

Check Case No. 5: DIFFERENCE PROCEDURES CHECK - This check case verifies difference procedures generation (low key through rollout) and data display selection (actual vs. reference).

Check Case No. 6: DISPLAY FORMAT CONSTRUCTION/INTEGRATION - This check case defines a new format (FMT 241) consisting of new columnar and fixed data for the PGP via the CDC 211, and verifies PGP capability to accept and display data according to the specified format. The capability to perform PGP data base changes is also verified.

Check Case No. 7: PERFORMANCE EVALUATION CHECK (ENTRY TO LOW KEY) - This check case verifies generation and auto sequencing of performance evaluation formats (entry to low key), deviation detection, performance data format generation, and obtains reference data for subsequent runs.

Check Case No. 9: VERIFY REAL TIME = POST RUN = SPS DATA AND ACCURACY OF COMPUTED DATA - The purpose of this check case is to verify that the PGP provides data display representing the SPS conditions in real time and post run.

2.1.3 Develop Computer Program

The purpose of this task was to generate a digital computer program which satisfies the PGP requirements consistant with the baseline hardware system and the computer system software existing at the start of task. The scope of the task includes software design, coding and checkout, and coordination of the SPS interface. Specific details of the performance of this task are discussed in the following paragraphs.

Design Studies

Concurrent with the development of the PGP it was necessary to perform several programming technique studies. Due to the large amount of data which must be accessed by the PGP, efficient methods for data file input/output were investigated. The PGP baseline system included a requirement for a tape interface with the Crew Procedures Documentation System (CPDS), thus a study was necessary to determine the tape formatting requirements between PGP and the CPDS. Crew Procedures Development Techniques Design Note No. 2 (Procedures Generation Program Data Processing Studies) documents the results of these studies. Input/output techniques available on the CDC 6400 computer in Building 35 were investigated and the conclusions reached that existing techniques were adequate for support of the PGP requirements. Also included in the documentation is the procedure for establishing an interface with the CPDS using magnetic tapes.

PGP Equations Document

The objective of this task was to translate the computer program requirements into detailed software requirements. The results are documented in McDonnell Douglas Report MDC E1043 (Procedures Generation Program

Equations Document). Functional flow diagrams and requirements traceability matrices which define the top-level design of the PGP are documented.

The design of the PGP incorporates four basic features:

(1) Modular design to simplify identification of necessary program structures,

(2) Real-time processing to provide the interface between the PGP and the SPS,

(3) Multi-computational-loops to ensure integrity of required data processing, and

(4) Data driven design to allow user definition of critical parameters which define the format of the procedures data and evaluation data.

Modular design was accomplished by assigning the computer program requirements to fourteen modules, and by further assignment of these requirements to subroutine and subroutine entry points within each module.

The fourteen PGP modules that were defined are listed below:

1. Initialization (INITIAL),
2. Sequence Control (SEQCON),
3. Real-time Interface (RTFACE),
4. Input/Output (INOUT),
5. Procedures Processor (PROCPR),
6. Difference Procedures Processor (DIFPPR),
7. Performance Processor (PERFPR),
8. Performance Evaluation Processor (EVALPR),
9. Procedures Formatter (PROCFM),

10. Difference Procedures Formatter (DIFPRM),
11. Performance Data Formatter (PERFFM),
12. Performance Evaluation Formatter (EVALFM),
13. Training Formatter (TRAINFM),
14. Post-Run (POSTRUN).

Figure 2-4 represents the top-level requirements traceability matrix that resulted in the definition of these modules. The requirements are listed by paragraph from the PGP Requirements Document.

As a result of the detailed design effort of the PGP that followed this top-level design, a fifteenth module, Real-Time INPUT/OUTPUT (RTIO), was identified. This module supported the multi-computational loop design philosophy to guarantee integrity of the required data processing.

The resulting PGP program design may be summarized by three computational loops: (1) Real-time Cycle (RTC), (2) Real-time Input/Output Cycle (RTIOC), and (3) Major Cycle (MC). The RTC provides the interface with the SPS and the processing required to assemble the run data. The RTIOC processes mass storage data transfer of run data. The MC processes user commands, run data selected for display, and data base input/output. The purpose of this multi-loop design is to insure that (1) processing of the SPS data to run data in the RTC is accomplished and (2) processing of the run data transfer to mass storage in the RTIOC is accomplished regardless of any user intervention within the MC. Figure 2-5 indicates a generalized flow of processing and data exchange of the PGP during the real-time operating mode.

As part of this task an analysis was completed for each PGP module which provided a more detailed specification of the module design. The analysis

FIGURE 2-4 TOP LEVEL REQUIREMENTS TRACEABILITY MATRIX FOR THE PGP

REQUIREMENTS NOTE (1)	MODULE / NOTE (2)	INITIAL	SEGCOM	RTFACE	INPUT	PROCPR	DIFFPR	PERFPR	EVALPR	PROCFM	DIFFFM	PERFFM	EVALFM	TRANSFM	POST RUN	DEFERRED
2.1 DATA TRANSFERRED FROM THE SPS	3			1-3												
2.2 DATA STORAGE REQUIREMENTS	2				1	1,2										
2.3 DISPLAY CAPABILITY	1				1											
2.4 DISPLAY CONSTRUCTION	3		2,3			1										
2.5 DATA MANIPULATION	4					1									2-4	
2.6 CPDS DATA TRANSFER	2														2	1
2.7 HOLLERITH STATEMENTS	4	4				1-3				2	2					1
2.8 EDIT Note (2)	1				1											2
2.9 RESET	1															1
2.10 CHECKPOINT	2															1,2
2.11 CUE INSERTION	1			1												
2.12 TIME	2	1	1							2						
3.1 PROCEDURES FORMAT SELECTION	2		2		2					1,2						
3.2 PROCEDURES FORMAT CONSTRUCTION	4	1-3								1						4
3.3 DETAILED PROCEDURES FORMAT	1									1						
3.4 SUMMARY PROCEDURES FORMAT	1									1						
3.5 TIMELINE CHECKLISTS FORMAT	1									1						
4.1 GENERAL REQUIREMENTS	2				2		1,2									
4.2 DATA TRANSFERRED FROM THE SPS	2	1		1,2			1									
4.3 HOLD CONFIGURATION DIFFERENCE REQUIREMENTS	8						1,2,4, 5,7,8									3,6
4.4 SWITCH CONFIGURATION DIFFERENCE REQUIREMENTS	3	2	3				1-3									
4.5 SEQUENCE DIFFERENCE REQUIREMENTS	4	4					1-4									4
4.6 DETAILED DIFFERENCE SUMMARY REQUIREMENTS	1						1									
4.7 SUMMARY PROCEDURES DIFFERENCE REQUIREMENTS	1						1									
5.1 DIFFERENCE PROCEDURES FORMAT SELECTION	2		1		1						1,2					
5.2 DIFFERENCE PROCEDURES FORMAT CONSTRUCTION	4	1-3									1,2					4
5.3 HOLD CONFIGURATION DIFFERENCE FORMAT	1										1					
5.4 SWITCH CONFIGURATION DIFFERENCE FORMAT	1										1					
5.5 SEQUENCE DIFFERENCE FORMAT	1										1					
5.6 DETAILED DIFFERENCE SUMMARY FORMAT	1										1					
5.7 SUMMARY PROCEDURES DIFFERENCE FORMAT	1										1					
6.1 DATA TRANSFERRED FROM THE SPS	3			1-3												
6.2 DATA STORAGE REQUIREMENTS	4	2			1			1,3,4	1,3,4							
6.3 DATA COMPUTATION REQUIREMENTS	1							1	1							
6.4 DISPLAY CAPABILITY	1				1							1	1			
6.5 PERFORMANCE EVALUATION	3								1,2				3			
6.6 PERFORMANCE PARAMETER DISPLAY CONSTRUCTION	2		2					2				1,2				
6.7 GRAPHICAL DISPLAY CONSTRUCTION	3							1-3								
6.8 RESET	2															1,2
6.9 CUE INSERTION	1			1				1	1							
7.1 PERFORMANCE FORMAT SELECTION	3		2,3		2,3			2				1,2	1,2			
7.2 PERFORMANCE FORMAT CONSTRUCTION	5	1,3-5										1,3-5	3-5			2
7.3 PERFORMANCE EVALUATION FORMATS	2								1				1,2			
7.4 PERFORMANCE PARAMETER FORMATS	4											1-3				4
7.5 NORDEN CRT PERFORMANCE FORMATS	5															1-5

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FIGURE 2-4 TOP LEVEL REQUIREMENTS TRACEABILITY MATRIX FOR THE PGP (continued)

REQUIREMENTS NOTE (1) \ MODULE	NOTE (2)	INITIAL	SCOCON	RTFACE	INPUT	PROCPR	DIFPPR	PEPFPP	EVALPR	PROCFM	DIFPFM	PEPFFM	EVALFM	TRAINFM	POST RUN	DEFERRED
8.1 BATCH OPERATIONS	3	1	1,3		1-3											
8.2 INTERACTIVE OPERATIONS	6		1-3 5,6		1,2,4											
8.3 REAL TIME OPERATIONS	8	3,4,6	2-4, 6	1,2,4 8	6-8							6	6		3,5,6	3,5
8.4 ERROR DETECTION AND RECOVERY	2	2	1,2	1	2			1	1						2	
8.5 PGP DATA BASE INPUT	3	1-3														
8.6 USER INTERFACE DISPLAYS	3	1,3													2,3	
8.7 DISPLAY FORMAT STANDARDS	2	2			1					2	2					
8.8 DISPLAY FORMAT DESCRIPTORS	2	1-2														
8.9 DISPLAY FORMAT SELECTION	5	5	1-3	3	4					1,3,5	1,3,5	1	1		1	
8.10 PGP OUTPUT NOTE (4)	3	1	1												1	3
9.1 TRAINING SCRIPT	7		3	2												1,4-7
9.2 TRAINING STATUS	6															1-6

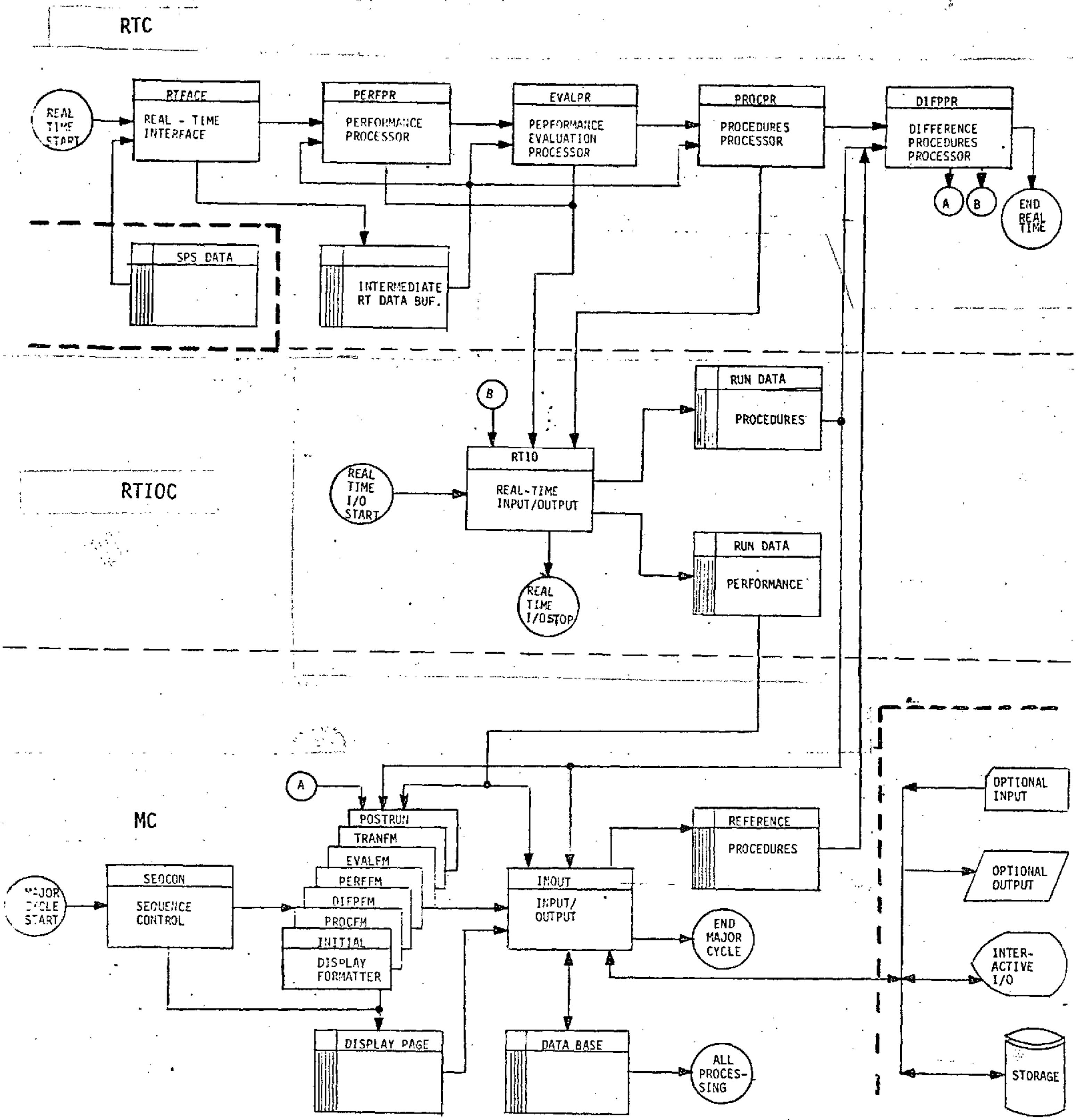
NOTE: (1) THE NUMBERS WITHIN THE MATRIX ARE SUBPARAGRAPH NUMBERS FROM REFERENCE I AND INDICATE THAT THE REQUIREMENT IS SATISFIED BY THE MODULE.

(2) TOTAL NUMBER OF SUBPRAGRAPHS WITHIN THE RESPECTIVE PARAGRAPH.

(3) TWO TYPES OF EDIT ARE DESCRIBED IN THE ONE PARAGRAPH.

(4) SUBPARAGRAPH 8.10.2 IS SATISFIED BY THE CDC 211 HARDWARE.

FIGURE 2-5 PGP TOP LEVEL FLOW AND DATA INTERFACE: REAL TIME



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resulted in the identification and top-level definition of subroutines within the modules to satisfy the PGP requirements. These subroutines are identified by module in Figure 2-6. Functional descriptions, logic flow diagrams, and requirements traceability were prepared for each of these subroutines.

SPS Modification Requirements for Data Transfer

A series of meetings were held between NASA (representatives of the Simulation Development Branch - Software Section) and MDAC-E personnel to determine the requirements and the software design of the interface between the SPS and the PGP. The results of these meetings were documented in Crew Procedures Development Techniques Design Note No. 4 (SPS Modifications Requirements For Data Transfer).

The SPS software and hardware requirements to support the PGP were reviewed, and an agreed upon list of SPS requirements to support PGP demonstration resulted. Design of the data transfer buffers for initialization data, crew station (procedures) data, and simulation (performance) data were the significant agreements regarding software design.

PGP inputs from the SPS are transferred through a common CDC 6400 computer buffer. Figure 2-7 illustrates the transfer buffer, which is 48 words long, for the initialization data and run data cases. For each reset (initialization) selection, this buffer is first loaded with the initialization data as defined in Table 2-3.

As the simulation goes to run, the transfer buffer is loaded with run data by the SPS each comp cycle. A comp cycle is that period of time during which the basic PGP and SPS equations are processed. The

FIGURE 2-6 PROCEDURES GENERATION PROGRAM (PGP) SOFTWARE IDENTIFICATION CHART

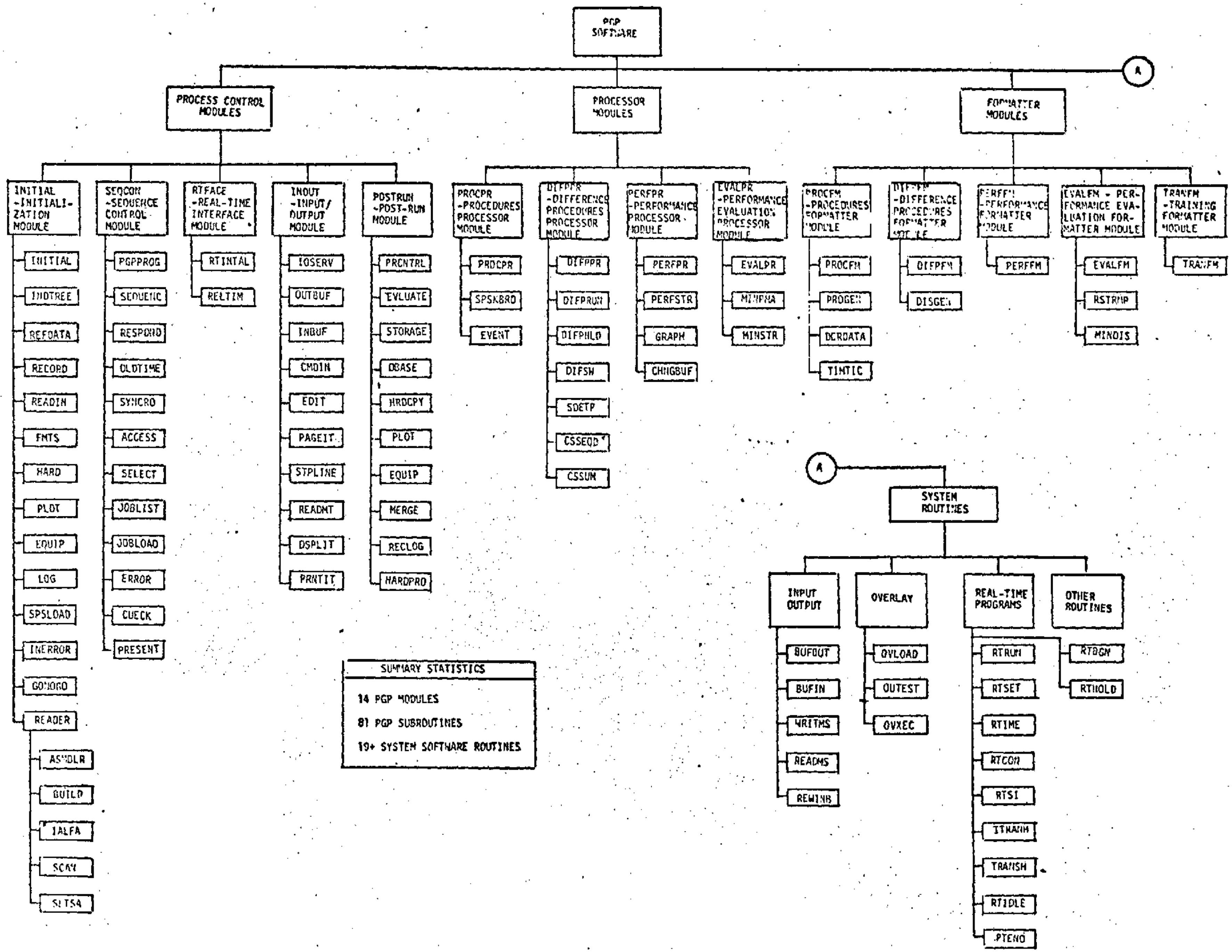

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FIGURE 2-7
SPS DATA TRANSFER BUFFER

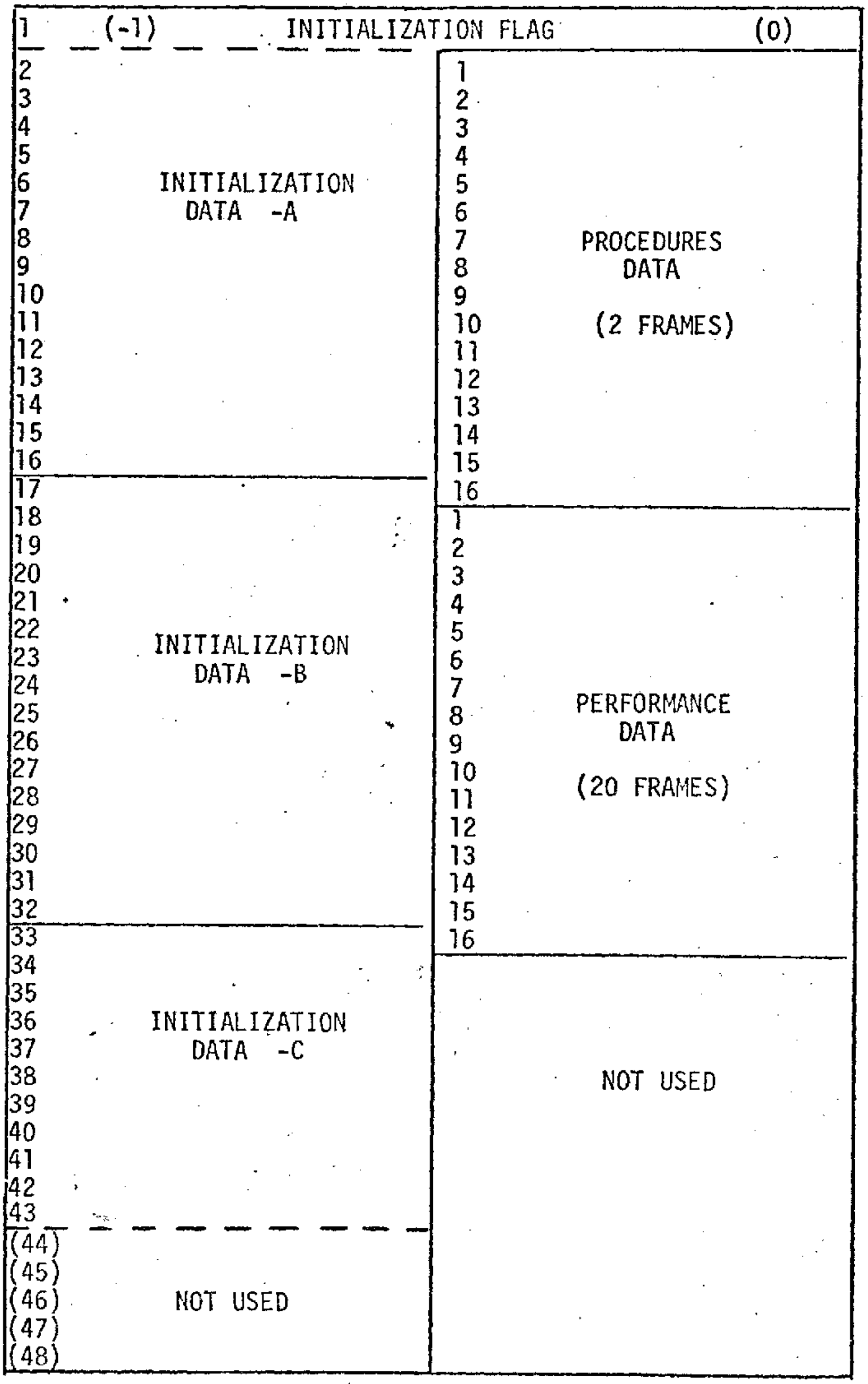


TABLE 2-3 DEFINITION OF INITIALIZATION DATA TRANSFER FROM SPS

FRAME #	DATA BLOCK RATE	LOCATION #	PARAMETER NAME	PARAMETER DEFINITION,	UNITS
1-A	--	1	IDATA	-1 INITIALIZATION 0 RUN DATA	-
(1)		2	PAR 333	LATE START	-
		3	PAR 334	MISSION PHASE	-
		4	PAR 367	WIND RANDOM GUST GAIN	-
		5	PAR 368	WIND PROFILE (1-5)	-
		6	PAR 369	WIND PEAK SPEED	FT/SEC
		7	PAR 370	WIND AZIMUTH WRT NORTH	DEG
		8	PAR 371	-1 SPHERICAL GRAVITY 0	-
		9	PAR 377	-1 RENDEZVOUS EQUA. 0	-
		10	PAR 398	GLIDE SLOPE (3.)	DEG
		11	PAR 399	GLIDE SLOPE DISPLAY RANGE (±.5)	DEG
		12	PAR 400	LOCALIZER DISPLAY RANGE (±2.5)	DEG
		13	PAR 401	GLIDE SLOPE ORIGIN (X-RUNWAY = 1200)	FT
		14	PAR 402	LOCALIZER ORIGIN (X-RUNWAY = 10,000)	FT
		15	PAR 403	OUTER MARKER ORIGIN (X-RUNWAY = -7)	NM
		16	PAR 404	MIDDLE MARKER ORIGIN (X RUNWAY = -3500)	FT
1-B (2)	--	17	PAR 405	X BODY AXIS C.G.	FT
		18	PAR 406	Y BODY AXIS C.G.	FT
		19	PAR 407	Z BODY AXIS C.G.	FT
		20	PAR 408	CNβ WRT CG (NON-NOMINAL)	1/RAD
		21	PAR 409	CNβ WRT CG (NON-NOMINAL)	1/RAD
		22	PAR 410	CNβ WRT CG (NON-NOMINAL)	1/RAD
		23	PAR 411	DESIRED INITIAL GLIDE SLOPE ANGLE	DEG
		24	PAR 412	ALTITUDE FOR GLIDE SLOPE TRANSITION	FT
		25	PAR 413	CN DELTA GAIN	-
		26	PAR 414	CA DELTA GAIN	-
		27	PAR 415	ROLL - MAX. RHC RANGE	DEG
		28	PAR 416	PITCH - MAX. RHC RANGE	DEG
		29	PAR 417	YAW-MAX. RHC RANGE	DEG
		30	PAR 418	RHC THRESHOLD	DEG
		31	PAR 419	ROLL RHC GAIN RATIO	-
		32	PAR 420	PITCH RHC GAIN RATIO	-
1-C	--	33	PAR 421	YAW RHC GAIN RATIO	-
		34	PAR 422	DENSITY RATIO	-
		35	PAR 423	MAX. BANK ACCELERATION (1.5)	DEG/SEC^2
		36	PAR 424	MAX. BANK RATE (8.)	DEG/SEC
		37	PAR 435	LONGITUDE BLACKOUT ERROR	DEG
		38	PAR 436	LATITUDE BLACKOUT ERROR	DEG
		39	PAR 491	DU #1 INITIAL DISPLAY	-
		40	PAR 492	DU #2 INITIAL DISPLAY	-
		41	PAR 493	DU #3 INITIAL DISPLAY	-
		42	PAR 498	≠0 CALCOMP DATA TAPE =0 NO TAPE	-
		43	PAR 499	PRINT ID NUMBER	-
		44 thru 48	NONE		

NOTE: (1) LOCATION 1 OF PROCEDURES DATA
(2) LOCATION 1 of PERFORMANCE DATA

transferred data is maximized by packing of discrete parameters (maximum of 60 per word) and through multiplexing techniques.

Table 2-4 defines the procedures data transfer. During a simulation run, the transfer buffer shown in Figure 2-7 is loaded by the SPS and contains alternately frame 1 and frame 2 procedures data. Locations 2 through 5 are the same for both frames and contain all of the discrete crew station switch position information. This provides discrete procedural data every comp cycle, and a complete set of procedures data (analog and discrete) every 2 comp cycles.

Table 2-5 defines the performance data transfer. During the simulation run, the transfer buffer contains one of the 20 frames of performance data. Each comp cycle the transfer buffer is loaded by the SPS with a new frame of data which the PGP reads and processes. A complete set of performance data is transferred in 20 comp cycles.

Detailed Math Flow Charts and Software Development

PGP math flow charts were developed to serve as the detailed design tool which translates the software requirements in the Program Equations Document into a form from which the program could be coded directly. These math flow charts not only served as a development aid, but upon program completion they represented the most detailed documentation of the program with the exception of the computer listings. McDonnell Douglas Report MDC E1195 (Procedures Generation Program Math Flow Charts) documents the final versions of the math flow charts and represent the design of the PGP at the completion of the Crew Procedures Development Techniques Study.

The detailed software development of the PGP has made use of several

TABLE 2-4 DEFINITION OF PROCEDURES DATA TRANSFER FROM SPS

FRAME #	DATA BLOCK RATE	LOCATION #	PARAMETER NAME	PARAMETER DEFINITION	UNITS
1	1/FRAME	1	TIME	SIMULATION TIME	SEC
	1/FRAME	2	PDBUF(1)	PACKED DISCRETE	-
	1/FRAME	3	PDBUF(2)	BUFFER	-
	1/FRAME	4	PDBUF(3)		-
	1/FRAME	5	PDBUF(4)		-
	1/FRAME	6	PDBUF(5)	(RESERVED)	-
	1/FRAME	7	PDBUF(6)	(RESERVED)	-
	1/2 FRAMES	8	THROT(1)	THROTTLE CONTROLLER #1	NORMALIZED
	1/2 FRAMES	9	THROT(2)	THROTTLE CONTROLLER #2	N
	1/2 FRAMES	10	THROT(3)	THROTTLE CONTROLLER #3	N
	1/2 FRAMES	11	THROT(4)	THROTTLE CONTROLLER #4	N
	1/FRAME	12	RHC(1)	HAND CONTROLLER - PITCH	N
	1/FRAME	13	RHC(2)	HAND CONTROLLER - ROLL	N
	1/FRAME	14	RHC(3)	HAND CONTROLLER - YAW	N
	1/FRAME	15	SPSMODE	SPS MODE *	-
	1/FRAME	16	IFRAME	FRAME COUNTER	-
2	1/FRAME	1	TIME		
	1/FRAME	2	PDBUF(1)		
	1/FRAME	3	PDBUF(2)		
	1/FRAME	4	PDBUF(3)		
	1/FRAME	5	PDBUF(4)		
	1/FRAME	6	PDBUF(5)		
	1/FRAME	7	PDBUF(6)		
	1/2 FRAMES	8	STEER	NOSE WHEEL STEERING (OR RUDDER)	N
	1/2 FRAMES	9	FLAP	FLAPS (OR SPEED BRAKE)	N
	1/2 FRAMES	10	BRAKE(1)	LEFT WHEEL BRAKE	N
	1/2 FRAMES	11	BRAKE(2)	RIGHT WHEEL BRAKE	N
	1/FRAME	12	RHC(1)	ROTATIONAL HAND CONTROLLER	N
	1/FRAME	13	RHC(2)	ROTATIONAL HAND CONTROLLER	N
	1/FRAME	14	RHC(3)	ROTATIONAL HAND CONTROLLER	N
	1/FRAME	15	SPS MODE	*	
	1/FRAME	16	IFRAME		

* SPS MODE: 1) HOLD, 2) RESET, 3) OPERATE, ---, 10) ERROR

TABLE 2-5 DEFINITION OF PERFORMANCE DATA TRANSFER FROM SPS

FRAME #	DATA BLOCK RATE	LOCATION #	PARAMETER NAME	PARAMETER DEFINITION	UNITS
1	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #1	2	CR	CROSS RANGE	NM
		3	DR	DOWN RANGE	NM
		4	R	RANGE	FT
		5	QDOT	HEATING RATE	BTU/FT^2-SEC
		6	HDOT	ALTITUDE RATE	FPS
		7	VREL	RELATIVE VELOCITY	FPS
		8	G	G LOAD	G
		9	GX	ACCELERATION IN X-AXIS	G
		10	GZ	ACCELERATION IN Z-AXIS	G
		11	HDTC	COMMANDED ALTITUDE RATE	FPS
		12	ICOORD	COORDINATE FLAG	--
	1/SEC #1	13		NONE	
		14	GMODE	GUIDANCE MODE CHANGES	--
		15		NONE	
	20/SEC	16	IFRAME	FRAME COUNTER	
2	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC	2	BANK	BANK ANGLE	DEG
		3	ALPHA	ANGLE OF ATTACK	DEG
		4	LATITUDE	VEHICLE GROUND TRACK LATITUDE	DEG
		5	LONGITUDE	VEHICLE GROUND TRACK LONGITUDE	DEG
		6	DELTAL	LOCALIZER ERROR	DOTS
		7	DELTAG	GLIDESLOPE ERROR	DOTS
		8	ELEV	ELEVON DEFLECTION	DEG
		9	DEFLEC	BODY FLAP DEFLECTION	DEG
		10	ALT	ALTITUDE	FT
		11	BCMD	COMMANDED BANK ANGLE	DEG
		12	MACHNO	MACH NUMBER	
	1/SEC #2	13		X	FPS
		14		Y MANEUVER VELOCITY COMPONENTS	FPS
		15		Z	FPS
	20/SEC	16	IFRAME	FRAME COUNTER	SEC
3	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #3	2		MAIN ENGINE GIMBAL ANGLE	DEG
		3		MAIN ENGINE GIMBAL ANGLE	DEG
		4		MAIN ENGINE GIMBAL ANGLE	DEG
		5		MAIN ENGINE GIMBAL ANGLE	DEG
		6		MAIN ENGINE GIMBAL ANGLE	DEG
		7		MAIN ENGINE GIMBAL ANGLE	DEG
		8	PBODY	ROLL RATE	DEG/SEC
		9	QBODY	PITCH RATE	DEG/SEC
		10	RBODY	YAW RATE	DEG/SEC
		11	GCMD	COMMANDED G LOAD	G
		12	VIAS	INDICATED AIRSPEED	KNOTS
	1/SEC #3	13		NONE	
		14		NONE	
		15		NONE	
	20/SEC	16	IFRAME	FRAME COUNTER	

TABLE 2-5 DEFINITION OF PERFORMANCE DATA TRANSFER FROM SPS (continued)

FRAME #	DATA BLOCK RATE	LOCATION #	PARAMETER NAME	PARAMETER DEFINITION	UNITS
4	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #4	2	THETAH	LOCAL HORIZONTAL ATTITUDE θ_{LH}	DEG
		3	PHIH	LOCAL HORIZONTAL ATTITUDE ϕ_{LH}	DEG
		4	PSIH	LOCAL HORIZONTAL ATTITUDE ψ_{LH}	DEG
		5	THETAI	INERTIAL ATTITUDE θ_I	DEG
		6	PHII	INERTIAL ATTITUDE ϕ_I	DEG
		7	PHII	INERTIAL ATTITUDE ψ_I	DEG
		8		COMMANDED ATTITUDE θ_C	DEG
		9		COMMANDED ATTITUDE ϕ_C	DEG
		10		COMMANDED ATTITUDE ψ_C	DEG
		11	RPOT	RANGE POTENTIAL	NM
		12	TLD	TOTAL LIFT TO DRAG RATIO	-
	1/SEC #4	13	RALT	ONBOARD RADAR ALTITUDE	FT
		14	GS	GROUND SPEED	FPS
		15		NONE	
	20/SEC	16	IFRAME	FRAME COUNTER	
5	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #1	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 1		
	1/SEC #5	13		NONE	
		14		NONE	
		15		NONE	
	20/SEC	16	IFRAME	FRAME COUNTER	
6	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #2	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 2		
	1/SEC #6	13		IMU ERRORS	DEG
		14			DEG
		15			DEG
	20/SEC	16	IFRAME	FRAME COUNTER	
7	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #3	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 3		
	1/SEC #7	13		ALTITUDE AT VEHICLE APOGEE	NM
		14		ALTITUDE AT VEHICLE PERIGEE	NM
		15		NONE	
	20/SEC	16	IFRAME	FRAME COUNTER	
8	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #4	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 4		
	1/SEC #8	13		ONBOARD POSITION ERROR	FT
		14			FT
		15			FT
	20/SEC	16	IFRAME	FRAME COUNTER	FT
9	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #1	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 1		
	1/SEC #9	13		ONBOARD VELOCITY ERROR	FPS
		14			FPS
		15			FPS
	20/SEC	16	IFRAME	FRAME COUNTER	

TABLE 2-5 DEFINITION OF PERFORMANCE DATA TRANSFER FROM SPS (continued)

FRAME #	DATA BLOCK RATE	LOCATION #	PARAMETER NAME	PARAMETER DEFINITION	UNITS
10	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #2	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 2		
	1/SEC #10	13		HORIZON SENSOR 1 ANGLES	DEG
		14			DEG
		15		NONE	
	20/SEC	16	IFRAME	FRAME COUNTER	
11	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #3	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 3		
	1/SEC #11	13		HORIZON SENSOR 2 ANGLES	DEG
		14			DEG
		15		NONE	
	20/SEC	16	IFRAME	FRAME COUNTER	
12	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #4	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 4		
	1/SEC #12	13		INCLINATION ANGLE	DEG
		14	GAMMA	FLIGHT PATH ANGLE	DEG
		15		NONE	
	20/SEC	16	IFRAME	FRAME COUNTER	
13	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #1	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 1		
	1/SEC #13	13	HEAD	HSI MAGNETIC HEADING	DEG
		14	DEV	HSI DEVIATION	DOTS
		15	RI	HSI DISTANCE	NM
	20/SEC	16	IFRAME	FRAME COUNTER	
14	20/SEC	1	[illegible]E	GROUND ELAPSED TIME	SEC
	5/SEC #2	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 2		
	1/SEC #14	13	X		FT
		14	Y	VEHICLE POSITION VECTOR	FT
		15	Z		FT
	20/SEC	16	IFRAME	FRAME COUNTER	
15	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #3	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 3		
	1/SEC #15	13	XDT		FPS
		14	YDT	VELOCITY VECTOR	FPS
		15	ZDT		FPS
	20/SEC	16	IFRAME	FRAME COUNTER	
16	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #4	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 4		
	1/SEC #16	13		STAR IDENTIFIER	-
		14		AZIMUTH ANGLE TO STAR	DEG
		15		ELEVATION ANGLE TO STAR	DEG
	20/SEC	16	IFRAME	FRAME COUNTER	
17	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #1	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 1		
	1/SEC #17	13	BALT	BARO ALTIMETER READING	FT
		14		BAROMETRIC PRESSURE	IN. HG.
		15		HORIZON SENSOR ERROR	DEG
	20/SEC	16	IFRAME	FRAME COUNTER	

TABLE 2-5 DEFINITION OF PERFORMANCE DATA TRANSFER FROM SPS (continued)

FRAME #	DATA BLOCK RATE	LOCATION #	PARAMETER NAME	PARAMETER DEFINITION	UNITS
18	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #2	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 2		
	1/SEC #18	13			DEG
		14		HORIZON SENSOR ERRORS	DEG
		15			DEG
	20/SEC	16	IFRAME	FRAME COUNTER	
19	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #3	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 3		
	1/SEC #19	13	RCS	RCS PROPELLANT USED	LBS
		14		OMS PROPELLANT USED	LBS
		15		ORB PROPELLANT REMAINING	LBS
	20/SEC	16	IFRAME	FRAME COUNTER	
20	20/SEC	1	TIME	GROUND ELAPSED TIME	SEC
	5/SEC #4	2-12	SAME AS 5/SEC PARAMETERS OF FRAME 4		
	1/SEC #20	13		STDN STATION I.O. NUMBER	-
		14		STDN COVERAGE AOS TIME	SEC
		15		STDN COVERAGE LOS TIME	SEC
	20/SEC	16	IFRAME	FRAME COUNTER	

features which make the design unique to the CDC 6400 computer system on which the PGP has been developed. A short discussion of these unique features is presented in the following paragraphs.

1. Common Block Description - Transfer of data between subroutines within PGP is performed via common blocks. Argument lists are used on support subroutines only. A controlled dictionary of each parameter in the common blocks has been maintained.
2. Overlay Structure and Support Software - The PGP design makes use of overlays where practical in order to save core and stay within the design goal of $20K_{10}$ (48000_8) words. This design goal represents one quarter of the available core in the CDC 6400, and represents the PGP core allocation requirement set by the SPS Resources Control Board.

   Table 2-6 summarizes the structure of the PGP overlay design. Those modules which are required in core at all times have been assigned to the main (0,0) overlay. Those modules which are required in core only on an as requested basis are assigned to primary and secondary overlays.

   The PGP utilizes the NASA Program Library Routines (RTOVL) which is unique to the Building 35 complex to process overlays loading and execution.

   Figure 2-8 presents data describing the current core utilization. Included is a detailed specification by module of the largest overlay and a graphical representation of the size of all the overlays. It should be noted that currently core utilization is running above the design goal. Several checkout buffers are allocated and the oversize of some of the common blocks account

Table 2-6

PGP Overlay Structure

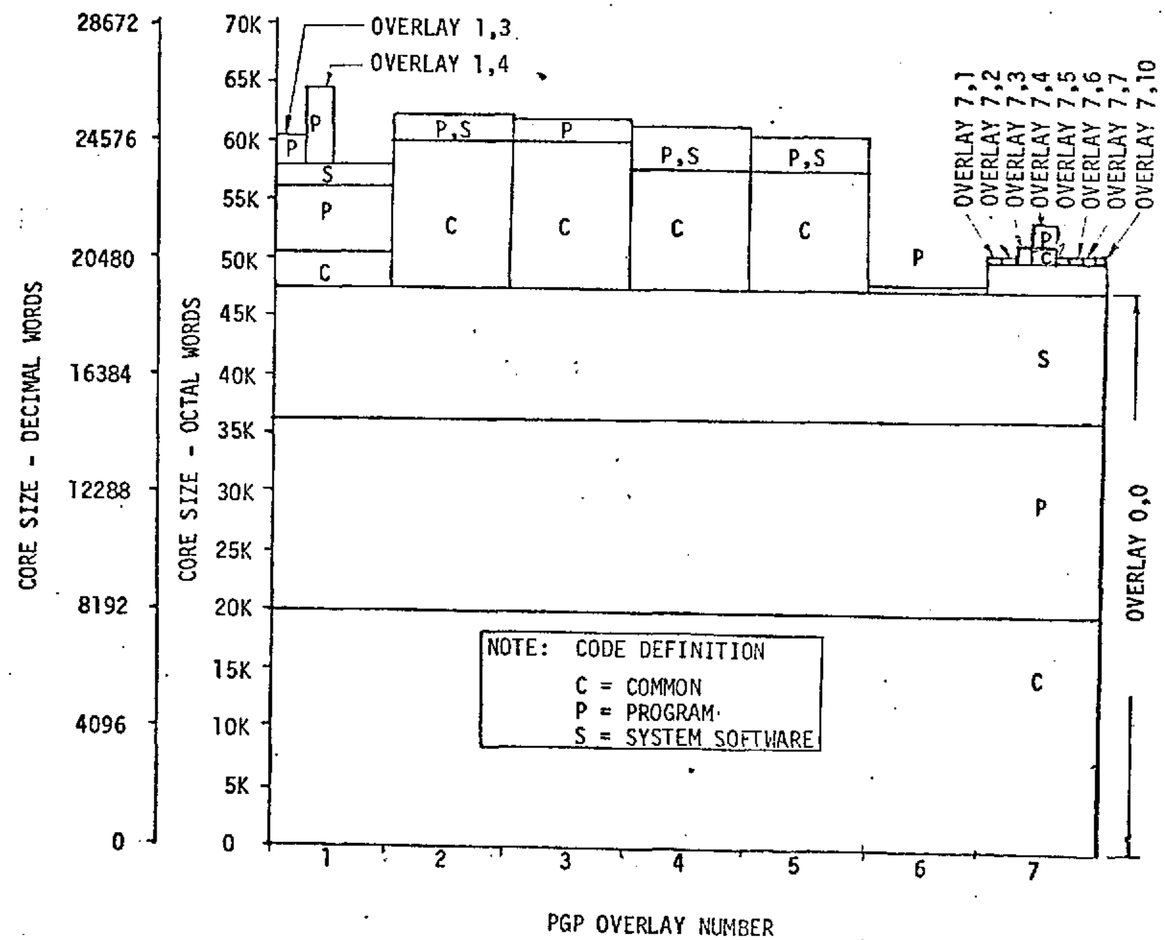
OVERLAY		
PRIMARY	SECONDARY	FUNCTIONAL DESCRIPTION/MODULE ASSIGNMENT
0	0	Sequence Control Module (SEQCON) Input/Output Module (INOUT) Real-time Interface Module (RTFACE) Real-time Input/Output Module (RTIO) Procedures Processor Module (PROCPR) Performance Processor Module (PERFPR) Support Functions/Subroutines
1	0	Initialization Module (INITIAL)
1	3	Data Base Input Submodules - Including routines READIN and READER
1	4	Format Descriptor Submodules - Including routines FMTS, and FMTCMDS
2	0	Procedures Formatter Module (PROCFM)
3	0	Difference Procedures Formatter Module (DIFPFM)
4	0	Performance Formatter Module (PERFM)
5	0	Performance Evaluation Formatter Module (EVALFM)
6	0	Training Formatter Module (TRANFM)
7	0	Post-Run Module (POST-RUN)
7	1	Training Evaluation Data Submodules (EVLUATE)
7	2	Run Data Storage Submodule (STORAGE)
7	3	Data Base File Cleanup Submodule (DBASE)
7	4	Post-Run Hardcopy Request Submodule (HRDCPY)
7	5	Post-Run Calcomp Plot Request Submodule (CPLOT)
7	6	PGP Run Data Merge Submodule (MERGE)
7	7	Post-Run Record Identifier Log Submodule (RECLOG)
7	10	Post-Run Equipment Shutdown Submodule (PEQUIP)

FIGURE 2-8 PGP SOFTWARE SIZING DATA

DETAILED SPECIFICATION OF LARGEST OVERLAY CORE UTILIZATION

		CORE SIZE	
		DECIMAL	OCTAL
OVERLAY 0,0	COMMON BLOCK	8200	20010
	SEQUENCE CONTROL	2436	4604
	INPUT/OUTPUT	844	1514
	REAL-TIME INTERFACE	154	232
	REAL-TIME I/O	251	373
	PROCEDURES PROCESSOR	890	1572
	PERFORMANCE PROCESSOR	338	522
	PERFORMANCE EVALUATION PROCESSOR	291	443
	DIFFERENCE PROCEDURES PROCESSOR	1246	2336
	FUNCTIONS	910	1616
	SYSTEM SOFTWARE	4714	11152
OVERLAY 1,0	COMMON BLOCK	600	1130
	INITIALIZATION	2830	5416
	SYSTEM SOFTWARE	590	1116
OVERLAY 1,4	FMTS (SOFTWARE DESCRIPTOR)	2637	5115
	TOTAL	26931	64463

GRAPHICAL SUMMARY OF CORE UTILIZATION



for some of the overrun. Reduction of these buffers and some program cleanup will result in PGP utilizing less than the design goal.

3. Real-time Software Routines - The PGP is required to operate in real-time in conjunction with the SPS. Initial design of the PGP utilized the CDC SCOPE 3.3 Time Critical Operating System to satisfy this requirement. However, it was necessary to convert to the Real-time SCOPE 3.4.1 system as a result of the upgrading of the computer operating system in the Building 35 facility.
4. CDC 6400 System Software and Machine Language - The PGP has been developed using the CDC 6400 computer, and the FORTRAN IV program language. The design has taken advantage of as many FORTRAN callable system software function and subroutines as possible. These include such functions as MASK, MOD, LOCF, MINO, etc. The reader is directed to review the program listing and math flow charts for other specifics. The PGP utilizes state-of-the-art programming techniques and is coded in standard FORTRAN IV language except for several subroutines which are coded in COMPASS.
5. PGP Data Base - The PGP utilizes several CDC 6400 system routines to access and retrieve the desired PGP Data Base files. The total data base is maintained external to the PGP as random access files on the high speed mass storage disc of the CDC 6400.

<u>Integrated Batch and Real-Time Checkout</u>

PGP Working Paper No. 11 (PGP Verification and Check Case Definition) documents the check cases developed for checkout and verification of the PGP operations and the SPS/PGP interface. The results of performing each of the defined check cases are discussed in Crew Procedures Development Techniques Design Note No. 9 (Simulation Results - PGP Verification).

Performance of the check cases resulted in the identification and correction of (1) minor programming errors, (2) check case definition errors, and (3) system errors. These details are summarized by check case in the design note.

The satisfactory results of performing the check cases indicated that the PGP design and development was complete enough to demonstrate the feasibility of automating the procedures development and performance data recording process.

Due to the limited amount of SPS real-time support that was provided the PGP, several system and programming problems that were identified during checkout still exist. PGP modifications for those problems have been prepared, but not checked out.

2.1.4 Users Guide

McDonnell Douglas Report MDC E1098 (Procedures Generation Program Users Guide) was prepared to describe the operations required to use the Procedures Generation Program and obtain desired procedures and performance data output. The material presented provides the PGP user general information on PGP system hardware and software, and detailed information on PGP operational requirements. The discussion of PGP operations describes initiation of CDC 211 operations, PGP operations for the three PGP phases (Initialization, Run, and Post-run), and termination of CDC 211 operations in support of a real-time run. A discussion is presented for the operational differences for the batch and batch interactive modes. A brief summary explanation is included which describes the information available on the different display formats.

2.1.5 Demonstration Plan

The demonstration of the PGP was scheduled to begin 15 November 1974 for the purpose of demonstrating the feasibility of automatic procedures generation and crew/vehicle performance monitoring. A Demonstration Plan was developed and documented in Crew Procedures Development Techniques Design Note No. 8 (Procedures Generation Program Demonstration Plan) to support the scheduled demonstration. The demonstration was designed to be performed in two exercises. Scripts were developed for each of these exercises which contain (1) the detailed operations to be performed at the PGP user console, (2) a functional description of what occurs in the SPS crew station, and (3) remarks relating objectives of the exercise.

Exercise 1 was designed to take approximately 1 1/2 hours and includes an overview of the total system capabilities with emphasis on procedures generation and performance monitoring and evaluation displays. A brief summary of the project history and synopsis for future development phases was also included in this Exercise.

Exercise 2 was designed to take approximately 1 hour and cover the difference procedures capability.

The actual demonstrations began 14 November 1974 and continued through 3 December 1974. Figure 2-9 represents the schedule and list of attendees at each of the demonstration exercises. Due to the extensive list of attendees scheduled to observe Exercise 1 and the limited availability of the SPS, only one Exercise 2 demonstration was performed.

FIGURE 2-9 FINAL PGP DEMONSTRATION SCHEDULE AND ATTENDEES

SUN	MON	TUES	WED	THURS	FRI	SAT
1200 HR 1330 HR				11-14 W.W.HINTON JR - MDTSCO R.T.HAMM - MDTSCO W.W.HAUFLER - MDTSCO S.G.PADDOCK - MDTSCO G.W.KNORI - MDTSCO	11-15 C.A.JACOBSON - MDTSCO E.A.THOMPSON - MDTSCO D.ARMSTRONG - MDTSCO	11-16 1200 HR 1330 HR
11-17 1200 HR 1330 HR	11-18 R.GIBBS - UAL S.GLENN - MDTSCO R.ANDERSON - MDTSCO D.WAMMACK - MDTSCO K.I.MANSFIELD - FE3 A.G.NOLTING - FE3	11-19 R.GIBBS - UAL (EXERCISE 2) D.C.SCHULTZ - CG2 R.G.ZEDEKAR - CG2 M.J.McRAE - MDTSCO D.K.WARREN - CG2 J.A.WEGENER - CG2	11-20 R.GIBBS - UAL CANCELLED DUE TO SYSTEM DOWN	11-21 R.GIBBS - UAL J.W.BILODEAU - CG C.B.SHELLEY - CG H.W.TINDALL JR-FA W.M.MERRITT - CG64 J.F.HONEYCUTT -CG6	11-22 OPEN J.P.LOFTUS JR - AT P.E.FITZGERALD JR - AT	11-23 1200 HR 1330 HR
11-24 1200 HR 1330 HR	11-25 P.C.KRAMER - EJ6 M.C.CONTELLA - EJ6 C.C.THOMAS - EJ6 J.C.AXFORD - EJ6 W.L.JACKSON - EJ6 A.R.FARLEY - FE3 K.S.KLEINKNECHT - CA E.F.KRANZ - CA J.W.ROACH - CA	11-26 T.W.HOLLOWAY - CG5 L.W.DUNN - MDTSCO C.O.LEWIS - CG2 M.V.JENKINS - FM4 J.C.HARPOLD - FM4	11-27 J.J.VAN BOCKEL-CG13 G.M.FERGUSON - CG13 M.S.BRZEZINSKI-CG13 D.K.MOSEL - CG2 D.L.BENTLEY - CG2 T.B.WARD - MDTSCO OPEN	11-28 THANKSGIVING	11-29 UNSCHEDULED UNSCHEDULED	11-30 1200 HR 1330 HR
12-1 1200 HR 1330 HR	12-2 UNSCHEDULED UNSCHEDULED	12-3 UNSCHEDULED L.ROBERTS - NASA HQ A.P.SANDERS - AT2 R.H.BROWN - FM3 R.D.DAVIS - FM4 J. GREEN - MDTSCO W.E.HAYES - MDTSCO W.T.MUSIAL - MDTSCO	12-4 DEMONSTRATIONS CANCELLED DUE TO UNAVAILABILITY OF SPS	12-5	12-6	12-7 1200 HR 1330 HR

A free format presentation approach was used during the PGP demonstration exercises to encourage participation and questions. This format also allowed the exercise presentation to concentrate on the PGP capabilities which were of unique interest to the different users represented by the audience in attendence. Crew Procedures Development Techniques Design Note No. 9 documents the results of the PGP Demonstration Plan. Selected questions and comments from the different audiences are documented. All questions and comments made during the demonstrations are being reviewed to determine if new and/or revised capabilities should be incorporated in the advanced PGP design.

2.1.6 Commercial Airline Applications

A study was performed which investigated the application of the PGP to current and future airline pilot training programs. This study of the PGP crew procedures development techniques and crew training concepts was conducted by United Airlines under subcontract support to McDonnell Douglas. The results of this study are being published concurrently with this report in Crew Procedures Development Techniques Design Note No. 10 (Procedures Generation Program (PGP) Applications to Commercial Airlines).

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

The Procedures Generation Program has been developed and documented in complete satisfaction of the Crew Procedures Development Techniques contract.

A number of new and modified detailed PGP requirements have been developed through the PGP development and checkout. These requirements are included in a separate report prepared under the Advanced Crew Procedures Development Techniques Study.

3.2 RECOMMENDATIONS

Development of the operational PGP is dependant upon SPS support and foreknowledge of SPS capabilities. Therefore, it is recommended that a SPS development plan be made available. This plan should include a description of the SPS capabilities over the developmental period. This plan should also show scheduled SPS down time for major modifications.

Section 4

BIBLIOGRAPHY

Several different documentation formats have been used to publish the progress and results of the Crew Procedures Development Techniques Study. These documentation formats and a summary of their contents are as follows:

MDC Reports - These documents correspond to the line item reports specified in the Data Requirements list of the contract. Delivery of these reports to NASA represents satisfactory completion of a major milestone of the project schedule.

Design Notes - These documents present technical information resulting from the completion of specific tasks performed on the study. They include such topics as pre-simulation, program verification, program development, data processing, simulation results, hardware modifications, user aids, advanced techniques, and commercial applications.

Working Papers - These documents represent informal publication of work as it is in progress within the PGP technical staff. Draft material documenting the development of a PGP Module or subroutine, or documentation of technical data to be exchanged among the PGP staff is published in a working paper.

Miscellaneous - Several reports required by the contract do not logically fall into any of the above categories. These include computer listings and tapes and status reports of the contract.

A complete annotated bibliography of the documentation prepared under the Crew Procedures Development Techniques Study is presented in Table 4-1. Included in the table is the report title, number, date of publication, list of authors, and synopsis of the contents of each of the documents written. The bibliography is subdivided according to the four format categories described above.

TABLE 4-1

BIBLIOGRAPHY OF CREW PROCEDURES DEVELOPMENT TECHNIQUES STUDY DOCUMENTATION (1 OF 5)

DOCUMENT - TITLE	DATE	AUTHOR	SYNOPSIS
MDC REPORTS			
MDC E1006 - PROCEDURES GENERATION PROGRAM REQUIREMENTS DOCUMENT	31 January 1974	R.L.BENBOW R.G.GIBBS M.L.HAWK W.W.HINTON JR	This document defines the computer program software requirements for the Procedures Generation Program. These requirements are the guidelines used for initial development of the PGP.
MDC E1043 - PROCEDURES GENERATION PROGRAM EQUATIONS DOCUMENT	15 March 1974	R.L.BENBOW R.T.HAMM W.W.HINTON JR A.MANGIARACINA J.L.McGAVERN R.L.WEST	This report presents the top-level design of the Procedures Generation Program. The requirements specified in the PGP Requirements Document are assigned to one of fifteen software modules, and further assigned to subroutines within these modules. Module and subroutine functional flow diagrams are also presented.
MDC ETBD - PROCEDURES GENERATION PROGRAM MATHFLOW CHARTS - PRELIMINARY	24 May 1974	R.L.BENBOW R.T.HAMM M.L.HAWK A.MANGIARACINA J.L.McGAVERN	This report contains the math flow charts for the subroutines contained in the Procedures Generation Program. Mathflow charts completed as of 24 May 1974 are presented.
MDC E1098 - PROCEDURES GENERATION PROGRAM USERS GUIDE	21 June 1974	J.D.ARBET M.L.HAWK	This report describes the operations required to use the Procedures Generation Program and obtain the desired procedures and performance data outputs. General information on PGP system hardware and software, and detailed information on PGP operational requirements are presented.
MDC E1195 - PROCEDURES GENERATION PROGRAM MATHFLOW CHARTS	3 January 1975	R.L.BENBOW M.L.HAWK A.MANGIARACINA J.L.McGAVERN M.C.SPANGLER	This report contains the mathflow charts for the subroutines contained in the Procedures Generation Program. These mathflow charts represent the status of the PGP as of the completion of the Crew Procedures Development Techniques Study.
MDC E1196 - CREW PROCEDURES DEVELOPMENT TECHNIQUES STUDY - FINAL REPORT	3 January 1975	J.D.ARBET R.L.BENBOW M.L.HAWK A.MANGIARACINA J.L.McGAVERN M.C.SPANGLER	This report presents a summary of the results of the work performed on the Crew Procedures Development Techniques Study. A technical synopsis, abstract, conclusions, recommendations, and annotated bibliography are included.

TABLE 4-1

BIBLIOGRAPHY OF CREW PROCEDURES DEVELOPMENT TECHNIQUES STUDY DOCUMENTATION (CONT'D - 2 OF 5)

DOCUMENT - TITLE	DATE	AUTHOR	SYNOPSIS
DESIGN NOTES			
CPDT DN 1 - CREW PROCEDURES DEVELOPMENT BASELINE SYSTEM AND ALTERNATES	5 October 1973	M.L.HAWK	This design note describes the baseline system for automated crew procedures development and performance monitoring and includes a brief evaluation of several alternatives to the baseline. System components, operational scenarios for a procedures developer and an SPS instructor, and baseline requirements are discussed. Alternative display terminal configurations and alternate means of interfacing the PGP with these configurations are discussed.
CPDT DN 2 - PROCEDURES GENERATION PROGRAM DATA PROCESSING STUDIES	31 January 1974	R.T.HAMM	This design note describes the results of a study of the data input/output techniques available on the CDC 6400. A procedure for establishing an interface with the Crew Procedures Documentation System using magnetic tape is discussed. A checkout program and resulting input/output timing data is presented.
CPDT DN 3 - PRE-SIMULATION DATA REQUIREMENTS FOR THE PGP DATA BASE	1 April 1974	G.R.RIDDLE M.L.HAWK	This design note details the contents of the Procedures Generation Program data base for the initial PGP Activation. Data is specified for the display formats, Hollerith statements for the crew station switch labels and procedural events, and the difference procedures comparison times and switch configurations.
CPDT DN 4 - SPS MODIFICATION REQUIREMENTS FOR DATA TRANSFER	7 May 1974	R.T.HAMM	This design note describes the results of a series of NASA/MDAC-H meetings which were held to determine the requirements and software design of the interface between the Shuttle Procedures Simulator and the Procedures Generation Program. Supporting data lists are presented for the initialization, crew station (procedures), and simulation (performance) data transfers.

TABLE 4-1

BIBLIOGRAPHY OF CREW PROCEDURES DEVELOPMENT TECHNIQUES STUDY DOCUMENTATION (CONT'D - 3 OF 5)

DOCUMENT - TITLE	DATE	AUTHOR	SYNOPSIS
CPDT DN 5 - PROGRAM VERIFICATION PLAN AND CHECK CASE DEFINITION	1 May 1974	J.D.ARBET G.R.RIDDLE	This design note details the check cases required to checkout and verify real-time Procedures Generation Program operations and Shuttle Procedures Simulator (SPS)/PGP interface on an integrated systems basis. Ten check cases are defined which cover the Shuttle return sequence starting at entry interface and continuing thru landing and rollout.
CPDT DN 8 - PROCEDURES GENERATION PROGRAM DEMONSTRATION PLAN	13 December 1974	J.L.McGAVERN M.L.HAWK	This design note describes the Procedures Generation Program demonstration plan scheduled for the period from 15 November to 1 December 1974. Two exercises are defined for demonstration of the PGP. Scripts are presented which contain the detailed operations which are performed at the PGP user console, a functional description of what occurs in the SPS crew station, and a remarks column relating objectives of the exercise.
CPDT DN 9 - SIMULATION RESULTS - PGP VERIFICATION	20 December 1974	R.L.BENBOW	The results of performing the PGP Demonstration Plan, and the results of the check case exercises performed to checkout and verify PGP operations and the Shuttle Procedures Simulator (SPS)/PGP interface are documented in this design note.
CPDT DN 10 - PROCEDURES GENERATION PROGRAM (PGP) APPLICATIONS TO COMMERCIAL AIRLINES	20 December 1974	R.G.GIBBS	This design note documents the results of an investigation by United Airlines of the application of PGP to current and future commercial airline training programs.
<u>WORKING PAPERS</u>			
PGP WP NO 1 - SOFTWARE DOCUMENTATION FORMAT	1 January 1974	R.T.HAMM	This working paper presents the documentation format of the draft material documenting development of a module or subroutine within the Procedures Generation Program.

TABLE 4-1

BIBLIOGRAPHY OF CREW PROCEDURES DEVELOPMENT TECHNIQUES STUDY DOCUMENTATION (CONT'D - 4 OF 5)

DOCUMENT - TITLE	DATE	AUTHOR	SYNOPSIS
PGP WP NO 2 - PGP MODULES AND FLOW	15 January 1974	R.T.HAMM	This working paper presents the top-level description of the Procedures Generation Program. The major PGP modules are corrolated with the program requirements from the PGP Requirements document. Top-level flow and proposed overlay structure of the PGP are included.
PGP WP NO 3 - PERFORMANCE EVALUATION DATA	29 January 1974	R.L.BENBOW	This working paper presents the initial design concept of the Performance evaluation data. An examination of each of the mini-phase performance evaluation display formats is documented. Included are equations definitions and logic flow diagrams for each mini-phase. A data driven software design for a single software program to perform the necessary mini-phase calculations for all mini-phases is proposed.
PGP WP NO 4 - SEQUENCE CONTROL TOP-LEVEL FLOW	31 January 1974	R.T.HAMM	The initial design of the Sequence Control Module of the Procedures Generation Program is documented in this working paper. The subroutines and their interface for Sequence Control and a logic flow diagram for the initial design concept is documented.
PGP WP NO 5 - PERFORMANCE DATA	Unpublished	R.L.BENBOW	This working paper documents the initial design concept of the performance data requirements of PGP.
PGP WP NO 6 - PGP REQUIREMENTS TRACEABILITY BY MODULE	4 February 1974	W.W.HINTON JR	A method for ensuring that all the requirements defined in the PGP Requirements Document get satisfied is described in this working paper. Preliminary results of the requirements assignments to the PGP Modules is documented.
PGP WP NO 7 - PROGRAMMING CONSIDERATIONS FOR PGP	7 February 1974	R.T.HAMM	A discussion is presented in this working paper of the basic module concepts, command conventions, error processing, and display definitions within PGP.
PGP WP NO 8 - EQUATIONS DOCUMENT OUTLINE AND ASSIGNMENTS	8 February 1974	R.T.HAMM	This working paper documents the proposed contents and authors of the various sections of the PGP Equations Document.

TABLE 4-1

BIBLIOGRAPHY OF CREW PROCEDURES DEVELOPMENT TECHNIQUES STUDY DOCUMENTATION (CONT'D - 5 OF 5)

DOCUMENT - TITLE	DATE	AUTHOR	SYNOPSIS
PGP WP NO 9 - DETAILED MATH FLOW CONVENTIONS AND SYMBOLS	21 March 1974	R.T.HAMM	This working paper defines the documentation format, math flow conventions and symbols, and some basic programming practices for the detailed (subroutine) math flow development of PGP.
PGP WP NO 11 - PROGRAM VERIFICATION AND CHECK CASE DEFINITION	18 October 1974	J.D.ARBET	This working paper documents the revised check cases for checkout and verification of the PGP operations and the SPS/PGP interface. Initial documentation of these check cases was presented in CPDT Design Note No 5. This working paper incorporates various changes to the PGP and SPS systems.
MISCELLANEOUS			
CREW PROCEDURES DEVELOPMENT TECHNIQUES PROGRESS REPORTS - NUMBER 1 TO 14	Monthly		These reports summarize the progress of the work effort each month. A brief summary status of the technical work accomplished during the reporting period are discussed.
PROGRAM LISTING	2 January 1975	A.MANGIARACINA	This is a computer listing of program instructions of the Procedures Generation Program.
PROGRAM TAPE	2 January 1975	A.MANGIARACINA	This is a complete computer tape of the Procedures Generation Program.
PGP PARAMETER DICTIONARY	2 January 1975	J.L.McGAVERN	This is a computer listing which documents the common block parameters within PGP. The name, dimension, common block location, and definition of each parameter in PGP is presented.
NEW TECHNOLOGY REPORT	3 January 1975	R.L.BENBOW R.T.HAMM	This report documents the new technology items developed in the performance of work under the Crew Procedures Development Techniques Study Contract.
SUMMARY OF NEW TECHNOLOGY REVIEW ACTIVITIES REPORT	16 September 1974	H.A.GILBERT	This report provides information reflecting the activities in complying with the New Technology Clause. This was an interim report, and a final report is in preparation concurrent with this report.