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HOUSTON ASTRONAUTICS DIVISION

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CONTINUATION OF ADVANCED CREW PROCEDURES DEVELOPMENT TECHNIQUES

DESIGN NOTE NO. 14

PPP/NONREAL-TIME TRAJECTORY PROGRAM INTERFACE REQUIREMENTS AND CAPABILITIES

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PREPARED BY:
J. L. McGavern
Software Group
Advanced Crew Procedures
Development Techniques
Study
483-2611

PREPARED BY:
J. D. Arbet
Requirements and Operations
Group Leader
Advanced Crew Procedures
Development Techniques
Study
483-2611

APPROVED BY:
R. L. Benbow
Principal Investigator
Advanced Crew Procedures
Development Techniques
Study
483-2611

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1.0 SUMMARY

This design note presents the requirements and capabilities for interfacing a trajectory program with the Procedures and Performance Program (PPP). The effort is in compliance with the Continuation of Advanced Crew Procedures Development Techniques (CACPDT) contract statement of work, Section 2.0.

2.0 INTRODUCTION

The CACPDT contract includes the task of interfacing a trajectory program with the PPP. The purpose of this interface is to provide summary procedures timelines for any desired trajectory profile. This timeline data will provide useful planning data for subsequent simulation activities. During the studies for selecting a trajectory program and its subsequent method of implementation, another highly desirable feature was recognized. This feature requires providing a new PPP procedures data merge capability. This capability combines existing PPP reference procedures with the new summary timelines to generate a new reference procedure and establish the initial detailed procedures for any trajectory profile. This capability will therefore be included as an implementation requirement.

3.0 DISCUSSION

This design note defines requirements and capabilities required to interface a nonreal-time trajectory program with the PPP. The availability of this interface provides various new PPP capabilities. Processing of the trajectory data by the PPP generates a summary timeline related to that unique trajectory profile. This summary timeline then may be merged with existing PPP reference procedures to develop reference procedures related to the new trajectory.

Considerations were given to two separate digital programs to satisfy these capabilities. One was the CDC 6400 digital program BANDITO previously used for Apollo and Skylab mission trajectory studies. The other was the Univac 1110 Space Vehicle Dynamics Simulation (SVDS) program developed for Shuttle program trajectory studies.

3.1 Trajectory Program Selection and Capabilities

The selection process for interfacing a nonreal-time trajectory program with the PPP included a feasibility study of using either the BANDITO or SVDS trajectory programs. The studies considered both program capabilities and methods of implementation.

In studying the BANDITO program, it became apparent that the implementation task involved with this program would be too enormous and time consuming. One problem was the amount of modification required to various models to reflect the Shuttle vehicle characteristics. Another problem was the absence of ascent and entry profile capabilities in the BANDITO program.

SVDS studies considered two different methods of implementation. One was to provide a SVDS program compatible with the CDC 6400 system. Due to the SVDS program size, programming techniques (related to

Univac 1110 capabilities), and the dynamic development state of the program, this method of implementation was also determined too enormous and time consuming. The second method of interfacing the SVDS with the PPP was via magnetic tape transfer of SVDS/Univac 1110 data outputs. The problems in this method were related to converting the Univac 1110 tape output into a usable CDC 6400 format. After considering all aspects of implementing each program, the SVDS was selected using the magnetic tape transfer capability.

The SVDS, as described in References 1 and 2, is a multivehicle program that has six-degree-of-freedom and three-degree-of-freedom capability. It currently simulates launch, staging and separation, on-orbit, and entry, but can be applied to any mission phase. The basic program can be applied to a variety of trajectory and vehicle dynamics problems, subsystems design, and flight software integration problems.

3.2 Data Transfer Requirements

A review was performed to determine the data transfer requirements from the SVDS to the PPP. The results are presented in Table 1. Included in the table is a listing of each parameter, their unit specification, and the mission phases for which the parameter is required. This list includes most of those parameters currently assigned for transfer from the SPS and incorporates those critical to procedures development and performance evaluation for all Shuttle mission phases. Availability of the parameters was determined through a detailed review of Reference 3. In general, the SVDS data transfer locations have been assigned to the same locations as the SPS data transfer. This allows PPP operational support capabilities for SPS

TABLE 1

SVDS/PPP DATA TRANSFER REQUIREMENTS

PARAMETER				MISSION PHASE								
INDEX NO.	PARAMETER NAME	DESCRIPTION	UNITS	ASCENT	ABORT ON ORBIT	RETURN TO LAUNCH	RENDEZVOUS	ON-ORBIT	DEORBIT	ENTRY	TAEM	APPROACH & LANDING
1	TIME	SIMULATED RUN TIME	SEC	X	X	X	X	X	X	X	X	X
2	CR	CROSS RANGE	NM			X			X	X	X	X
3	DR	DOWN RANGE	NM			X			X	X	X	X
4	R	RANGE (TO TOUCHDOWN)	NM			X			X	X	X	X
5	QDOT	VEHICLE HEATING RATE	BTU/FT^2-SEC		X	X		X		X		
6	HDOT	ALTITUDE RATE	FPS	X	X	X	X	X	X	X	X	X
7	RDTT	RANGE RATE TO TARGET	FPS				X					
8	G	G-LOAD	G	X	X	X				X	X	X
9	GX	ACCELERATION IN X-AXIS	G	X	X	X				X	X	X
10	GZ	ACCELERATION IN Z-AXIS	G	X	X	X				X	X	X
11	HDOTC	COMMANDED ALTITUDE RATE	FPS	X	X	X	X	X	X	X	X	X
12	RLS	RANGE FROM LAUNCH SITE	NM	X	X	X						
13	BANK	BANK ANGLE	DEG	X	X	X			X	X	X	X
14	ALPHAP	ANGLE OF ATTACK - PITCH	DEG	X	X	X			X	X	X	X
15	LATD	VEHICLE GROUND TRACK LATITUDE	DEG	X	X	X	X	X	X	X	X	X
16	LONGD	VEHICLE GROUND TRACK LONGITUDE	DEG	X	X	X	X	X	X	X	X	X
17	DELTAL	LOCALIZER ERROR	DEG			X					X	X
18	DELTAG	GLIDESLOPE ERROR	DEG			X					X	X
19	HA	VEHICLE APOGEE ALTITUDE	NM	X	X		X	X				
20	HP	VEHICLE PERIGEE ALTITUDE	NM	X	X		X	X				
21	ALT	ALTITUDE	FT	X	X	X	X	X	X	X	X	X
22	AINC	INCLINATION ANGLE	DEG	X	X	X						
23	MACH	MACH NUMBER	-	X		X				X	X	X
24	GAMMA	FLIGHT PATH ANGLE	DEG	X	X	X			X	X	X	X
25	RTV	RANGE TO TARGET VEHICLE	NM				X					
26	ALPHAY	ANGLE OF ATTACK - YAW	DEG	X	X	X			X	X	X	X
27	STDN1	GROUND STATION (1) CONTACT IDENTIFIER	-	X	X	X	X	X	X	X	X	X
28	STDN2	GROUND STATION (2) CONTACT IDENTIFIER	-	X	X	X	X	X	X	X	X	X
29	STDN3	GROUND STATION (3) CONTACT IDENTIFIER	-	X	X	X	X	X	X	X	X	X
30	THETDT	VEHICLE INERTIAL ATTITUDE RATE ($\dot{\theta}$)	DEG/SEC	X	X	X	X	X	X	X	X	X
31	PHIDT	VEHICLE INERTIAL ATTITUDE RATE ($\dot{\phi}$)	DEG/SEC	X	X	X	X	X	X	X	X	X
32	PSIDT	VEHICLE INERTIAL ATTITUDE RATE ($\dot{\psi}$)	DEG/SEC	X	X	X	X	X	X	X	X	X
33	VIAS	INDICATED AIRSPEED (CALIBRATED)	KNOTS	X		X					X	X
34	P	VEHICLE BODY RATE - PITCH	DEG/SEC	X	X	X	X	X	X	X	X	X
35	Q	VEHICLE BODY RATE - YAW	DEG/SEC	X	X	X	X	X	X	X	X	X
36	R	VEHICLE BODY RATE - ROLL	DEG/SEC	X	X	X	X	X	X	X	X	X
37	THETIA	VEHICLE INERTIAL ATTITUDE (θ)	DEG	X	X	X	X	X	X	X	X	X
38	PHII	VEHICLE INERTIAL ATTITUDE (ϕ)	DEG	X	X	X	X	X	X	X	X	X
39	PSII	VEHICLE INERTIAL ATTITUDE (ψ)	DEG	X	X	X	X	X	X	X	X	X
40	XV	VEHICLE ONBOARD X-POSITION VECTOR	FT	X	X	X	X	X	X	X	X	X
41	YV	VEHICLE ONBOARD Y-POSITION VECTOR	FT	X	X	X	X	X	X	X	X	X

TABLE 1 (CONTINUED)

SVDS/PPP DATA TRANSFER REQUIREMENTS

PARAMETER				MISSION PHASE								
INDEX NO.	PARAMETER NAME	DESCRIPTION	UNITS	ASCENT	ABORT TO ORBIT	RETURN TO LAUNCH	RENDEZVOUS	ON-ORBIT	DEORBIT	ENTRY	TAEM	APPROACH & LANDING
42	ZV	VEHICLE ONBOARD Z-POSITION VECTOR	FT	X	X	X	X	X	X	X	X	X
43	XVDT	VEHICLE ONBOARD X-VELOCITY VECTOR	FPS	X	X	X	X	X	X	X	X	X
44	YVDT	VEHICLE ONBOARD Y-VELOCITY VECTOR	FPS	X	X	X	X	X	X	X	X	X
45	ZVDT	VEHICLE ONBOARD Z-VELOCITY VECTOR	FPS	X	X	X	X	X	X	X	X	X
46	BETA	SUN ANGLE	DEG	X			X	X	X			
47	IGMODE	GUIDANCE MODE FLAG (MAJOR MODE)	-	X	X	X	X	X	X	X	X	X
48	QBAR	DYNAMIC PRESSURE	$SLUG/FT-SEC^2$	X	X	X				X	X	
49	DVX	APPLIED X-MANEUVER COMPONENT (RDV)	FPS				X	X	X			
50	DVY	APPLIED Y-MANEUVER COMPONENT (RDV)	FPS				X	X	X			
51	DVZ	APPLIED Z-MANEUVER COMPONENT (RDZ)	FPS				X	X	X			
52	DVT	APPLIED MANEUVER PERIOD (RDZ)	SEC				X	X	X			
53	DVTC	COMMANDED IGNITION TIME (RDZ)	SEC				X	X	X			
54	DVTA	ACTUAL IGNITION TIME (RDZ)	SEC				X	X	X			
55	DVXC	COMMANDED X-MANEUVER COMPONENT (RDZ)	FPS				X	X	X			
56	DVYC	COMMANDED Y-MANEUVER COMPONENT (RDZ)	FPS				X	X	X			
57	DVZC	COMMANDED Z-MANEUVER COMPONENT (RDZ)	FPS				X	X	X			
58	XE	VEHICLE ENVIRONMENT X-POSITION VECTOR	FT	X	X	X	X	X	X	X	X	X
59	YE	VEHICLE ENVIRONMENT Y-POSITION VECTOR	FT	X	X	X	X	X	X	X	X	X
60	ZE	VEHICLE ENVIRONMENT Z-POSITION VECTOR	FT	X	X	X	X	X	X	X	X	X
61	XDE	VEHICLE ENVIRONMENT X-VELOCITY VECTOR	FPS	X	X	X	X	X	X	X	X	X
62	YDE	VEHICLE ENVIRONMENT Y-VELOCITY VECTOR	FPS	X	X	X	X	X	X	X	X	X
63	ZDE	VEHICLE ENVIRONMENT Z-VELOCITY VECTOR	FPS	X	X	X	X	X	X	X	X	X
64	XT	ONBOARD EST. TARGET X-POSITION VECTOR	FT	X			X					
65	YT	ONBOARD EST. TARGET Y-POSITION VECTOR	FT	X			X					
66	ZT	ONBOARD EST. TARGET Z-POSITION VECTOR	FT	X			X					
67	XTV	ONBOARD EST. TARGET X-VELOCITY VECTOR	FPS	X			X					
68	YTV	ONBOARD EST. TARGET Y-VELOCITY VECTOR	FPS	X			X					
69	ZTV	ONBOARD EST. TARGET Z-VELOCITY VECTOR	FPS	X			X					
70	DX	TRAILING DISPLACEMENT (RDZ)	NM				X					
71	DH	DIFFERENTIAL ALTITUDE (RDZ)	NM				X					
72	DZ	OUT-OF-PLANE DISPLACEMENT	NM				X					
73	PHIIT	TARGET INERTIAL ATTITUDE (ROLL)	DEG	X			X					
74	THETAIT	TARGET INERTIAL ATTITUDE (PITCH)	DEG	X			X					
75	PSIIT	TARGET INERTIAL ATTITUDE (YAW)	DEG	X			X					
76	PHITD	TARGET INERTIAL ATTITUDE RATE (ROLL)	DEG/SEC	X			X					
77	THETTD	TARGET INERTIAL ATTITUDE RATE (PITCH)	DEG/SEC	X			X					
78	PSITD	TARGET INERTIAL ATTITUDE RATE (YAW)	DEG/SEC	X			X					
79	SAT	COMMUNICATION SATELLITE (AOS/LOS)	-	X	X	X	X	X	X	X	X	X
80	TSCH	TRACKING SCHEDULE	-				X	X				
81	ALSCH	ALIGNMENT SCHEDULE	-				X	X				
82	LAMAN	LONGITUDE OF ASCENDING NODE	DEG	X	X	X	X	X	X			
83	LAMTAN	TIME OF ASCENDING NODE	SEC	X	X	X	X	X	X			
84	VW	VEHICLE WEIGHT	LBS	X	X	X	X	X	X	X	X	X
85	DNI	DAY/NIGHT INDICATOR	-	X	X	X	X	X	X	X	X	X

ascent and rendezvous and entry simulations (if computer core is available) without major modification to the PPP data transfer buffer.

3.3 PPP Real-Time Procedures Recording Requirements

After the SVDS data output has been converted to the final form compatible with the CDC 6400 system, PPP operations will follow the standard PPP simulated real-time capabilities. During these operations, both alpnanumeric and graphical formats will be available for run identification and data verification. PPP data reconstruction and hardcopy capabilities will also be available to further aid data verification. The minimum desired output resulting from these real-time operations is the development of a summary procedures timeline. A typical entry sequence summary procedures timeline is shown in Figure 1.

FIGURE 1

SUMMARY PROCEDURE TIMELINE OUTPUT

```
SUMMARY PROCEDURES TIMELINE                    ACTUAL
ROOCEOOONOOOCOOOPOOOIOOO BATCH XX/XX/XX FMT221
  GET  L   STDN          EVENT
  0/15 *          ENTRY INTERFACE
   -
  0/17            .05G
   -
  0/19
   -       VAN
  0/21
   -
  0/23
   -
  0/25
   -              EQUILBRM GLIDE PHASE
  0/27
   -
  0/29
```

Presently, the PPP only contains logic to detect and output major events for the entry mission phase. Another task associated with implementing this trajectory program capability will include the definition and subsequent software implementation of other mission phase major events.

3.4 PPP Post-Run Procedures Merge Requirements

Following PPP processing of the SVDS data during simulated real-time, a new post-run merge capability will be developed. The capability will allow the user to merge existing PPP reference procedures data into the summary procedures timeline generated from the SVDS data. The user interface with the merge function will be via tutorial display. The user will only be required to specify the reference procedure desired and the merge will be completed automatically. Subsequent to the merge operation, the PPP post-run reconstruction and hardcopy capabilities will allow the user to review and verify the procedures data. Initially, the new procedures will be structured with respect to Shuttle mission events, but the capability to structure them with respect to other constraints will also be considered. A typical detailed procedures timeline is shown in Figure 2.

FIGURE 2

DETAILED PROCEDURES TIMELINE OUTPUT

```
DETAILED PROCEDURES TIMELINE                    ACTUAL
ROOOEOOONOOOCOOOPOOOIOOO BATCH XX/XX/XX FMT221
  GET  LT    OPERATIONS            PNL
  0/15 *  ENTRY INTERFACE
       *  CRT 1-GNC                C2
       *  CRT 2-GNC                C2
       *  CRT 3-GNC                C2
       *  KEYBOARD SEL-OFF         C2
       *  OPS 313 PRO              C2L
       *  OPS 313 PRO              C2R
   -   *
  0/17    .05G
   -
  0/19
   -    * KEYBOARD SEL-LEFT        C2
        * FAULT                    C2L
        * KEYBOARD SEL-OFF         C2
  0/21  *
   -    *
```

3.5 SVDS/PPP Interface Design Philosophy

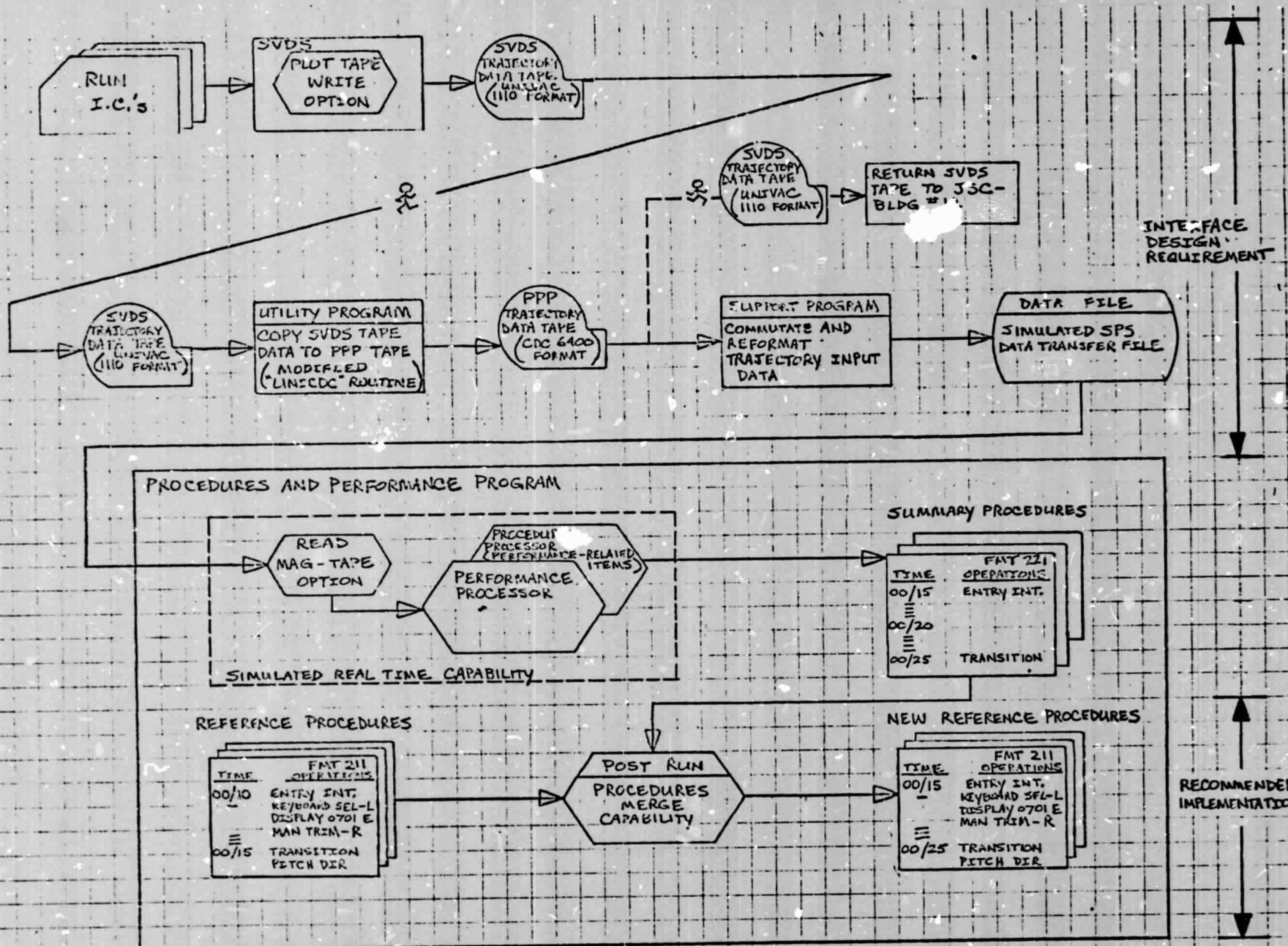
An interface design for the SVDS nonreal-time trajectory program and the PPP has been developed (see Figure 3). The SVDS trajectory program will be provided with PPP selected initial conditions according to the desired mission phase. A variable plot output option will be utilized to write user selected performance parameters at a prescribed frequency to a Univac 1110 tape. The maximum data block size for output under this option is ninety-five (95) words.

Upon receipt of the SVDS trajectory data tape, a PPP utility program will be executed which will copy the SVDS data tape to a usable CDC 6400 tape. The utility program will utilize a modified NASA Program Library (PL) routine, UNICDC. This new trajectory data tape has been reformatted to be consistent with the CDC 6400 word structure.

A PPP support program will then be executed which will commutate the PPP trajectory tape data input to a file in a format identical to a simulated SPS data transfer and recognizable by the PPP. The generated performance data transfer file will then be accessible through the simulated real-time option. The PPP performance and procedures processors will now be able to generate an unique summary procedures timeline.

FIGURE 3

SVDS/PPP INTERFACE DESIGN



4.0 REFERENCES

1. JSC-07950, Volume I, Revision 3 - JSC Internal Note No. 73-FM-67, Volume I, User's Guide for the Space Vehicle Dynamics Simulation (SVDS) Program, Revision 3, dated September 26, 1975, Software Development Branch, MPAD.

2. JSC-07950, Volume II, Revision 3 - JSC Internal Note No. 73-FM-67, Volume II, Appendices of the User's Guide for the Space Vehicle Dynamics Simulation (SVDS) Program, Revision 3, dated September 26, 1975, Software Development Branch, MPAD.

3. JSC-07969, Revision 3 - JSC Internal Note No. 73-FM-76, SVDS Programming Support Displays, Revision 3, dated October 23, 1975, Software Development Branch, MPAD.