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HOUSTON ASTRONAUTICS DIVISION

SPACE SHUTTLE ENGINEERING AND OPERATIONS SUPPORT

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GROUND POWER TO FUEL CELL SWITCH-OVER STUDY

AVIONICS SYSTEM ENGINEERING

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1.0 Summary

The purpose of this report is to present a functional operational description of Orbiter ground power to fuel cell switch-over provisions. Emphasis is placed on the description of implementation, procedure and monitoring provisions associated with turn-around operations at the Kennedy Space Center (KSC) ground operations and launch facility. Material contained in this report represents information gathered through review of Orbiter subsystem schematics, turn-around allocation documents and discussions with KSC and R/SD test operations personnel.

2.0 Implementation

Figure 1 is a simplified diagram depicting the ground and orbiter provisions for transferring from ground power to fuel cell power for orbiter Main DC Bus A and is typical for Main DC Buses B and C.

Ground DC power to the orbiter is provided by three isolated DC power supplies located on Mobile Launch Pad (MLP). DC power is switched to the T-0 umbilical through the Launch Processing System (LPS) Handware Interface Module (HIM). Ground initiated orbiter switching functions are controlled by a GSE computer in the LPS. Computer access is via the launch data bus through launch dedicated MDMs.

Application of fuel cell power to the main dc buses can be initiated by the ground computer or by the crew. During ground operation, power transfer will be initiated by commands from the GSE computer via the Launch Data Bus through the forward launch MDM-LFI. This provides

a 28 VDC control signal to an RPC in the Main DC distribution assembly which actuates a motor driven switch and places fuel cell power on the Main DC bus. Auxilliary contacts on the motor driven switch provide a discrete signal to the instrumentation system for control function status monitoring and applies a ground to a Display and Control system indicator located on the pilot console. Manual or crew control of power transfer is provided by a circuit breaker and momentary switch located on the Pilot console panels. Power Transfer is manually initiated by momentarily placing the Main DC Bus A ON-OFF switch to "ON' which actuates the motor driven switch and places fuel cell power on the main bus.

Ground power is removed from the Aft main bus by hardwire commands from the LPS to an RPC controlling a motor driven switch located in the Aft Power Control Assembly. Ground power to the aft main dc buses is controlled by the ground only. No parallel crew control is provided.

3. Monitoring Provisions

Voltage, current and control discrete measurements available to support management of power transfer are listed in Table 1.

On-board monitoring of main bus voltage and fuel cell voltage and current is provided by a panel mounted voltmeter and ammeter. A single rotory switch allows serial selection of Main Bus and fuel cell voltages and also selects fuel cell current simultaneously

with the appropriate fuel cell voltage. Voltmeter accuracy within the expected range to be measured is ± 0.5 volts. Ammeter accuracy is ± 2%. These parameters can also be displayed on any one of three panel mounted CRTs. Data selection and display format is called up by means of keyboards mounted on console panel C2.

Aft Local DC Bus current is implemented on the Orbiter in the Development Flight Instrumentation (DFI) system for OV101 and 102. Current transformers located in the feeder lines between the Mid and Aft Main DC Buses provide an analog input to the DFI system and are available in the TM downlist for display in the Ground Operations station. R/SD feels that these current measurements will be retained for the operational vehicles and thus will be available for the entire Shuttle Program.

Those Orbiter voltage and current measurements which are hardwired thru the T-0 umbilical (continuous bus monitoring) will not be displayed real time in the ground station. These measurements will be recorded on mag tape and used as a trouble shooting aid for anomolies encountered during ground operations.

4.0 Procedural Overview

Table 2 is a general procedure for performing ground power to fuel cell switch-over for Main Bus A, and is typical for Main Bus B and C.

The Orbiter Project Schedules and Status Summary, dated March 4 1975, indicates fuel cell cryogenic servicing will occur at approximately T-10 hrs. Fuel cell activation will occur at approximately T-4 hrs. After fuel cell activation and prior to transferring fuel cell

power to the Main Buses reactants will be supplied by a seperate GSE source. Transfer to orbiter reactants will occur at approximately T-10 minutes and transfer to fuel cell power at T-9 minutes.

During launch count down, cell switch-over will be controlled by the ground. Transfer should be accomplished on one Main Bus at a time with the buses isolated from each other (Main Tie switches open) to minimize the effects of fuel cell loading.

After landing at KSC, fuel cells will be operated (to preclude cryo tank venting) until one or both reactants have been expended or until the orbiter reaches the Orbiter Processing Facility (OPF), which ever occurs first. Transfer of Orbiter power from fuel cells to ground power after landing will be controlled by the orbiter crew.

Present test and operations plans specify first activation of fuel cells in the orbiter vehicles to occur at Edwards AFB for OV101 and at KSC for OV102 just prior to flight. Fuel cells will not be activated at the Palmdale test facility and in general fuel cell power will not be utilize to support any ground test or preflight operation.

5.0 Conclusions

Definition of ground operations are currently in the conceptual or preliminary stage and ground support systems have not been defined in detail. As more significant definition becomes available follow-on reports will address other aspects of ground power to fuel cell switch-over such as ground software requirements, effects of switch-over on orbiter load distribution and transient effects.

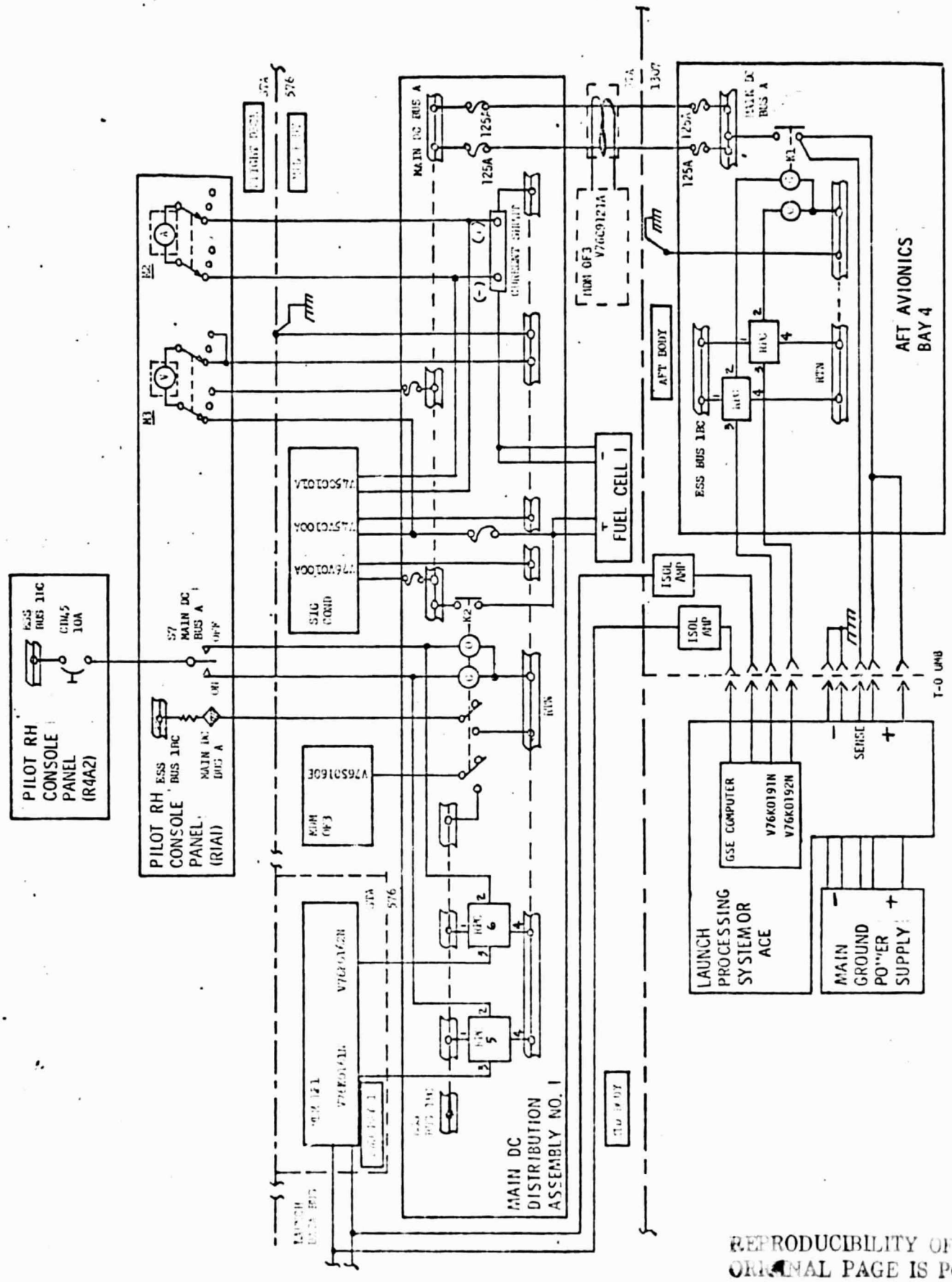

TABLE 1 EPDC MEASUREMENTS

MEASUREMENT	TITLE	FUNCTION	COCKPIT DISPLAY	TM DOWNLINK*	GROUND DISPLAY
V76V0100A	MAIN BUS A VOLTS	DC VOLTS	METER/CRT	OI	CRT
V76V0200A	MAIN BUS B VOLTS	DC VOLTS	METER/CRT	OI	CRT
V76V0300A	MAIN BUS C VOLTS	DC VOLTS	METER/CRT	OI	CRT
V45V0100A	FUEL CELL 1 VOLTS	DC VOLTS	METER/CRT	OI	CRT
V45V0200A	FUEL CELL 2 VOLTS	DC VOLTS	METER/CRT	OI	CRT
V45V0300A	FUEL CELL 3 VOLTS	DC VOLTS	METER/CRT	OI	CRT
V45C0101A	FUEL CELL 1 CURRENT	DC AMPS	METER/CRT	OI	CRT
V45C0201A	FUEL CELL 2 CURRENT	DC AMPS	METER/CRT	OI	CRT
V45C0301A	FUEL CELL 3 CURRENT	DC AMPS	METER/CRT	OI	CRT
V76C9121E	AFT LOCAL BUS A CURRENT	DC AMPS		DFI	CRT
V67C9122E	AFT LOCAL DC BUS B CURRENT	DC AMPS		DFI	CRT
V76C9123E	AFT LOCAL DC BUS C CURRENT	DC AMPS		DFI	CRT
V7650160E	F/C 1 TO MN BUS A IND.	EVENT	IND/CRT	OI	CRT
V7650260E	F/C 2 TO MN BUS B IND.	EVENT	IND/CRT	OI	CRT
V7650360E	F/C 3 TO MN BUS C IND.	EVENT	IND/CRT	OI	CRT
V45X0105E	F/C NO. 1 READY	EVENT	IND/CRT		
V45X0205E	F/C NO. 2 READY	EVENT	IND/CRT		
V45X0305E	F/C NO. 3 READY	EVENT	IND/CRT		

TABLE 1 MEASUREMENTS (CONT)

MEASUREMENT	TITLE	FUNCTION	COCKPIT DISPLAY	TM DOWNLINK*	GROUND DISPLAY
GND. MEAS.**	GSE MN 1 SENSE VOLTS	DC VOLTS			CRT
GND. MEAS.**	GSE MN 2 SENSE VOLTS	DC VOLTS			CRT
GND. MEAS.**	GSE MN 3 SENSE VOLTS	DC VOLTS			CRT

* ALL OI AND DFI MEASUREMENTS ARE AVAILABLE IN THE TM DOWNLINK FOR DISPLAY IN THE GROUND STATION.

** MONITORED IN THE GROUND STATION VIA T-0 UMBILICAL HARDWIRE.

TABLE 2 - DC POWER TRANSFER PROCEDURE

	PROCEDURE	MEAS/STIM. IDEN.	SPECIFICATION
I	GROUND POWER TO FUEL SWITCH-OVER		
	a. Verify Fuel Cell Ready ind. - on	V45X0105E	event on
	b. Verify Main Bus A Tie Sw. - open	V76X0106E	event off
	c. Verify Main Bus A voltage	V76V0100A	Nominal
	d. Verify Fuel Cell 1 voltage	V45V0100A	Nominal
	e. Initiate Fuel Cell 1 to MN Bus A Transfer	V76K0161N	Gnd cmd-on
	f. Verify Fuel Cell to MN Bus A ind - on	V76S0160E	event on
	g. Verify Main Bus A voltage	V76V0100A	Nominal
	h. Verify Fuel Cell No. 1 current	V45C0101A	Nominal
	i Remove GSE power from Aft Main Bus A via ground command	V76K0192A	Cmd on
	j. Verify Aft GSE pwr MN Bus A ind	V76S0190N	Event Off
	k. Verify Main Bus A voltage	V76S0100E	Nominal
	l. Verify Fuel Cell 1 current	V45C0101A	Nominal
	m. Verify Aft Local DC Bus A current	V76C9121A	Nominal
II.	FUEL CELL TO GROUND POWER SWITCHOVER		
	a. Verify/adjust GSE power supply volts	Gnd cntl (manual)	Not less than 0.5 volts above Aft Main Bus a voltage.
	b. Verify Main Bus A Tie ind.	V76X0106E	event-off
	c. Transfer GSE pwr to Aft Mn Bus A	V76K0191N	CMD-on

TABLE 2 - DC POWER TRANSFER PROCEDURE (CONT)

d.	Verify Aft GSE pwr MN Bus A Ind. - on	V76S0190N	Event-on
e.	Verify Main Bus A voltage	V76V0100A	Nominal
f.	Verify Aft Local DC Bus A current	V76C0121A	Nominal
g.	Disconnect Fuel Cell 1 from Mn Bus A	V76K0162N	Gnd cmd - on
h.	Verify Main Bus A voltage	V76V0100A	Nominal
i.	Verify Fuel Cell 1 current	V45C0101A	Low level. (< 5 amps)