Aerospace
Systems Division

Power Conditioner Unit Operational Conditions for Maximum Reliability	EATM-78
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Errata Sheet

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Section 4.0, Line 1. "Table 3-1" should read "Figure 4-1",

Figure 4-1. Elements listed in PCU Operational Block Diagram are:

Element	Nomenclature
01	PCU - Side 1
02-1	Automatic Voltage Sensor
02-2	Relay Driver Circuit
02-3	Up-Link Command
03	PCU - Side 2
04	Filters

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Line 5 "considered the unreliability of that element". Should read, "considered or the unreliability of that element".

Equation 4-3 should read:

$$P_f = Q\,(02\text{-}1) \cdot R\,(02\text{-}2) \cdot (1 - (R\,(01) \cdot R\,(04))). \quad \text{Equation 4-3}$$

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Section 6.0, Line 2. Change the word "obtained" to "incurred".

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1.0 INTRODUCTION

During recent discussions on the operational modes of the EASEP Central Station, a question was directed to Reliability to assess the most reliable mode of PCU operation in that with the consideration that no failures having occurred during the first Lunar Day, switchover will automatically occur from Side 1 to Side 2 operation at the end of that Lunar Day; a determination based on reliability math model techniques should guide the choice of staying in Side 2 for the duration of the mission compared with the risk of commanding a switchover into a possible failed side at the advent of each succeeding Lunar Day, which choice would be irreversible and catastrophic,

2.0 SUMMARY

If upon switchover to Side 2, no earth command is transmitted to switch the PCU into Side 1 operation during the balance of the mission, the overall reliability of PCU operation is 0.994338.

However, if such commands are effectively transmitted with Side 1 in a successful operational mode at the times of such transmission, the overall reliability of PCU operation is 0.999375.

The gain achieved in so commanding a switchback is therefore an increase in PCU reliability of 0.005037. By comparison, the potential risk experienced in transmission of such commands is 0.45×10^{-5}.

Since the potential gain in transmission of the switchback commands is greater than the risk involved, it is recommended that PCU operation within the EASEP Central Station be governed by the precept that with Side 1 operation being satisfactory each Lunar Day, switchback to such operation be commanded at the outset of each succeeding Lunar Day.

3.0 METHOD OF ANALYSIS

This problem was considered on the basis that the reliability of any element within the PCU may be derived through the exponential distribution whereby:

$$R_i = e^{-xi} \qquad \text{(Equation 3-1)}$$

Here, R_i = Element Reliability based on x_i, the failure exponent applicable to that element.

The failure exponents for these elements were derived from applicable failure rate data contained in ATM-274, Revision G, originally prepared for the ALSEP Program. These failure rate data were multiplied by the applicable failure rate modifiers for the EASEP operational profile, these products bring the failure exponents of interest.

Next, these element failure exponents were added as appropriate to provide the failure exponents applicable to the reliability of the major circuitry within the PCU. Results obtained by this procedure are as noted in Table 3-1.

Table 3-1. PCU Major Circuitry Reliability Summary

Major Circuitry	Element Number	Failure Exponent (x 10^5)	Reliability
Side 1 (1)	01	513.617	0.994878
Automatic Command & Switchover	02	161.835	0.998383
Side 2 (1)	03	513.617	0.994878
Filters	04	54.165	0.999458

Notes: (1) Each Side noted within the PCU contains a Regulator-Inverter circuit plus a transformer-rectifier circuit. These circuits are identical to each side of the PCU.

(2) The PCU also contains a set of sensors utilized for collection of Housekeeping data, failure of which does not affect PCU operation.

In this regard it is noted that with rudundancy present within the PCU, the only catastrophic failure modes existant are: (1) Shorting of both capacitors of any of the 12 pairs present within the power filter; (2) Presence of an open circuit within any of the seven inductors within the PCU; (3) Hang up of contacts during switchover within the PCU's relay. The probability of such failures occurring is low (0.00029) and we are protected against other failure modes during Side 1 operation by virtue of automatic or earth command switchover occurring as needed into Side 2 operation.

Therefore, it is considered that such failure modes need not be considered in the problem at hand with the result that the applicable reliability, mathematical models for each operational condition were developed on the basis of secondary failure modes with computer analyses conducted to derive the results of interest based on these math models and the data contained in Table 3-1.

4.0 RELIABILITY MATHEMATICAL MODELS

For full understanding of the problem at hand, ~~Table 3-1~~ FIGURE 4-1 is presented for reference in description of PCU operation.

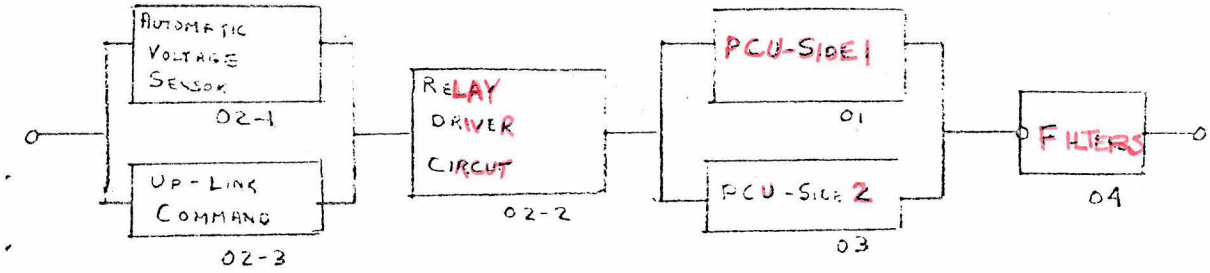

Figure 4-1. PCU Operational Block Diagram

Notes: (1) Elements 02-1 and 02-2 compose the Automatic Command and Switchover Circuitry defined as element 02 in Table 3-1. The probability of success of 02-1 and 02-2 are essentially equivalent, the failure exponent for each being $80.9\ 18 \times 10^{-5}$ and the reliability of each being 0.999191.

(2) The Up-Link Command, Element 02-3, is not reflected in Table 3-1 in that its probability of success has arbitrarily been equated to 1.0 for the problem at hand.

Under normal operating circumstances, it is considered that the PCU is operating in Side 1 with the provision that upon Uplink Command (via earth transmission) or through command at the Automatic Voltage sensor, the Relay Driver Circuit will be energized so as to shift PCU operation from Side 1 to Side 2.

For EASEP application, such a command of the Automatic Voltage Sensor will be transmitted under either of two conditions:

(1) Catastrophic failure of Side 1 causing an increase or decrease in output voltage beyond the limits prescribed for satisfactory Side 1 operation

(2) Approach of Lunar Night under which condition, the output power from the EASEP Solar panels decreases to an extent that Side 1 output voltage correspondingly decreases beyond the limits so prescribed.

It is considered that for purposes of this analysis, catastrophic failure of Side 1 will be recognized by those responsible for EASEP operation such that if this occurs, no command will be transmitted for shift of Side 2 operation into Side 1 operation.

At the same time, it is noted that the automatic voltage sensor is capable only of energizing the relay driver circuitry from Side 1 to Side 2 operation. Shift of PCU operation from Side 2 to Side 1 operation will occur only upon receipt of an U plink Command.

With this in mind, the following reliability block diagrams become applicable to the problem at hand:

Operational Mode A, Side 1 Operation

For purposes of this analysis it is considered that transmission from Side 1 to Side 2 operation occurs only through the automatic voltage sensor. With this in mind, the applicable reliability block diagram is:

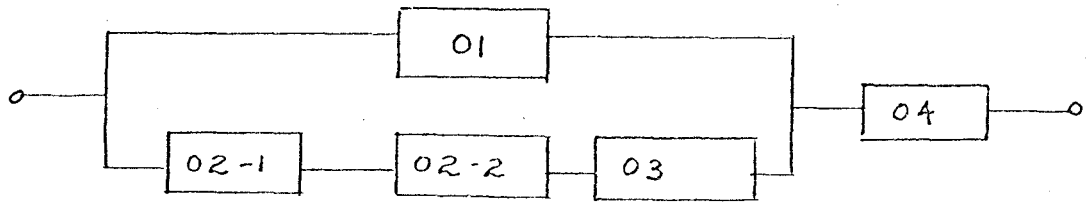

Figure 4-2. Side 1 Operation Reliability Block Diagram

It is noted that the listed elements in this diagram are those noted in Figure 4-1. With this in mind, the reliability math model expressing the probability of success of this operational mode is:

$$P_S = R(01) \cdot R(04) + Q(01) \cdot R(02\text{-}1) \cdot R(02\text{-}2) \cdot R(03) \cdot R(04)$$

Equation 4-1

Here, R (XX) = Reliability of Element XX; Q (XX) = 1-R (XX); and P_S = Overall PCU operational reliability while in this operational mode.

It is noted that this is the normal operational mode for the PCU during Lunar Day conditions.

Operational Mode B, Side 2 Operations

Figure 4-3. Side 2 Operation Reliability Block Diagram

For this operational mode, elements being as defined in Table 3-1, the applicable reliability math model is:

$$P_S = R(03) \cdot R(04) \qquad \text{Equation 4-2}$$

This is the operational mode experienced due either to Side 1 failure or due to switchover caused by Lunar Night conditions. Again, restoration to Operational Mode A may be experienced only by transmission of an Up-Link Command.

Operational Mode C, Side 2 to Side 1 Switchover Failure Mode

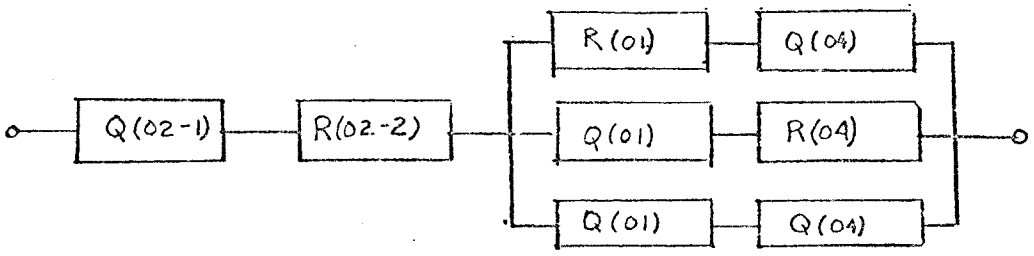

Figure 4-4. Side 2 to Side 1 Failure Block Diagram

Figure 4-4 depicts the operational circumstances under which PCU failure will occur upon uplink command for switchover from Side 2 to Side 1 operation. In this regard, for simplicity of description, notations in each block indicate whether the reliability of the element of concern is so considered, or the unreliability of that element.

In this regard three points are worth mentioning:

1) If the automatic voltage sensor is properly operating, the PCU will never switch back to a failed Side 1. Thus, for such a switchover to occur, the probability of failure of this element is the item of consideration

2) The paths of failure shown for Side 1 and the filters (elements 01 and 04) are representative of the fact that failure can occur upon successful switchover if either of the elements or both have failed. This may be expressed mathematically as $1- \quad (R(01) \cdot R(04))$.

3) As stated before, R (02-3) is presumed to equal 1.0.

Therefore, the total probability of successfully switching into a failed Side 1 may be expressed as follows:

$$P_f = Q(02\text{-}1) \cdot R(02\text{-}2) \cdot \left(1- \quad (R(01) \cdot R(04))\right). \qquad \text{Equation 4-3}$$

5.0 RESULTS

By computation utilizing the data contained in Table 3-1 and the reliability math models in Section 4.0, the following results are obtained:

Operational Mode A - $P_S = 0.999375$

Operational Mode B - $P_S = 0.994338$

Operational Mode C - $P_f = 0.000045$*

* - Therefore, probability of this operational mode not occurring is 0.9999955.

6.0 CONCLUSIONS

It is concluded on the basis of the results noted in Section 5.0 that the risk ~~obtained~~ incurred in commanding switchover from Side 2 to Side 1 in the manner defined previously in this report is minimal as compared to the gain in reliability available through transmission of such commands.

Thus, it is recommended that for maximum PCU operational reliability to be experienced, such switchover be commanded as is applicable to the operational status of the EASEP system.