

# Second International Diagnostic Competition (DXC'10)

Industrial Track

Diagnostic Problem Descriptions

## Introduction

This document expands on section 3.4 of the DXC'10 announcement (please refer to the announcement for generic competition information). We provide a detailed description of the fault types that will be injected, the concept of operations for each diagnostic use case, and example scenarios with scoring. The information for the first use case (*i.e.*, Single-string Unmanned Aircraft System Mission) includes a system description and the mapping between system failure modes and abort/no-abort recommendations. Similarly, for the second use case (*i.e.*, Redundant Systems Unmanned Aircraft System Mission) we provide descriptions of nominal system configurations, critical/noncritical loads, and the mapping between system failure modes/parameters and recovery recommendations. The document is intended to help Diagnostic Algorithm (DA) developers in their modeling and development of diagnostic strategies.

## Fault Types in DXC'10 Industrial Track

Table 1 lists the high level characteristics of the two diagnostic problems in the Industrial Track. This year we introduce drift and intermittent faults to Diagnostic Problem I.

Table 1. DXC'10 Industrial Track Characteristics.

Aspect		Diagnostic Problem I	Diagnostic Problem II
<b>System</b>		ADAPT-Lite	ADAPT
<b>Fault Types</b>	Abrupt Persistent	Yes	Yes
	Drift (Incipient)	Yes	No
	Abrupt Intermittent	Yes	No
<b>Multiple Faults</b>		No	Yes

Each of the three fault types changes a characteristic property associated with the component that is faulty (*e.g.*, the output from a sensor, the resistance of a load, *etc.*). Let  $P(t)$  denote the characteristic property of the component.  $P_n(t)$  represents the value of the property before the fault.  $P_f(t)$  represents the value of the property at any time  $t$  after the fault has been injected. Consequently, the following equation applies to all subsequent examples.

$$P(t) = \begin{cases} P_n(t), & t < t_{inj}, \\ P_f(t), & t \geq t_{inj}. \end{cases}$$

### Abrupt Persistent

Abrupt persistent faults are injected by a step change in the characteristic property of the component:

$$P_f(t) = P_n(t) + \Delta P \text{ (where } \Delta P \text{ is a positive or negative constant).}$$

Abrupt persistent faults are characterized by, and a DA is expected to estimate, the time at which the fault is injected,  $t_{inj}$ , and  $\Delta P$ , as illustrated in Figure 1.

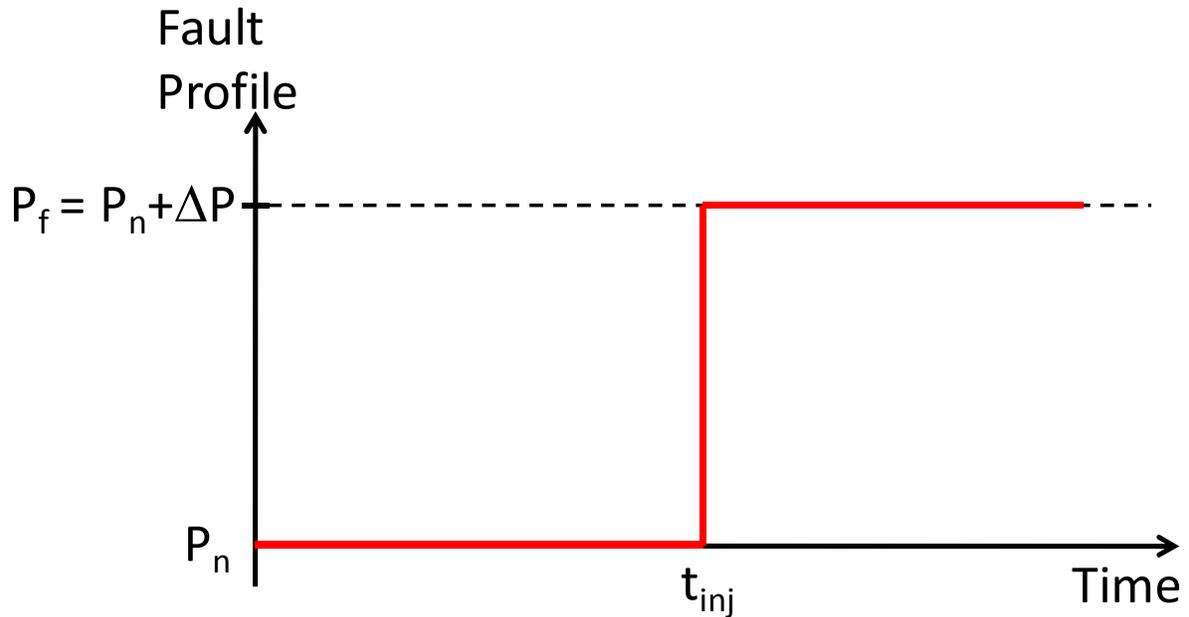


Figure 1. Abrupt persistent fault profile.

There is a special type of abrupt persistent fault for sensors where the sensor value becomes stuck at a specific reading. In this case, the characteristic value is not offset by  $\Delta$  but rather fixed according to

$$P_f(t) = c \text{ (where } c \text{ is a constant within the range of the sensor).}$$

For this case, the fault is characterized by  $t_{inj}$  and  $c$ .

### Drift

Drift faults are injected by a linear ramp (positive or negative) in the characteristic property:

$$P_f(t) = P_n(t) + m(t - t_{inj}) \text{ (where the slope } m \text{ is any constant and } t_{inj} \text{ is the time at which the fault is injected)}$$

Drift faults are characterized by, and a DA is expected to estimate,  $t_{inj}$  and  $m$ , as illustrated in Figure 2.

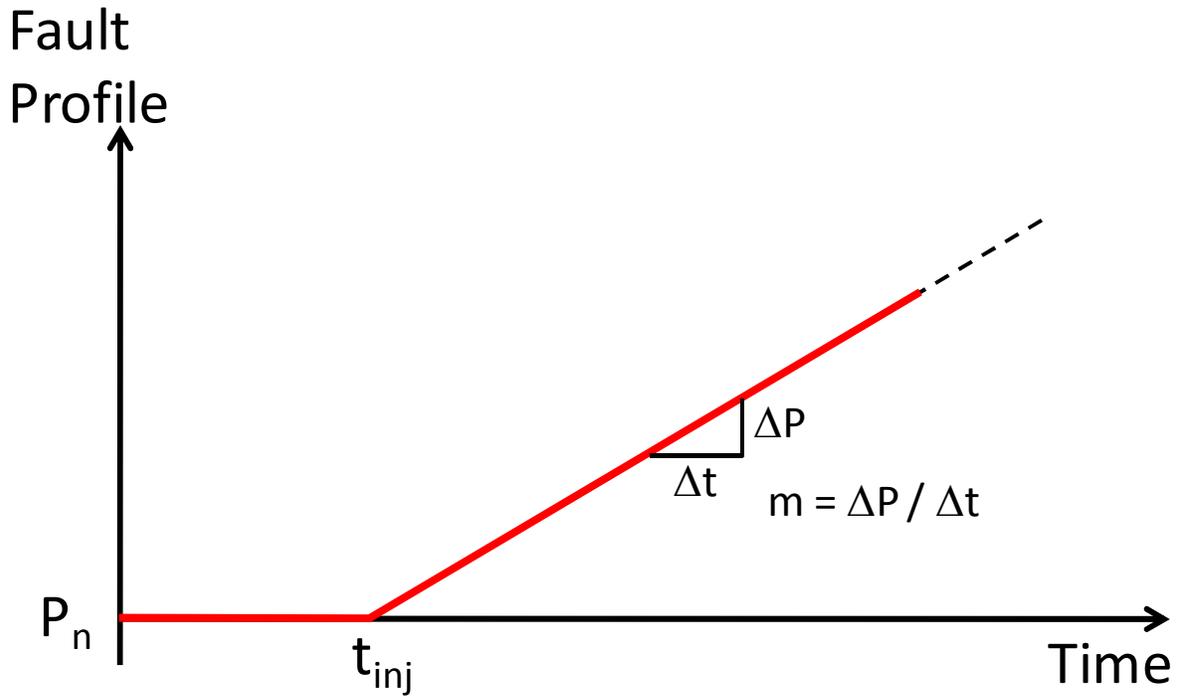


Figure 2. Drift fault profile.

### Abrupt Intermittent

Abrupt intermittent faults are injected by alternating between the presence and absence of step changes of the characteristic property, *i.e.*, the property is  $P_n(t) + \Delta P_i$  in some time steps and  $P_n(t)$  in other time steps. Figure 3 illustrates the abrupt intermittent fault profile.

$$P_f(t) = \begin{cases} P_n(t) + \Delta P_i, & \text{step is present,} \\ P_n(t), & \text{step is not present.} \end{cases}$$

The fault duration for each step change,  $\Delta t_{fi}$ , and the length of time between step changes,  $\Delta t_{ni}$ , are drawn from shifted exponential distributions while the fault magnitude,  $\Delta P_i$ , is drawn from a Gaussian distribution. Abrupt intermittent faults are characterized by, and a DA is expected to estimate, four parameters:  $t_{inj}$ , the time at which the first fault is injected;  $\mu_{\Delta P}$ , the mean of the characteristic property step change (note that we do not require estimation of the variance);  $\mu_f$ , the mean of the fault durations  $\Delta t_{fi}$  (*i.e.*, when a component becomes faulty, how long it stays faulty on average); and  $\mu_n$ , the mean of time intervals between faults  $\Delta t_{fn}$  (*i.e.*, when a component is nominal, how long it stays nominal on average).

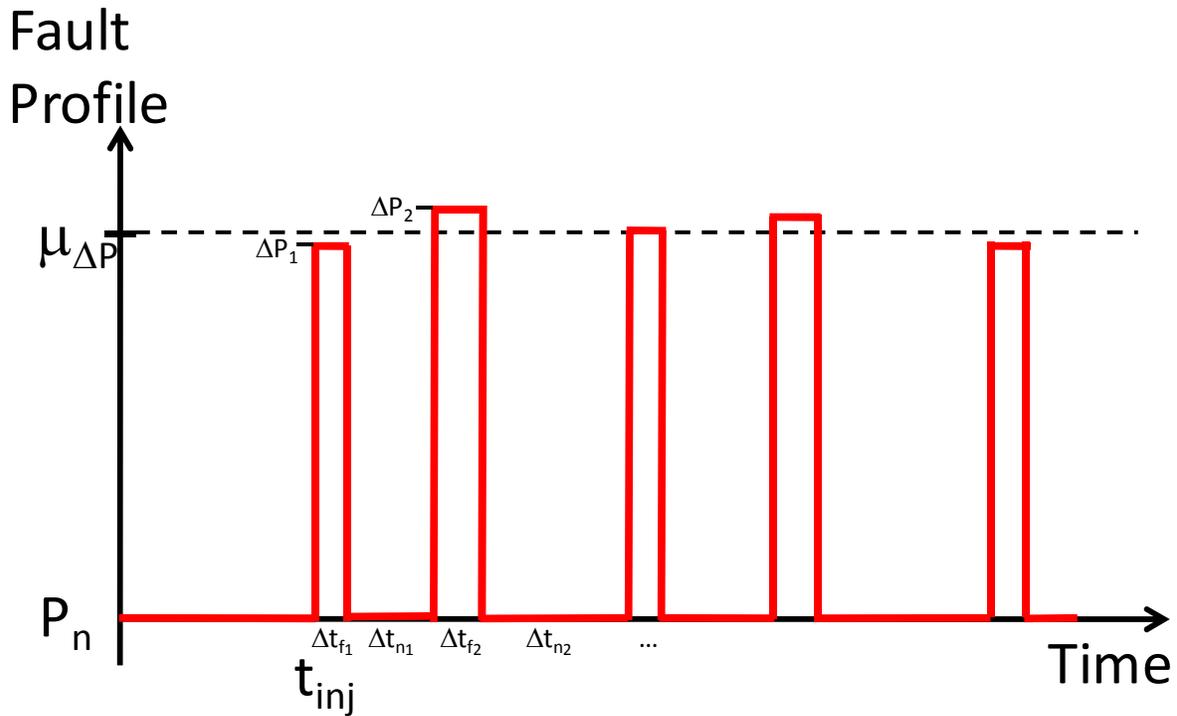


Figure 3. Abrupt intermittent fault profile.

### Diagnostic Problem I

The use case for Diagnostic Problem I is to make an abort recommendation to a remote pilot or an autonomous controller for a single-string Unmanned Aircraft System (UAS). For this problem, the ADAPT-Lite Electrical Power System (EPS) is supplying power to vehicle systems and payloads which are necessary for successful mission completion. The details of the mission are not important, but one can consider that there are instruments onboard which acquire scientific data.

There is one path from the power source to the loads, as listed in Table 2 and shown in Figure 4. The scenario begins with all relays and circuit breakers in the closed position and power flowing to the loads.

Table 2. Diagnostic Problem I Configuration.

Source	Load Bank	Loads
BAT2	LB2 (EY260)	L2C (EY272) on
		L2F (EY275) on
		L2H (EY284) on

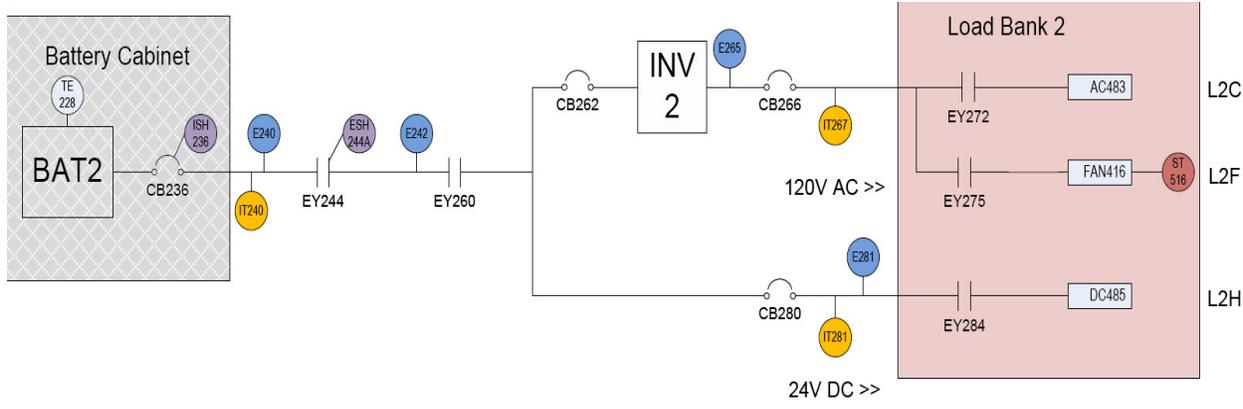


Figure 4. Diagnostic Problem I EPS Schematic.

The sensors for ADAPT-Lite are shown in Table 3, which indicates the rate at which the data will be presented to the Diagnostic Algorithms (DAs).

Table 3. Diagnostic Problem I Sensor Rate Groups.

Sensor Rate Groups		
1 Hz	2 Hz	10 Hz
TE228	E265	E240
	E281	E242
	IT267	ESH244A
	IT281	ISH236
	ST516	IT240

The correct recommendation for a scenario in Diagnostic Problem I depends on the injected failure mode as given in Table 4 (complete table is given in appendix). Any failure which cuts off power to any of the three loads listed in Table 2 results in a recommendation to abort the UAS; e.g., circuit breaker FailedOpen, relay StuckOpen, or a FailedOff load failure.

Table 4. Diagnostic Problem I Abort Recommendations by Failure Mode (complete table in appendix).

Comp.	Failure Mode	Parameters	Recommendation
AC483	FailedOff	$t_{inj}$	Abort
	ResistanceOffset	$t_{inj}, \Delta r$	Conditional
	ResistanceDrift	$t_{inj}, m$	Conditional
	IntermittentResistanceOffset	$t_{inj}, \mu_{\Delta r}, \mu_r, \mu_n$	Conditional
BAT2	AbruptParasiticLoad	$t_{inj}, r$	None
CB236	FailedOpen	$t_{inj}$	Abort
	StuckClosed	$t_{inj}$	None
...	...	...	...

Other recommendations are either contingent on the component failure mode or on parameters of the failure mode. In the contingent-on-failure-mode recommendation category, failure mode FAN416.OverSpeed is considered an undesirable situation where the load is drawing excessive power and the corresponding recommendation is to abort. On the other hand, FAN416.UnderSpeed is a degraded mode of operation which still allows the mission objectives to be achieved. Note that for ADAPT-EPS the degree of OverSpeed or UnderSpeed is fixed by the system properties and there is no associated threshold for abort; it is sufficient to determine which mode the FAN is in (sample data will be provided). The stuck failure mode for critical sensors IT240, IT267, IT281, and ST516 also results in a recommendation to abort, irrespective of the sensor value.

The contingent-on-parameters recommendation category includes the component failure modes labeled “conditional” in the table. For these failure modes, the recommendation depends on fault parameters, which need to be estimated by DAs. For abrupt persistent faults, the decision to abort or not is determined by a threshold on the magnitude of the step change in the characteristic property:

$$\left. \begin{array}{l} \Delta P_{offset} > \Delta P_{offset+}^{abort}, \Delta P > 0 \\ \Delta P_{offset} < \Delta P_{offset-}^{abort}, \Delta P < 0 \end{array} \right\} \Rightarrow \text{abort}$$

In Table 4 abrupt changes to load resistances are denoted by  $\Delta r$  and abrupt changes to sensor values are denoted by  $\Delta s$ .

For drift faults, the decision to abort or not is determined by how far the fault has progressed at a critical time point, which we define to be the end of the scenario:

$$\left. \begin{array}{l} \Delta P_{drift}(t_{end}) = m(t_{end} - t_{inj}) > \Delta P_{drift+}^{abort}, \Delta P > 0 \\ \Delta P_{drift}(t_{end}) = m(t_{end} - t_{inj}) < \Delta P_{drift-}^{abort}, \Delta P < 0 \end{array} \right\} \Rightarrow \text{abort}$$

For intermittent faults, the abort decision depends on a normalized estimate of the fault severity:

$$\left. \begin{array}{l} \mu_{\Delta P} \left( \frac{\mu_f}{\mu_f + \mu_n} \right) > \Delta P_{int+}^{abort}, \Delta P > 0 \\ \mu_{\Delta P} \left( \frac{\mu_f}{\mu_f + \mu_n} \right) < \Delta P_{int-}^{abort}, \Delta P < 0 \end{array} \right\} \Rightarrow \text{abort}$$

Figure 5 illustrates three example scenarios for a conditional failure mode: a drift fault which causes an abort (red), an offset fault which does not cause an abort (green), and an intermittent fault which does not cause an abort. In last example, had the fault been persistent rather than intermittent the recommendation would have been to abort. In the figure, the thresholds for the offset fault and drift fault are set to the same value for simplicity.

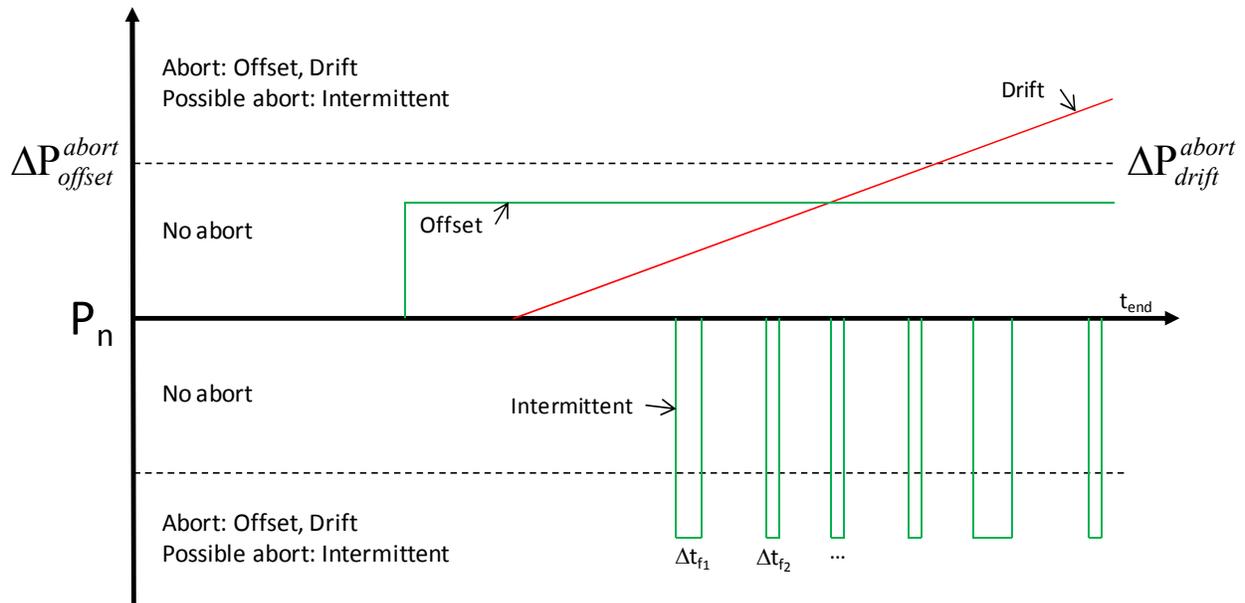


Figure 5. Diagnostic Problem I conditional failure modes.

Please note that DAs do not have to implement the mapping from the failure mode to the abort recommendation in Table 4. DAs may query the DXC framework with a diagnosis (component, failure mode, and failure mode parameters) and receive the correct recommendation for that diagnosis. Alternatively, DAs may query the DXC framework with a diagnosis and a recommendation and receive the corresponding cost. Details will be provided in the framework documentation. By including this capability in the framework a DA will only be responsible for managing ambiguities in its diagnosis and coming up with the final recommendation.

## Diagnostic Problem I: Scenario Examples

Table 5 provides example scenarios for Diagnostic Problem I. The table illustrates a set of “injected” vs. “diagnosed” fault cases, recommendations and cost considerations.

Injected faults (component, failure mode, and parameters) are listed in the first three columns of the table. The fourth column lists the correct recommendation for a particular fault injection. As described before, this recommendation may be dependent on the parameters of the injected fault; these cases are listed as “conditional” scenarios in the table.

Diagnosed faults are listed in columns 5-7. These are intended to illustrate generic cases of different DA outputs. For example, a DA may completely miss the fault, isolate the fault to a correct component and failure mode, and correctly estimate all parameters of the fault. Alternatively, a DA may be correct in diagnosing and isolating a fault but may not be able to estimate some or all parameters of the fault, or it may be incorrect in isolating the fault. The final recommendation of the DA (listed in the 8<sup>th</sup> column) depends on the failure mode and parameters estimated by the DA.

Table 5. Diagnostic Problem I Scenario Examples.

INJECTED (ACTUAL)				DIAGNOSED				COST
Component	Failure Mode	Parameters	Correct Recom.	Component	Failure Mode	Estimated Parameter	DA Recom.	Case
<b>Nominal Scenario</b>								
—	—	—	None	—	—	—	None	Case IV
				ISH236	Stuck	$t_{inj, c}$	None	Case IV
				CB236	FailedOpen	$t_{inj}$	Abort	Case II
<b>Non-Conditional Scenario</b>								
AC483	FailedOff	$t_{inj}$	Abort	AC483	FailedOff	$t_{inj}$	Abort	Case I
				—	—	—	None	Case III
				CB236	FailedOpen	$t_{inj}$	Abort	Case I
				ISH236	Stuck	$t_{inj, c}$	None	Case III
ESH244	Stuck	$t_{inj, c}$	None	ESH244	Stuck	$t_{inj, c}$	None	Case IV
				—	—	—	None	Case IV
				CB236	FailedOpen	$t_{inj}$	Abort	Case II
				ISH236	Stuck	$t_{inj, c}$	None	Case IV
<b>Conditional Scenario</b>								
AC483	ResistanceOffset	$t_{inj, \Delta r}$	Abort	AC483	ResistanceOffset	$t_{inj, \Delta r}$	Abort	Case I
				AC483	ResistanceOffset	$t_{inj, \Delta r}$	None	Case III
				—	—	—	None	Case III
				CB236	FailedOpen	$t_{inj}$	Abort	Case I
				ISH236	Stuck	$t_{inj, c}$	None	Case III
AC483	ResistanceOffset	$t_{inj, \Delta r}$	None	AC483	ResistanceOffset	$t_{inj, \Delta r}$	None	Case IV
				AC483	ResistanceOffset	$t_{inj, \Delta r}$	Abort	Case II
				—	—	—	None	Case IV
				CB236	FailedOpen	$t_{inj}$	Abort	Case II
				ISH236	Stuck	$t_{inj, c}$	None	Case IV

The cost calculations for Diagnostic Problem I will be based on the costs incurred if the DA's recommendation is accepted. The two main categories of costs are cost of losing the vehicle ( $C_{vehicle}$ ) and cost of not completing the mission objectives ( $C_{mission}$ ). For this problem, the DA is only responsible for deciding if a mission should be aborted or not. There are 4 cost cases listed in the last column of Table 5 (2 answers from the DA versus 2 actual situations), which are enumerated in Table 6.

Table 6. Diagnostic Problem I Decision Costs.

DA Recommendation \ Actual Situation	Actual Situation	
	Abort	Non-abort
Abort	Case I: 0	Case II: $C_{mission}$
Non-abort	Case III: $C_{mission} + C_{vehicle}$	Case IV: 0

Note that since the cost calculation will be solely based on the correct recommendation vs. the DA recommendation, a DA may get credit even in cases of false negatives, false positives, and misdiagnosis. However, we will still compute metrics associated with the correctness of the DA diagnosis/isolation (as defined for DXC'09) and will use them as tiebreakers.

## Diagnostic Problem II

For this problem, the ADAPT EPS supplies power to five critical load functions and four non-critical loads. Figure 6 shows the ADAPT EPS schematic. In case of fault(s), the objective is to make sure that the five critical load functions are powered by recommending appropriate recovery actions. The system employs passive redundancy for the critical load functions such that there are two identical loads for each critical function, as shown in Table 7. Only one load of the redundant load pair is on at any given time. The scenarios will start with all relays open and commands will be sent to the EPS to transition the system to one of the 24 configurations listed in Table 8 (complete table is given in appendix). In each of these configurations, the critical loads will nominally remain on for the duration of the scenario while the non-critical loads may be turned on and off.

Table 7. Diagnostic Problem II Critical Load Functions.

No.	Type	Critical to	Redundant Load Pair	
1	AC	Vehicle	L1A (EY170)	L2E (EY274)
2	AC	Mission	L1B (EY171)	L2F (EY275)
3	AC	Vehicle	L1E (EY174)	L2A (EY270)
4	AC	Mission	L1F (EY175)	L2B (EY271)
5	DC	Vehicle	L1G (EY183)	L2H (EY284)

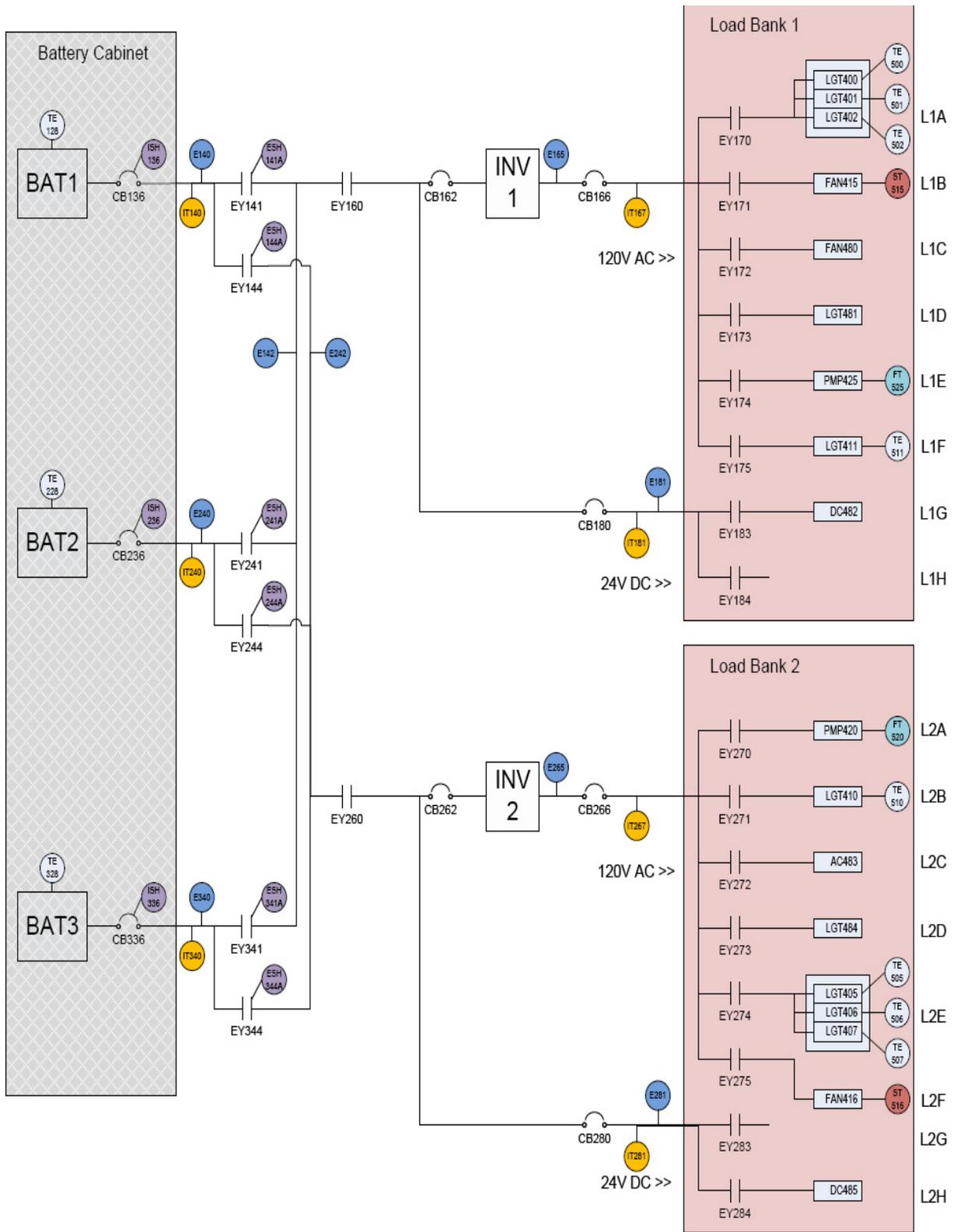


Figure 6. Diagnostic Problem II EPS Schematic.

Table 8. Diagnostic Problem II Nominal EPS Configurations (complete table in appendix).

Conf.	Sources	Load Banks	Loads (active critical highlighted)
1	BAT1 (EY141)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) on
			L1H (EY184) off
	BAT2 (EY244)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
			L2G (EY283) off
			L2H (EY284) off
2	...	...	...

The sensors for ADAPT are shown in Table 9, which indicates the rate at which the data will be presented to the DAs.

Table 9. Diagnostic Problem II Sensor Rate Groups.

Sensor Rate Groups		
1 Hz	2 Hz	10 Hz
TE128	E165	E140
TE228	E181	E142
TE328	E265	E240
TE500	E281	E242
TE501	FT520	E340
TE502	FT525	ESH141A
TE505	IT167	ESH144A
TE506	IT181	ESH241A
TE507	IT267	ESH244A
TE510	IT281	ESH341A
TE511	ST515	ESH344A

ST516	ISH136
	ISH236
	ISH336
	IT140
	IT240
	IT340

The correct recovery for a scenario in Diagnostic Problem II depends only on the injected failure mode(s) (not the parameters of the failure modes) and how the five critical functions are affected. Table 10 (complete table is given in appendix) lists which failure modes require at least one recovery recommendation. Any failure which cuts off power to any of the five critical load functions listed in Table 7 requires one or more recovery recommendations. Example failure modes in this category include circuit breaker FailedOpen, relay StuckOpen, inverter or critical load FailedOff. Furthermore, any fault to a component that is considered critical for UAS safety or mission completion results in one or more recovery actions. Example failure modes in this category include Stuck or Offset for ST515, ST516, TE510, and TE511. Note that there are three components that comprise the first critical load function in Table 7. L1A includes LGT400, LGT401, LGT402; L2E includes LGT405, LGT406, LGT407. When one of the components fails a recovery action is not required but if two (or three) fail, it is necessary to switch to the redundant load function.

**Table 10. Diagnostic Problem II Recovery by Failure Modes (complete table in appendix).**

Comp.	Failure Mode	Recovery?
AC483	FailedOff	No
BAT1	AbruptParasiticLoad	No
BAT2	AbruptParasiticLoad	No
BAT3	AbruptParasiticLoad	No
CB136	FailedOpen	Yes
	StuckClosed	No
...	...	...

For the failure modes in Table 10 which indicate a recovery is necessary (Yes), the recovery action set may include one or more commands from Table 11. There is a special command which is not listed in Table 11 – ‘ABORT’. This command would be the only member in the recovery action set and is the correct command in multiple fault scenarios for which it is impossible to recover one of the critical loads.

**Table 11. Diagnostic Problem II Possible Commands in Action Set.**

(Close) Command
EY141
EY144

EY241
EY244
EY341
EY344
EY170
EY171
EY174
EY175
EY270
EY271
EY274
EY275

Please note that DAs do not have to implement the mapping from failure mode(s) to the recovery action(s) in Table 4 and Table 10. DAs may query the DXC framework with a diagnosis (component(s) and failure mode(s)) and receive the lowest cost action(s) for that diagnosis. Alternatively, DAs may query the DXC framework with a diagnosis and specific action(s) and receive the corresponding cost. Details will be provided in the framework documentation. By including this capability in the framework a DA will only be responsible for managing ambiguities in its diagnosis and coming up with the final recovery action(s). Note that this problem does not include active diagnosis and no actions will actually be taken during the scenario.

## Diagnostic Problem II: Scenario Examples

Table 12 provides example scenarios for Diagnostic Problem II. Similar to Table 5, Table 12 illustrates a set of “injected” vs. “diagnosed” fault cases, recommendations and cost considerations. Note that multiple faults may be injected for Diagnostic Problem II. All scenarios depicted in the table assume Nominal EPS Configuration 1 as per Table 8, meaning that critical loads will be connected at load bank locations [L1A, L1B, L1G, L2A, L2B] respectively.

For each scenario, the component and failure mode are listed in the first two columns of the table. The third column lists a vector representing the impact of the injected fault(s) on the critical loads of the system (“1” meaning functional, and “0” meaning impacted). In case of an impact, the task of the DA is to recover the system to a fully functional state for all critical loads, or to abort the mission for safety. The fourth column lists the correct recovery action for a given scenario. As described before, this action may either be “none”, “abort”, or a set of “relay commands” that will recover the system to a desired state.

For diagnosed faults, the diagnoses (the component and failure mode) by the DA are listed in the first two columns of the table. These are intended to illustrate generic cases of different DA outputs. For example, a DA may completely miss the fault, misdiagnose the fault, or correctly diagnose/isolate the fault. As far as the recovery action recommendations, a DA may issue an optimum recommendation (least number of commands), or may choose to issue commands that may result in a non-optimum

recovery, or a partial recovery. The final recovery action recommendations of the DA are listed in the 4<sup>th</sup> column. The mitigation level that will be achieved (*i.e.*, how the critical functions will be affected) by executing the DA's recovery action recommendation is shown in Column 3.

Table 12. Diagnostic Problem II Scenario Examples.

<b>Nominal Scenario</b>				
<b>INJECTED (ACTUAL)</b>				
Component	Failure Mode	Impact on Critical Functions [L1A, L1B, L1G, L2A, L2B]	Correct Recovery Action	
—	—	[1,1,1,1,1]	None	
<b>DIAGNOSED</b>				
Component	Failure Mode	Mitigation on Critical Functions [L1A, L1B, L1G, L2A, L2B]	DA Recommended Recovery Action	Cost
—	—	[1,1,1,1,1]	None	0
ISH236	Stuck	[1,1,1,1,1]	None	0
EY170	FailedOpen	[1,1,1,1,1]	{EY274}	C <sub>action</sub>
EY171 INV2	FailedOpen FailedOff	N/A	Abort	C <sub>mission</sub>
<b>Single Fault Scenario Requiring No Recovery Action</b>				
<b>INJECTED (ACTUAL)</b>				
Component	Failure Mode	Impact on Critical Functions [L1A, L1B, L1G, L2A, L2B]	Correct Recovery Action	
LGT484	FailedOff	[1,1,1,1,1]	None	
<b>DIAGNOSED</b>				
Component	Failure Mode	Mitigation on Critical Functions [L1A, L1B, L1G, L2A, L2B]	DA Recommended Recovery Action	Cost
LGT484	FailedOff	[1,1,1,1,1]	None	0
—	—		None	0
IT267	Offset	[1,1,1,1,1]	None	0
EY271	FailedOpen	[1,1,1,1,1]	{EY175}	C <sub>action</sub>
EY271 INV1	FailedOpen FailedOff	N/A	Abort	C <sub>mission</sub>

Single Fault Scenario Requiring Single Recovery Action				
INJECTED (ACTUAL)				
Component	Failure Mode	Impact on Critical Functions [L1A, L1B, L1G, L2A, L2B]	Correct Recovery Action	
EY170	FailedOpen	[0,1,1,1,1]	{EY274}	
DIAGNOSED				
Component	Failure Mode	Mitigation on Critical Functions [L1A, L1B, L1G, L2A, L2B]	DA Recommended Recovery Action	Cost
EY170	FailedOpen	[1,1,1,1,1]	{EY274}	$C_{action}$
—	—	[0,1,1,1,1]	None	$C_{mission} + C_{vehicle}$
IT140	Stuck	[0,1,1,1,1]	None	$C_{mission} + C_{vehicle}$
FAN415	FailedOff	[0,1,1,1,1]	{EY275}	$C_{mission} + C_{action} + C_{vehicle}$
INV1	FailedOff	[1,1,1,1,1]	{EY274, EY275}	$2 * C_{action}$
EY271 INV1	FailedOpen FailedOff	N/A	Abort	$C_{mission}$
Single Fault Scenario Requiring Multiple Recovery Actions				
INJECTED (ACTUAL)				
Component	Failure Mode	Impact on Critical Functions [L1A, L1B, L1G, L2A, L2B]	Correct Recovery Action	
EY160	FailedOpen	[0,0,0,1,1]	{EY274, EY275, EY284}	
DIAGNOSED				
Component	Failure Mode	Mitigation on Critical Functions [L1A, L1B, L1G, L2A, L2B]	DA Recommended Recovery Action	Cost
EY160	FailedOpen	[0,0,0,1,1]	{EY274, EY275, EY284}	$3 * C_{action}$
—	—	[0,0,0,1,1]	None	$C_{mission} + C_{vehicle}$
E265	Stuck	[0,0,0,1,1]	None	$C_{mission} + C_{vehicle}$
INV1	FailedOff	[1,1,0,1,1]	{EY274, EY275}	$C_{mission} + 2 * C_{action} + C_{vehicle}$
TE510	Stuck	[0,0,0,1,0]	{EY175}	$C_{mission} + C_{action} + C_{vehicle}$

CB136	FailedOpen	[0,0,0,1,1]	{EY341}	$C_{mission} + C_{action} + C_{vehicle}$
INV1 INV2	FailedOff FailedOff	N/A	Abort	$C_{mission}$
<b>Multiple Fault Scenario Requiring No Recovery Action</b>				
<b>INJECTED (ACTUAL)</b>				
<b>Component</b>	<b>Failure Mode</b>	<b>Impact on Critical Functions [L1A, L1B, L1G, L2A, L2B]</b>	<b>Correct Recovery Action</b>	
LGT481 IT140	FailedOff Stuck	[1,1,1,1,1]	None	
<b>DIAGNOSED</b>				
<b>Component</b>	<b>Failure Mode</b>	<b>Mitigation on Critical Functions [L1A, L1B, L1G, L2A, L2B]</b>	<b>DA Recommended Recovery Action</b>	<b>Cost</b>
LGT481 IT140	FailedOff Stuck	[1,1,1,1,1]	None	0
—	—	[1,1,1,1,1]	None	0
LGT481	FailedOff	[1,1,1,1,1]	None	0
FAN415	FailedOff	[1,1,1,1,1]	{EY275}	$C_{action}$
INV1 INV2	FailedOff FailedOff	N/A	Abort	$C_{mission}$
<b>Multiple Fault Scenario Requiring Single Recovery Action</b>				
<b>INJECTED (ACTUAL)</b>				
<b>Component</b>	<b>Failure Mode</b>	<b>Impact on Critical Functions [L1A, L1B, L1G, L2A, L2B]</b>	<b>Correct Recovery Action</b>	
EY244 E140	StuckOpen Stuck	[1,1,1,0,0]	{EY344}	
<b>DIAGNOSED</b>				
<b>Component</b>	<b>Failure Mode</b>	<b>Mitigation on Critical Functions [L1A, L1B, L1G, L2A, L2B]</b>	<b>DA Recommended Recovery Action</b>	<b>Cost</b>
EY244 E140	StuckOpen Stuck	[1,1,1,1,1]	{EY344}	$C_{action}$
—	—	[1,1,1,0,0]	None	$C_{mission} + C_{vehicle}$
IT267	Stuck	[1,1,1,0,0]	None	$C_{mission} + C_{vehicle}$

LGT410	FailedOff	[1,1,1,0,1]	{EY175}	$C_{mission} + C_{action} + C_{vehicle}$
INV1 INV2	FailedOff FailedOff	N/A	Abort	$C_{mission}$
<b>INJECTED (ACTUAL)</b>				
<b>Component</b>	<b>Failure Mode</b>	<b>Impact on Critical Functions [L1A, L1B, L1G, L2A, L2B]</b>	<b>Correct Recovery Action</b>	
ST515 E140	Stuck Stuck	[1,0,1,1,1]	{EY275}	
<b>DIAGNOSED</b>				
<b>Component</b>	<b>Failure Mode</b>	<b>Mitigation on Critical Functions [L1A, L1B, L1G, L2A, L2B]</b>	<b>DA Recommended Recovery Action</b>	<b>Cost</b>
ST515 E140	Stuck Stuck	[1,1,1,1,1]	{EY275}	$C_{action}$
—	—	[1,0,1,1,1]	None	$C_{mission}$
IT267	Stuck	[1,0,1,1,1]	None	$C_{mission}$
LGT410	FailedOff	[1,0,1,1,1]	{EY175}	$C_{mission} + C_{action}$
INV1 INV2	FailedOff FailedOff	N/A	Abort	$C_{mission}$
<b>Multiple Fault Scenario Requiring Multiple Recovery Actions</b>				
<b>INJECTED (ACTUAL)</b>				
<b>Component</b>	<b>Failure Mode</b>	<b>Impact on Critical Functions [L1A, L1B, L1G, L2A, L2B]</b>	<b>Correct Recovery Action</b>	
DC482 INV2	FailedOff FailedOff	[1,1,0,0,0]	{EY284, EY174, EY175}	
<b>DIAGNOSED</b>				
<b>Component</b>	<b>Failure Mode</b>	<b>Mitigation on Critical Functions [L1A, L1B, L1G, L2A, L2B]</b>	<b>DA Recommended Recovery Action</b>	<b>Cost</b>
DC482 INV2	FailedOff FailedOff	[1,1,1,1,1]	{EY284, EY174, EY175}	$3 * C_{action}$
—	—	[1,1,0,0,0]	None	$C_{mission} + C_{vehicle}$
IT181 IT267	Stuck Stuck	[1,1,0,0,0]	None	$C_{mission} + C_{vehicle}$

DC482 PMP420	FailedOff FailedOff	[1,1,1,1,0]	{EY284, EY174}	$C_{mission} + 2 * C_{action}$
INV1 INV2	FailedOff FailedOff	N/A	Abort	$C_{mission}$
<b>Multiple Fault Scenario Requiring Abort Action</b>				
<b>INJECTED (ACTUAL)</b>				
<b>Component</b>	<b>Failure Mode</b>	<b>Impact on Critical Functions [L1A, L1B, L1G, L2A, L2B]</b>	<b>Correct Recovery Action</b>	
CB166 EY270	FailedOpen StuckOpen	[0,0,1,0,1]	Abort	
<b>DIAGNOSED</b>				
<b>Component</b>	<b>Failure Mode</b>	<b>Mitigation on Critical Functions [L1A, L1B, L1G, L2A, L2B]</b>	<b>DA Recommended Recovery Action</b>	<b>Cost</b>
CB166 EY270	FailedOpen StuckOpen	N/A	Abort	$C_{mission}$
—	—	[0,0,1,0,1]	None	$C_{mission} + C_{vehicle}$
IT167 IT267	Stuck Stuck	[0,0,1,0,1]	None	$C_{mission} + C_{vehicle}$
CB166 EY270	FailedOpen StuckOpen	[1,1,1,0,1]	{EY274, EY275, EY174}	$C_{mission} + 3 * C_{action} + C_{vehicle}$
INV1 INV2	FailedOff FailedOff	N/A	Abort	$C_{mission}$

The cost calculations for Diagnostic Problem II will be based on the costs incurred if the DA's recommendation is accepted. Again, there will be costs associated with losing the vehicle ( $C_{vehicle}$ ) and not completing the mission objectives ( $C_{mission}$ ). In addition, for this problem, there will be costs associated with performing each recommended recovery action ( $C_{action}$ ). The total cost incurred for each example scenario is listed in the last column of Table 12. Note that since the cost calculation will be solely based on the correct recovery recommendation vs. the DA recommended recovery actions, a DA may not get penalized even in cases of false negatives, false positives, and misdiagnosis. However, we will still compute metrics associated with the correctness of the DA diagnosis/isolation (as defined for DXC'09) and will use them as tiebreakers.

## **Appendix**

Table 4. Diagnostic Problem I Abort Recommendations by Failure Mode.

Comp.	Failure Mode	Parameters	Recommendation
AC483	FailedOff	$t_{inj}$	Abort
	ResistanceOffset	$t_{inj}, \Delta r$	Conditional
	ResistanceDrift	$t_{inj}, m$	Conditional
	IntermittentResistanceOffset	$t_{inj}, \mu_{\Delta r}, \mu_r, \mu_n$	Conditional
BAT2	AbruptParasiticLoad	$t_{inj}, r$	None
CB236	FailedOpen	$t_{inj}$	Abort
	StuckClosed	$t_{inj}$	None
CB262	FailedOpen	$t_{inj}$	Abort
CB266	FailedOpen	$t_{inj}$	Abort
CB280	FailedOpen	$t_{inj}$	Abort
DC485	FailedOff	$t_{inj}$	Abort
	ResistanceOffset	$t_{inj}, \Delta r$	Conditional
	ResistanceDrift	$t_{inj}, m$	Conditional
	IntermittentResistanceOffset	$t_{inj}, \mu_{\Delta r}, \mu_r, \mu_n$	Conditional
E240	Offset	$t_{inj}, \Delta s$	None
	Stuck	$t_{inj}, c$	None
	Drift	$t_{inj}, m$	None
	IntermittentOffset	$t_{inj}, \mu_{\Delta s}, \mu_r, \mu_n$	None
E242	Offset	$t_{inj}, \Delta s$	None
	Stuck	$t_{inj}, c$	None
	Drift	$t_{inj}, m$	None
	IntermittentOffset	$t_{inj}, \mu_{\Delta s}, \mu_r, \mu_n$	None
E265	Offset	$t_{inj}, \Delta s$	None
	Stuck	$t_{inj}, c$	None
	Drift	$t_{inj}, m$	None
	IntermittentOffset	$t_{inj}, \mu_{\Delta s}, \mu_r, \mu_n$	None
E281	Offset	$t_{inj}, \Delta s$	None
	Stuck	$t_{inj}, c$	None
	Drift	$t_{inj}, m$	None
	IntermittentOffset	$t_{inj}, \mu_{\Delta s}, \mu_r, \mu_n$	None
ESH244A	Stuck	$t_{inj}, c$	None
EY244	StuckOpen	$t_{inj}$	Abort
	StuckClosed	$t_{inj}$	None
EY260	StuckOpen	$t_{inj}$	Abort
	StuckClosed	$t_{inj}$	None
EY272	StuckOpen	$t_{inj}$	Abort
	StuckClosed	$t_{inj}$	None
EY275	StuckOpen	$t_{inj}$	Abort
	StuckClosed	$t_{inj}$	None
EY284	StuckOpen	$t_{inj}$	Abort

	StuckClosed	$t_{inj}$	None
FAN416	OverSpeed	$t_{inj}$	Abort
	UnderSpeed	$t_{inj}$	None
	FailedOff	$t_{inj}$	Abort
INV2	FailedOff	$t_{inj}$	Abort
ISH236	Stuck	$t_{inj}, c$	None
IT240	Offset	$t_{inj}, \Delta s$	Conditional
	Stuck	$t_{inj}, c$	Abort
	Drift	$t_{inj}, m$	Conditional
	IntermittentOffset	$t_{inj}, \mu_{\Delta s}, \mu_f, \mu_n$	Conditional
IT267	Offset	$t_{inj}, \Delta s$	Conditional
	Stuck	$t_{inj}, c$	Abort
	Drift	$t_{inj}, m$	Conditional
	IntermittentOffset	$t_{inj}, \mu_{\Delta s}, \mu_f, \mu_n$	Conditional
IT281	Offset	$t_{inj}, \Delta s$	Conditional
	Stuck	$t_{inj}, c$	Abort
	Drift	$t_{inj}, m$	Conditional
	IntermittentOffset	$t_{inj}, \mu_{\Delta s}, \mu_f, \mu_n$	Conditional
ST516	Offset	$t_{inj}, \Delta s$	Conditional
	Stuck	$t_{inj}, c$	Abort
	Drift	$t_{inj}, m$	Conditional
	IntermittentOffset	$t_{inj}, \mu_{\Delta s}, \mu_f, \mu_n$	Conditional
TE228	Offset	$t_{inj}, \Delta s$	None
	Stuck	$t_{inj}, c$	None
	Drift	$t_{inj}, m$	None
	IntermittentOffset	$t_{inj}, \mu_{\Delta s}, \mu_f, \mu_n$	None

Table 8. Diagnostic Problem II Nominal EPS Configurations.

Conf.	Sources	Load Banks	Loads (active critical highlighted)
1	BAT1 (EY141)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) on
			L1H (EY184) off
	BAT2 (EY244)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
2	BAT1 (EY141)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) on
			L1H (EY184) off
	BAT3 (EY344)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
3	BAT2 (EY241)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off

			L1F (EY175) off
			L1G (EY183) on
			L1H (EY184) off
	BAT1 (EY144)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
			L2G (EY283) off
			L2H (EY284) off
4	BAT2 (EY241)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) on
			L1H (EY184) off
	BAT3 (EY344)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
			L2G (EY283) off
			L2H (EY284) off
5	BAT3 (EY341)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) on
			L1H (EY184) off
	BAT1 (EY144)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
			L2G (EY283) off
			L2H (EY284) off
6	BAT3 (EY341)	LB1 (EY160)	L1A (EY170) on

			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) on
			L1H (EY184) off
	BAT2 (EY244)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
			L2G (EY283) off
			L2H (EY284) off
7	BAT1 (EY141)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) off
			L1H (EY184) off
	BAT2 (EY244)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
			L2G (EY283) off
			L2H (EY284) on
8	BAT1 (EY141)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) off
			L1H (EY184) off
	BAT3 (EY344)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off

			L2F (EY275) off
			L2G (EY283) off
			L2H (EY284) on
9	BAT2 (EY241)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) off
			L1H (EY184) off
	BAT1 (EY144)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
			L2G (EY283) off
			L2H (EY284) on
10	BAT2 (EY241)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) off
			L1H (EY184) off
	BAT3 (EY344)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
			L2G (EY283) off
			L2H (EY284) on
11	BAT3 (EY341)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) off
			L1H (EY184) off
	BAT1 (EY144)	LB2 (EY260)	L2A (EY270) on

			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
			L2G (EY283) off
			L2H (EY284) on
12	BAT3 (EY341)	LB1 (EY160)	L1A (EY170) on
			L1B (EY171) on
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) off
			L1F (EY175) off
			L1G (EY183) off
			L1H (EY184) off
	BAT2 (EY244)	LB2 (EY260)	L2A (EY270) on
			L2B (EY271) on
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) off
			L2F (EY275) off
			L2G (EY283) off
			L2H (EY284) on
13	BAT1 (EY141)	LB1 (EY160)	L1A (EY170) off
			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on
			L1F (EY175) on
			L1G (EY183) on
			L1H (EY184) off
	BAT2 (EY244)	LB2 (EY260)	L2A (EY270) off
			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on
			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) off
14	BAT1 (EY141)	LB1 (EY160)	L1A (EY170) off
			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on

			L1F (EY175) on
			L1G (EY183) on
			L1H (EY184) off
	BAT3 (EY344)	LB2 (EY260)	L2A (EY270) off
			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on
			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) off
15	BAT2 (EY241)	LB1 (EY160)	L1A (EY170) off
			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on
			L1F (EY175) on
			L1G (EY183) on
			L1H (EY184) off
	BAT1 (EY144)	LB2 (EY260)	L2A (EY270) off
			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on
			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) off
16	BAT2 (EY241)	LB1 (EY160)	L1A (EY170) off
			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on
			L1F (EY175) on
			L1G (EY183) on
			L1H (EY184) off
	BAT3 (EY344)	LB2 (EY260)	L2A (EY270) off
			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on
			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) off
17	BAT3 (EY341)	LB1 (EY160)	L1A (EY170) off

			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on
			L1F (EY175) on
			L1G (EY183) on
			L1H (EY184) off
	BAT1 (EY144)	LB2 (EY260)	L2A (EY270) off
			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on
			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) off
18	BAT3 (EY341)	LB1 (EY160)	L1A (EY170) off
			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on
			L1F (EY175) on
			L1G (EY183) on
			L1H (EY184) off
	BAT2 (EY244)	LB2 (EY260)	L2A (EY270) off
			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on
			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) off
19	BAT1 (EY141)	LB1 (EY160)	L1A (EY170) off
			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on
			L1F (EY175) on
			L1G (EY183) off
			L1H (EY184) off
	BAT2 (EY244)	LB2 (EY260)	L2A (EY270) off
			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on

			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) on
20	BAT1 (EY141)	LB1 (EY160)	L1A (EY170) off
			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on
			L1F (EY175) on
			L1G (EY183) off
			L1H (EY184) off
	BAT3 (EY344)	LB2 (EY260)	L2A (EY270) off
			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on
			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) on
21	BAT2 (EY241)	LB1 (EY160)	L1A (EY170) off
			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on
			L1F (EY175) on
			L1G (EY183) off
			L1H (EY184) off
	BAT1 (EY144)	LB2 (EY260)	L2A (EY270) off
			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on
			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) on
22	BAT2 (EY241)	LB1 (EY160)	L1A (EY170) off
			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on
			L1F (EY175) on
			L1G (EY183) off
			L1H (EY184) off
	BAT3 (EY344)	LB2 (EY260)	L2A (EY270) off

			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on
			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) on
23	BAT3 (EY341)	LB1 (EY160)	L1A (EY170) off
			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on
			L1F (EY175) on
			L1G (EY183) off
			L1H (EY184) off
	BAT1 (EY144)	LB2 (EY260)	L2A (EY270) off
			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on
			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) on
24	BAT3 (EY341)	LB1 (EY160)	L1A (EY170) off
			L1B (EY171) off
			L1C (EY172) on/off
			L1D (EY173) on/off
			L1E (EY174) on
			L1F (EY175) on
			L1G (EY183) off
			L1H (EY184) off
	BAT2 (EY244)	LB2 (EY260)	L2A (EY270) off
			L2B (EY271) off
			L2C (EY272) on/off
			L2D (EY273) on/off
			L2E (EY274) on
			L2F (EY275) on
			L2G (EY283) off
			L2H (EY284) on

Table 10. Diagnostic Problem II Recovery by Failure Modes.

Comp.	Failure Mode	Recovery?
AC483	FailedOff	No
BAT1	AbruptParasiticLoad	No
BAT2	AbruptParasiticLoad	No
BAT3	AbruptParasiticLoad	No
CB136	FailedOpen	Yes
	StuckClosed	No
CB162	FailedOpen	Yes
CB166	FailedOpen	Yes
CB180	FailedOpen	Yes
CB236	FailedOpen	Yes
	StuckClosed	No
CB262	FailedOpen	Yes
CB266	FailedOpen	Yes
CB280	FailedOpen	Yes
CB336	FailedOpen	Yes
	StuckClosed	No
DC482	FailedOff	Yes
DC485	FailedOff	Yes
E140	Offset	No
	Stuck	No
E142	Offset	No
	Stuck	No
E165	Offset	No
	Stuck	No
E181	Offset	No
	Stuck	No
E240	Offset	No
	Stuck	No
E242	Offset	No
	Stuck	No
E265	Offset	No
	Stuck	No
E281	Offset	No
	Stuck	No
E340	Offset	No
	Stuck	No
ESH141A	Stuck	No
ESH144A	Stuck	No
ESH241A	Stuck	No
ESH244A	Stuck	No

ESH341A	Stuck	No
ESH344A	Stuck	No
EY141	StuckOpen	Yes
	StuckClosed	No
EY144	StuckOpen	Yes
	StuckClosed	No
EY160	StuckOpen	Yes
	StuckClosed	No
EY170	StuckOpen	Yes
	StuckClosed	No
EY171	StuckOpen	Yes
	StuckClosed	No
EY172	StuckOpen	No
	StuckClosed	No
EY173	StuckOpen	No
	StuckClosed	No
EY174	StuckOpen	Yes
	StuckClosed	No
EY175	StuckOpen	Yes
	StuckClosed	No
EY183	StuckOpen	Yes
	StuckClosed	No
EY184	StuckOpen	No
	StuckClosed	No
EY241	StuckOpen	Yes
	StuckClosed	No
EY244	StuckOpen	Yes
	StuckClosed	No
EY260	StuckOpen	Yes
	StuckClosed	No
EY270	StuckOpen	Yes
	StuckClosed	No
EY271	StuckOpen	Yes
	StuckClosed	No
EY272	StuckOpen	No
	StuckClosed	No
EY273	StuckOpen	No
	StuckClosed	No
EY274	StuckOpen	Yes
	StuckClosed	No
EY275	StuckOpen	Yes
	StuckClosed	No
EY283	StuckOpen	No
	StuckClosed	No

EY284	StuckOpen	Yes
	StuckClosed	No
EY341	StuckOpen	Yes
	StuckClosed	No
EY344	StuckOpen	Yes
	StuckClosed	No
FAN415	OverSpeed	Yes
	UnderSpeed	No
	FailedOff	Yes
FAN416	OverSpeed	Yes
	UnderSpeed	No
	FailedOff	Yes
FAN480	FailedOff	No
FT520	Offset	No
	Stuck	No
FT525	Offset	No
	Stuck	No
INV1	FailedOff	Yes
INV2	FailedOff	Yes
ISH136	Stuck	No
ISH236	Stuck	No
ISH336	Stuck	No
IT140	Offset	No
	Stuck	No
IT167	Offset	No
	Stuck	No
IT181	Offset	No
	Stuck	No
IT240	Offset	No
	Stuck	No
IT267	Offset	No
	Stuck	No
IT281	Offset	No
	Stuck	No
IT340	Offset	No
	Stuck	No
LGT400	FailedOff	No
LGT401	FailedOff	No
LGT402	FailedOff	No
LGT405	FailedOff	No
LGT406	FailedOff	No
LGT407	FailedOff	No
LGT410	FailedOff	Yes
LGT411	FailedOff	Yes

LGT481	FailedOff	No
LGT484	FailedOff	No
PMP420	FlowRestricted	No
	FailedOff	Yes
PMP425	FlowRestricted	No
	FailedOff	Yes
ST515	Offset	Yes
	Stuck	Yes
ST516	Offset	Yes
	Stuck	Yes
TE128	Offset	No
	Stuck	No
TE228	Offset	No
	Stuck	No
TE328	Offset	No
	Stuck	No
TE500	Offset	No
	Stuck	No
TE501	Offset	No
	Stuck	No
TE502	Offset	No
	Stuck	No
TE505	Offset	No
	Stuck	No
TE506	Offset	No
	Stuck	No
TE507	Offset	No
	Stuck	No
TE510	Offset	Yes
	Stuck	Yes
TE511	Offset	Yes
	Stuck	Yes