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Acquisition Interface System Upgrade at TA-55*

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RELIABILITY ANALYSIS FOR THE FACILITY DATA ACQUISITION INTERFACE SYSTEM UPGRADE AT TA-55

by

W. J. Turner, N. G. Pope, and R. E. Brown

ABSTRACT

Because replacement parts for the existing facility data acquisition interface system at TA-55 have become scarce and are no longer being manufactured, reliability studies were conducted to assess various possible replacement systems. A new control system, based on Allen-Bradley Programmable Logic Controllers (PLCs), was found to have a likely reliability 10 times that of the present system, if the existing Continuous Air Monitors (CAMs) were used. Replacement of the old CAMs with new CAMs will result in even greater reliability as these are gradually phased in. The new PLC-based system would provide for hot standby processors, redundant communications paths, and redundant power supplies, and would be expandable and easily maintained, as well as much more reliable.

I. INTRODUCTION

The facility data acquisition interface system (FDAIS) at the Los Alamos National Laboratory Plutonium Facility is approaching the end of its expected useful life. New repair parts for most components are not available because their manufacturer has been out of business for some time. Therefore, it is necessary to consider replacing the existing system with a new system. One proposed solution is to replace the present system with a control system based on Allen-Bradley Programmable Logic Controllers (PLCs). This paper presents a reliability analysis of the PLC system and its associated hardware.

II. EXISTING SYSTEM

The existing system consists of 23 Field Multiplex Units (FMUs). These units are located throughout the plant. Each one has a communications connection to a Data General computer located in the TA-55 Operations Center, where all ladder logic is performed. There are approximately 2200 input/output (I/O) points connected to the existing system.

III. PROPOSED REPLACEMENT SYSTEM

The replacement system consists of 19 PLCs. FMUs will be replaced by PLCs and the corresponding I/O hardware. There are four locations where two FMUs are located; one PLC can replace two FMUs in these locations. Some subsystems, such as fire alarms, may be consolidated to a single location rather than remaining distributed throughout the complex. Also, plans are underway to install a new type of Continuous Air Monitor (CAM). If these changes are made, additional PLCs will be added to the system to allow it to incorporate the CAM control functions. The goals of the design effort for a new control system were to design a system that would provide for hot standby processors, redundant communications paths, and redundant power supplies. In addition, the system must be expandable, easily maintained, and reliable. The proposed architecture is shown in Fig. 1. Replacing sensors and sensor field wiring has not been considered.

Fig. 1. Proposed facility control system architecture.

This reliability analysis is restricted to a proposed system incorporating 19 PLC units. Several variations of the system architecture have been analyzed.

Model 1	Dual processor Communication protocol: Ethernet and Data Highway Plus New CAMs
Model 2	Dual processor Communication protocol: dual Ethernet New CAMs
Model 3	Dual processor Communication protocol: Ethernet and Data Highway Plus Old CAMs
Model 4	Dual processor Communication protocol: dual Ethernet Old CAMs
Model 5	Single processor Communication protocol: Ethernet and Data Highway Plus New CAMs
Model 6	Single processor Communication protocol: dual Ethernet New CAMs
Model 7	Single processor Communication protocol: Ethernet and Data Highway Plus Old CAMs
Model 8	Single processor Communication protocol: dual Ethernet Old CAMs

The existing CAM has an output that is a pulse train with a rate that is proportional to the reading. This signal can be measured with a high-speed counter module. It is expected that ~70 modules will be required throughout the plant to monitor these CAMs. The new CAM, on the other hand, uses an RS485 protocol for communication and has much more data available. When the new CAMs are installed, it may be feasible to use only one communication module to obtain data from the entire CAM network. This change in module count from ~70 to 1 will provide a significant change in reliability, as shown later in this report.

IV. DEFINITIONS

The following definitions are used in the rest of this report. They can be found in Juran's Quality Control Handbook, Fourth Edition, J. M. Juran, Ed. (McGraw-Hill, New York, 1988).

MTBF Mean Time between Failures

MTTR Mean Time to Repair

Reliability The probability of a product performing (without failure) a specified function for a specified period of time.

Probability of Survival (P_s), another measure of reliability, is the given by

$$P_s = \exp - \frac{t}{\mu} = \exp - t\lambda$$

where $e = 2.718$
 t = a specified period of failure-free operation
 μ = MTBF
 λ = failure rate (reciprocal of μ).

Availability (A) $A = \frac{MTBF}{MTBF + MTTR}$.

Maintainability Probability of restoring service in the time period specified.

RAM Reliability, availability, and maintainability.

V. THEORY

When analyzing RAM, it is customary to start with either computed or historical data for the MTBF and MTTR. This data is required for each component of the system. The availability of each component is computed, and the system is then analyzed to determine which items are redundant. The system availability for the redundant items is computed using probability theory.

The following is an example of a RAM analysis of the system power supplies. The power supplies can be configured in sets of two, three, or four, depending on load requirements. In each case, one power supply can fail without causing failure of the system.

For the two-supply case, the analysis is straightforward. The individual availability of each supply is computed as outlined in the definition of *availability*. From this the probability of failure of one supply is given by

$$P_f = 1 - A.$$

The probability of both power supplies failing simultaneously is the calculation that is required. If the failures are independent, then the probability is the product of

the individual probabilities, which is given by

$$P_{\text{Both Fail}} = (1 - A)^2.$$

The availability of the redundant power supply is then given by

$$A_{\text{Two-Supply System}} = 1 - (1 - A)^2.$$

The three-supply system is slightly more complicated to compute, since we must now be concerned with any two of the three failing and the remote possibility that all three would fail at the same time. Out of a total of three power supplies (if the failures are independent), there are three ways that two can fail at the same time. This is given by

$$P_{\text{Two Fail}} = 3(1 - A)^2.$$

The other possibility is that all three fail at the same time, which would be given by

$$P_{\text{Three Fail}} = (1 - A)^3.$$

Therefore, the probability of system failure for the three-supply system would be given by

$$P_{\text{System Failure}} = 3(1 - A)^2 + (1 - A)^3.$$

The availability of the three-supply system is then

$$A_{\text{Three-Supply System}} = 1 - [3(1 - A)^2 + (1 - A)^3].$$

Similarly, the probability of failure of the four-supply system is given by

$$P_{\text{System Failure}} = 6(1 - A)^2 + 4(1 - A)^3 + (1 - A)^4,$$

and the availability of the four-supply system is

$$A_{\text{Four-Supply System}} = 1 - [6(1 - A)^2 + 4(1 - A)^3 + (1 - A)^4].$$

We can be thankful that our hypothetical manufacturer in this example doesn't produce a five-supply system.

We will now examine the hot-standby or redundant-PLC configuration. Figure 2 shows a single-PLC system. This consists of a

- (1) chassis,
- (2) PLC,
- (3) Backup Communication Module, and
- (4) a two-power-supply system as described above.

Fig. 2. A single-PLC subsystem.

The availability for this subsystem is then

$$\begin{aligned}
 A_{\text{Single-PLC Subsystem}} &= (A_{\text{Chassis}}) (A_{\text{PLC}}) (A_{\text{BCM}}) (A_{\text{Two-Supply System}}) \\
 &= (A_{\text{Chassis}}) (A_{\text{PLC}}) (A_{\text{BCM}}) [1 - (1 - A_{\text{Power Supply}})^2] .
 \end{aligned}$$

This leads to the availability of the redundant PLC subsystem as

$$A_{\text{Redundant PLC}} = 1 - [1 - (1 - A_{\text{Single-PLC Subsystem}})^2] .$$

VI. CALCULATIONS

A QuickBasic program was written to make the calculations required by our reliability analysis. A copy of the program is included in Appendix A, and a sample output is shown in Appendix B.

The tables below provide a summary of our calculated results from this program. The rows correspond to the eight models, as follows:

DPNCED	Model 1 (dual processor, new CAMs, Ethernet and Data Highway Plus)
DPNCEE	Model 2 (dual processor, new CAMs, dual Ethernet)
DPOCED	Model 3 (dual processor, old CAMs, Ethernet and Data Highway Plus)
DPOCEE	Model 4 (dual processor, old CAMs, dual Ethernet)
SPNCED	Model 5 (single processor, new CAMs, Ethernet and Data Highway Plus)
SPNCEE	Model 6 (single processor, new CAMs, dual Ethernet)
SPOCED	Model 7 (single processor, old CAMs, Ethernet and Data Highway Plus)
SPOCEE	Model 8 (single processor, old CAMs, dual Ethernet).

Model	MTBF (hours)
DPNCED	10246.89
DPNCEE	10246.53
DPOCED	3205.03
DPOCEE	3204.99
SPNCED	5715.87
SPNCEE	4625.17
SPOCED	2567.38
SPOCEE	2321.10

As indicated earlier, the MTBF for each of the models containing the new CAMs is far better than the MTBF for the models that use the old CAMs. This performance

difference is due to the counters required for the old CAMs. The counters are complicated modules that have a low MTBF. When the CAMs are replaced, the counters will come out of the system, and the system MTBF will increase.

Probability of Survival (P_s)	0.37	0.5	0.95
Model	MTBF (hours)	(hours)	(hours)
DPNCED	10246.89	7102.60	525.60
DPNCEE	10246.53	7102.36	525.58
DPOCED	3205.03	2221.56	164.40
DPOCEE	3204.99	2221.53	164.39
SPNCED	5715.87	3961.94	293.19
SPNCEE	4625.17	3205.92	237.24
SPOCED	2567.38	1779.60	131.69
SPOCEE	2321.10	1608.86	119.06

The P_s row indicates the probability of survival for the number of hours given. If the hypothesis is that Model 1 will survive for 525 hours without a failure, then the hypothesis can be expected to be correct 95% of the time (i.e., the model has a P_s of 0.95). Since the distribution of the failures is exponential, the probability of survival to the MTBF is not 0.5 (as might be expected) but only 0.37.

The dual processor model for the old CAMs (Model 3) shows a 0.95 probability of survival for 164 hours. This system can be contrasted with the existing system, which has a 0.95 probability of survival of only about 12 hours.

VII. CONCLUSIONS

The old-CAM version of the new control system is at least 10 times more reliable than the existing system. This analysis has assumed that any failure would cause a system failure. This assumption is not really true because many signals only turn on status lights or have other noncritical consequences that will not take the system down.

The design that was examined uses several redundant components. The reliability results that are shown take these redundancies into account. This does not mean that individual components cannot fail or cannot fail simultaneously but means that when a redundant component fails, its function can usually be maintained without systemwide consequences.

Appendix A
QuickBasic Program

THE QUICKBASIC PROGRAM

NOTE: The MTBF and availability numbers have been removed because the company considers those numbers to be proprietary information. The system numbers still remain.

```

DECLARE SUB fill11 ()
DECLARE FUNCTION avail# (m1#, m2#)
DECLARE FUNCTION availparallel# (m1#)
DECLARE SUB fill ()
DEFDBL A, M
DEFINT N

LPRINT SPACE$(10), DATE$, TIME$

MTTRchassis = 8
MTTRmodule = 8
MTTRsystem = 8

LPRINT SPACE$(5); "ASSUMPTIONS  (1)  It will take "; MTTRchassis;
" hours to replace a chassis"
LPRINT SPACE$(5); "(2)  It will take "; MTTRmodule; " hours to
replace a module "
LPRINT SPACE$(5); "(3)  It will take "; MTTRsystem; " hours to
repair the system."

m1771vhsc = xxxxxx2
m1771life = xxxxxx4
m1771libd = xxxxxx01
m1771asb = xxxxxx6
m1771p4r = xxxxxx20
m1771a4b = xxxxxx621
m1771psc = xxxxxx720
m1785bcm = xxxxxx4
m1771a1b = xxxxxx22
m1785l20b = xxxxxx3
m1771ow16 = xxxxxx82
m1771own = xxxxxx60
m1771dmc = xxxxxx3
m5110a4 = xxxxxx80
m5120p1 = xxxxxx8
m5130rm1 = xxxxxx0
m5250lp1 = xxxxxx0
m5250lp2 = xxxxxx0

'compute availability of each component

a1771vhsc = avail(m1771vhsc, MTTRmodule)
LPRINT SPACE$(10); "a1771vhsc", a1771vhsc
a1771life = avail(m1771life, MTTRmodule)
LPRINT SPACE$(10); "a1771life", a1771life
a1771libd = avail(m1771libd, MTTRmodule)
LPRINT SPACE$(10); "a1771libd", a1771libd

```

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```
a1771asb = avail(m1771asb, MTTRmodule)
LPRINT SPACE$(10); "a1771asb", a1771asb
a1771p4r = avail(m1771p4r, MTTRmodule)
LPRINT SPACE$(10); "a1771p4r", a1771p4r
a1771a4b = avail(m1771a4b, MTTRchassis)
LPRINT SPACE$(10); "a1771a4b", a1771a4b
a1771psc = avail(m1771psc, MTTRchassis)
LPRINT SPACE$(10); "a1771psc", a1771psc
a1785bcm = avail(m1785bcm, MTTRmodule)
LPRINT SPACE$(10); "a1785bcm", a1785bcm
a1771a1b = avail(m1771a1b, MTTRchassis)
LPRINT SPACE$(10); "a1771a1b", a1771a1b
a1785l20b = avail(m1785l20b, MTTRmodule)
LPRINT SPACE$(10); "a1785l20b", a1785l20b
a1771ow16 = avail(m1771ow16, MTTRmodule)
LPRINT SPACE$(10); "a1771ow16", a1771ow16
a1771own = avail(m1771own, MTTRmodule)
LPRINT SPACE$(10); "a1771own", a1771own
a1771dmc = avail(m1771dmc, MTTRmodule)
LPRINT SPACE$(10); "a1771dmc", a1771dmc

n1 = 0 'make n1=1 for single processor, make n1=0 for dual
processor
n2 = 1 'make n2=1 for old CAM, make n2=0 for new CAM
n3 = 0 'make n3=1 for dual ethernet, make n3=0 for ethernet DH+
FOR n1 = 0 TO 1
FOR n2 = 0 TO 1
FOR n3 = 0 TO 1

    IF n3 THEN
        nee = 1
        ned = 0
    ELSE
        nee = 0
        ned = 1
    END IF

    IF n1 THEN
        nsp = 1
        ndp = 0
    ELSE
        nsp = 0
        ndp = 1
    END IF

    IF n2 THEN
        noc = 1
        nnc = 0
    ELSE
        noc = 0
        nnc = 1
    END IF
```

```

IF nee AND nsp THEN
neensp = 1
ELSE
neensp = 0
END IF

```

```

IF nee AND ndp THEN
neendp = 1
ELSE
neendp = 0
END IF

```

```

IF ned AND nsp THEN
nednsp = 1
ELSE
nednsp = 0
END IF

```

```

IF ned AND ndp THEN
nedndp = 1
ELSE
nedndp = 0
END IF

```

```

IF nsp = 1 THEN LPRINT SPACE$(5); "This calculation uses a single
processor model"
IF ndp = 1 THEN LPRINT SPACE$(5); "This calculation uses a dual
processor model"
IF noc = 1 THEN LPRINT SPACE$(5); "This calculation uses the old
CAM model"
IF nnc = 1 THEN LPRINT SPACE$(5); "This calculation uses the new
CAM model"
IF nee = 1 THEN LPRINT SPACE$(5); "This calculation uses dual
ethernet model"
IF ned = 1 THEN LPRINT SPACE$(5); "This calculation uses ethernet
and Data Highway+ model"

```

```

'calculate redundant power supply availability

```

```

ap1771p4r = availparallel(a1771p4r)
LPRINT SPACE$(10); "ap1771p4r", ap1771p4r

```

```

'calculate single path availability for dual processor
configuration

```

```

availsp = ap1771p4r * a1785bcm * a1785l20b * a1771a1b
LPRINT SPACE$(10); "availsp", availsp

```


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'calculate parallel path availability for dual processor configuration

```
availdp = availparallel(availsp)
LPRINT SPACE$(10); "availdp", availdp
```

'calculate powersupply availability for remote i/o (four supplies)

```
DIM SHARED atotaledplc(20), modules(20, 3), nCAM(20, 4)
```

```
apsrio(4) = a1771psc * availparallel(a1771p4r ^ 2)
LPRINT SPACE$(10); "apsrio(4)", apsrio(4)
```

'calculate powersupply availability for remote i/o (two supplies)

```
apsrio(2) = a1771psc * availparallel(a1771p4r)
LPRINT SPACE$(10); "apsrio(2)", apsrio(2)
```

```
availspee = apsrio(2) * a1771alb * a1785l20b * a1771dmc *
a1785bcm
availdpee = availparallel(availspee)
```

```
availsystem = 1
```

```
CALL fill1
```

```
CALL fill
```

```
FOR i = 1 TO 19 STEP 1
```

```
atotaledplc(i) = availdpee ^ neendp * availspee ^ neensp *
a1771a4b * availdp ^ nedndp * availsp ^ nednsp * a1771asb *
a1771ife ^ modules(i, 1) * a1771libd ^ modules(i, 2) * a1771own ^
modules(i, 3) * apsrio(nCAM(i, noc)) * a1771vhsc ^ (noc * nCAM(i
, 2))
```

```
LPRINT SPACE$(10); "atotaledplc"; i; atotaledplc(i)
```

```
availsystem = availsystem * atotaledplc(i)
```

```
NEXT
```

```
LPRINT SPACE$(10); "availsystem"; availsystem
```

```
mtbfsystem = MTTRsystem * availsystem / (1 - availsystem)
```

```
LPRINT SPACE$(10); "mtbfsystem", mtbfsystem
```

```
LPRINT CHR$(12)
```

```
NEXT
```

```
NEXT
```

```
NEXT
```

```
DEFSNG N
```

```
FUNCTION avail (m1, m2) STATIC
```

```
avail = m1 / (m1 + m2)
```

```
END FUNCTION
```

```

FUNCTION availparallel (m1)
availparallel = 1 - (1 - m1) ^ 2
END FUNCTION

```

```

SUB fill

```

```

'modules(n,i)=value n is PLC #,
'for i=1 value is number of analog modules in rio of PLC #n
'for i=2 value is number of discrete input modules in rio of PLC
#n
'for i=3 value is number of discrete output modules in rio of
PLC#n

```

```

modules(1, 1) = 2
modules(1, 2) = 3
modules(1, 3) = 2

```

```

modules(2, 1) = 2
modules(2, 2) = 3
modules(2, 3) = 1

```

```

modules(3, 1) = 2
modules(3, 2) = 3
modules(3, 3) = 1

```

```

modules(4, 1) = 2
modules(4, 2) = 4
modules(4, 3) = 1

```

```

modules(5, 1) = 3
modules(5, 2) = 4
modules(5, 3) = 2

```

```

modules(6, 1) = 1
modules(6, 2) = 3
modules(6, 3) = 1

```

```

modules(7, 1) = 1
modules(7, 2) = 3
modules(7, 3) = 1

```

```

modules(8, 1) = 1
modules(8, 2) = 9
modules(8, 3) = 2

```

```

modules(9, 1) = 1
modules(9, 2) = 3
modules(9, 3) = 1

```

```

modules(10, 1) = 2
modules(10, 2) = 4
modules(10, 3) = 1

```

```

modules(11, 1) = 2

```

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```
modules(11, 2) = 2
modules(11, 3) = 1
,
modules(12, 1) = 3
modules(12, 2) = 4
modules(12, 3) = 1
,
modules(13, 1) = 2
modules(13, 2) = 4
modules(13, 3) = 1
,
modules(14, 1) = 3
modules(14, 2) = 4
modules(14, 3) = 1
,
modules(15, 1) = 1
modules(15, 2) = 9
modules(15, 3) = 1
,
modules(16, 1) = 1
modules(16, 2) = 2
modules(16, 3) = 1
,
modules(17, 1) = 1
modules(17, 2) = 10
modules(17, 3) = 2
,
modules(18, 1) = 1
modules(18, 2) = 2
modules(18, 3) = 3
,
modules(19, 1) = 2
modules(19, 2) = 3
modules(19, 3) = 2
,
```

END SUB

DEFINT N

SUB fill1

'nCAM(plc,0)=number of rio power supplies for new CAM

'nCAM(plc,1)=number of rio power supplies for old CAM

'nCAM(plc,2)=number of vhsc modules for old CAM

nCAM(1, 0) = 4

nCAM(1, 1) = 4

nCAM(1, 2) = 7

,

nCAM(2, 0) = 2

nCAM(2, 1) = 4

nCAM(2, 2) = 4

,

nCAM(3, 0) = 2

nCAM(3, 1) = 4

nCAM(3, 2) = 6

,

```
nCAM(4, 0) = 2
nCAM(4, 1) = 2
nCAM(4, 2) = 2
,
nCAM(5, 0) = 4
nCAM(5, 1) = 4
nCAM(5, 2) = 0
,
nCAM(6, 0) = 2
nCAM(6, 1) = 4
nCAM(6, 2) = 8
,
nCAM(7, 0) = 2
nCAM(7, 1) = 4
nCAM(7, 2) = 7
,
nCAM(8, 0) = 4
nCAM(8, 1) = 4
nCAM(8, 2) = 0
,
nCAM(9, 0) = 2
nCAM(9, 1) = 4
nCAM(9, 2) = 8
,
nCAM(10, 0) = 2
nCAM(10, 1) = 4
nCAM(10, 2) = 4
,
nCAM(11, 0) = 2
nCAM(11, 1) = 4
nCAM(11, 2) = 6
,
nCAM(12, 0) = 4
nCAM(12, 1) = 4
nCAM(12, 2) = 8
,
nCAM(13, 0) = 2
nCAM(13, 1) = 4
nCAM(13, 2) = 3
,
nCAM(14, 0) = 4
nCAM(14, 1) = 4
nCAM(14, 2) = 5
,
nCAM(15, 0) = 2
nCAM(15, 1) = 4
nCAM(15, 2) = 0
,
nCAM(16, 0) = 2
nCAM(16, 1) = 2
nCAM(16, 2) = 0
,
nCAM(17, 0) = 4
nCAM(17, 1) = 4
```

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nCAM(17, 2) = 0

,

nCAM(18, 0) = 4

nCAM(18, 1) = 4

nCAM(18, 2) = 0

,

nCAM(19, 0) = 4

nCAM(19, 1) = 4

nCAM(19, 2) = 0

,

END SUB

Appendix B
Sample Output

SAMPLE OUTPUT

02-10-1995 12:01:17

ASSUMPTIONS (1) It will take 8 hours to replace a chassis

- (2) It will take 8 hours to replace a module
 (3) It will take 8 hours to repair the system.

a1771vhsc	.xxxxx48158408361
a1771life	.xxxxx0674599474
a1771libd	.xxxxx7847268547
a1771asb	.xxxxx1128794381
a1771p4r	.xxxxx39275618858
a1771a4b	.xxxxx94585312429
a1771psc	.xxxxx94372034414
a1785bcm	.xxxxx9556708379
a1771a1b	.xxxxx86933933066
a1785l20b	.xxxxx92116539468
a1771ow16	.xxxxx58480166494
a1771own	.xxxxx56516256397
a1771dmc	.xxxxx32186960508

This calculation uses a dual processor model

This calculation uses the new CAM model

This calculation uses ethernet and Data Highway+ model

ap1771p4r	.xxxxx99999631255
availsp	.xxxxx7461976665
availdp	.xxxxx9998941277
apsrio(4)	.xxxxx94370559444
apsrio(2)	.xxxxx94371665669
atotaldplc 1	.999956218384679
atotaldplc 2	.9999605666981861
atotaldplc 3	.9999605666981861
atotaldplc 4	.9999584140516224
atotaldplc 5	.9999447407753053
atotaldplc 6	.9999698918179413
atotaldplc 7	.9999698918179413
atotaldplc 8	.9999526275897312
atotaldplc 9	.9999698918179413
atotaldplc 10	.9999584140516224
atotaldplc 11	.9999627193493839
atotaldplc 12	.9999490889282852
atotaldplc 13	.9999584140516224
atotaldplc 14	.9999490889282852
atotaldplc 15	.9999569758876239
atotaldplc 16	.9999720444892136
atotaldplc 17	.9999504749602584
atotaldplc 18	.9999633478919044
atotaldplc 19	.999956218384679
availsystem	.999219884446688
mtbfsystem	10246.89104278906

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This calculation uses a dual processor model

This calculation uses the new CAM model

This calculation uses dual ethernet model

apl771p4r	.xxxxxx99999631255
availsp	.xxxxxx7461976665
availdp	.xxxxxx9998941277
apsrio(4)	.xxxxxx94370559444
apsrio(2)	.xxxxxx94371665669
atotaledplc 1	.9999562169552955
atotaledplc 2	.9999605652687965
atotaledplc 3	.9999605652687965
atotaledplc 4	.9999584126222359
atotaledplc 5	.9999447393459383
atotaledplc 6	.9999698903885383
atotaledplc 7	.9999698903885383
atotaledplc 8	.999952626160353
atotaledplc 9	.9999698903885383
atotaledplc 10	.9999584126222359
atotaledplc 11	.9999627179199911
atotaledplc 12	.9999490874989119
atotaledplc 13	.9999584126222359
atotaledplc 14	.9999490874989119
atotaledplc 15	.9999569744582394
atotaledplc 16	.9999720430598076
atotaledplc 17	.9999504735308831
atotaledplc 18	.9999633464625108
atotaledplc 19	.9999562169552955
availsystem	.9992198573084018
mtbfsystem	10246.53431296156

This calculation uses a dual processor model
This calculation uses the old CAM model
This calculation uses ethernet and Data Highway+ model

ap1771p4r	.xxxxx99999631255
availsp	.xxxxx7461976665
availdp	.xxxxx9998941277
apsrio(4)	.xxxxx94370559444
apsrio(2)	.xxxxx94371665669
atotaledplc 1	.9997799503066913
atotaledplc 2	.9998598377285391
atotaledplc 3	.9998094771041023
atotaledplc 4	.9999080484621246
atotaledplc 5	.9999447407753053
atotaledplc 6	.9997684422573708
atotaledplc 7	.9997936212190586
atotaledplc 8	.9999526275897312
atotaledplc 9	.9997684422573708
atotaledplc 10	.9998576852988179
atotaledplc 11	.999811629430044
atotaledplc 12	.9997476436691685
atotaledplc 13	.9998828665080732
atotaledplc 14	.9998231808851646
atotaledplc 15	.999956975777006
atotaledplc 16	.9999720444892136
atotaledplc 17	.9999504749602584
atotaledplc 18	.9999633478919044
atotaledplc 19	.999956218384679
availsystem	.9975101394724409
mtbfsystem	3205.031377240559

Reliability Analysis for the TA-55 FDAIS Upgrade

This calculation uses a dual processor model

This calculation uses the old CAM model

This calculation uses dual ethernet model

ap1771p4r	.xxxxxx99999631255
availsp	.xxxxxx7461976665
availdp	.xxxxxx9998941277
apsrio(4)	.xxxxxx94370559444
apsrio(2)	.xxxxxx94371665669
atotaledplc 1	.9997799488775598
atotaledplc 2	.9998598362992934
atotaledplc 3	.9998094756749286
atotaledplc 4	.99990804703281
atotaledplc 5	.9999447393459383
atotaledplc 6	.9997684408282558
atotaledplc 7	.9997936197899076
atotaledplc 8	.999952626160353
atotaledplc 9	.9997684408282558
atotaledplc 10	.9998576838695753
atotaledplc 11	.9998116280008673
atotaledplc 12	.9997476422400832
atotaledplc 13	.9998828650787946
atotaledplc 14	.9998231794559713
atotaledplc 15	.9999569743476215
atotaledplc 16	.9999720430598076
atotaledplc 17	.9999504735308831
atotaledplc 18	.9999633464625108
atotaledplc 19	.9999562169552955
availsystem	.9975101123805901
mtbfsystem	3204.996417041454

This calculation uses a single processor model
This calculation uses the new CAM model
This calculation uses ethernet and Data Highway+ model

ap1771p4r	.xxxxx99999631255
availsp	.xxxxx7461976665
availdp	.xxxxx9998941277
apsrio(4)	.xxxxx94370559444
apsrio(2)	.xxxxx94371665669
atotaledplc 1	.9999236828445534
atotaledplc 2	.9999280310165796
atotaledplc 3	.9999280310165796
atotaledplc 4	.9999258784400565
atotaledplc 5	.9999122056086263
atotaledplc 6	.9999373558329236
atotaledplc 7	.9999373558329236
atotaledplc 8	.9999200921664392
atotaledplc 9	.9999373558329236
atotaledplc 10	.9999258784400565
atotaledplc 11	.9999301835977367
atotaledplc 12	.9999165536201304
atotaledplc 13	.9999258784400565
atotaledplc 14	.9999165536201304
atotaledplc 15	.9999244403228514
atotaledplc 16	.9999395084341546
atotaledplc 17	.9999179396070063
atotaledplc 18	.9999308121198063
atotaledplc 19	.9999236828445534
availsystem	.9986023452429307
mtbfsystem	5715.874196782925

Reliability Analysis for the TA-55 FDAIS Upgrade

This calculation uses a single processor model

This calculation uses the new CAM model

This calculation uses dual ethernet model

apl771p4r	.xxxxxx99999631255
availsp	.xxxxxx7461976665
availdp	.xxxxxx9998941277
apsrio(4)	.xxxxxx94370559444
apsrio(2)	.xxxxxx94371665669
atotaledplc 1	.9999063400771416
atotaledplc 2	.9999106881737528
atotaledplc 3	.9999106881737528
atotaledplc 4	.9999085356345643
atotaledplc 5	.9998948630402769
atotaledplc 6	.9999200128283665
atotaledplc 7	.9999200128283665
atotaledplc 8	.9999027494613046
atotaledplc 9	.9999200128283665
atotaledplc 10	.9999085356345643
atotaledplc 11	.9999128407175754
atotaledplc 12	.9998992109763687
atotaledplc 13	.9999085356345643
atotaledplc 14	.9998992109763687
atotaledplc 15	.999907097542302
atotaledplc 16	.9999221653922624
atotaledplc 17	.9999005969392059
atotaledplc 18	.9999134692287439
atotaledplc 19	.9999063400771416
availsystem	.9982733194555519
mtbfsystem	4625.167394931695

This calculation uses a single processor model

This calculation uses the old CAM model

This calculation uses ethernet and Data Highway+ model

ap1771p4r	.xxxxx99999631255
availsp	.xxxxx7461976665
availdp	.xxxxx9998941277
apsrio(4)	.xxxxx94370559444
apsrio(2)	.xxxxx94371665669
atotaledplc 1	.9997474205017939
atotaledplc 2	.9998273053243475
atotaledplc 3	.9997769463384926
atotaledplc 4	.999875514489302
atotaledplc 5	.9999122056086263
atotaledplc 6	.9997359128269104
atotaledplc 7	.9997610909693512
atotaledplc 8	.9999200921664392
atotaledplc 9	.9997359128269104
atotaledplc 10	.9998251529646598
atotaledplc 11	.9997790985944042
atotaledplc 12	.999715114915431
atotaledplc 13	.9998503333545951
atotaledplc 14	.9997906496736755
atotaledplc 15	.9999244402122371
atotaledplc 16	.9999395084341546
atotaledplc 17	.9999179396070063
atotaledplc 18	.9999308121198063
atotaledplc 19	.9999236828445534
availsystem	.9968936569275494
mtbfsystem	2567.375550418117

Reliability Analysis for the TA-55 FDAIS Upgrade

This calculation uses a single processor model

This calculation uses the old CAM model

This calculation uses dual ethernet model

ap1771p4r	.xxxxxx99999631255
availsp	.xxxxxx7461976665
availdp	.xxxxxx9998941277
apsrio(4)	.xxxxxx94370559444
apsrio(2)	.xxxxxx94371665669
atotaledplc 1	.9997300807914924
atotaledplc 2	.9998099642285163
atotaledplc 3	.9997596061160923
atotaledplc 4	.9998581725573267
atotaledplc 5	.9998948630402769
atotaledplc 6	.9997185733161991
atotaledplc 7	.9997437510219478
atotaledplc 8	.9999027494613046
atotaledplc 9	.9997185733161991
atotaledplc 10	.9998078119061593
atotaledplc 11	.9997617583346748
atotaledplc 12	.9996977757654405
atotaledplc 13	.9998329918593636
atotaledplc 14	.9997733092136032
atotaledplc 15	.9999070974316897
atotaledplc 16	.9999221653922624
atotaledplc 17	.9999005969392059
atotaledplc 18	.9999134692287439
atotaledplc 19	.9999063400771416
availsystem	.9965651941295534
mtbfsystem	2321.098150446483