ENCLOSURE 11

SOFTWARE RELIABILITY ASSESSMENT OF RADIATION MONITORING SYSTEM

FEBRUARY 24, 1997

NUCLEAR SAFETY GROUP

PROBABILISTIC RISK ASSESSMENT

SOFTWARE RELIABILITY ASSESSMENT OF RADIATION MONITORING SYSTEM

FEBRUARY 24, 1997

REPORT NSG-9.-001

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1. OBJECTIVE

Perform reliability assessment to compare failure probabilities between the digital/software based radiation monitoring system and the analog based radiation monitoring system.

2. WORK SCOPE

The purpose of this study is to perform a reliability assessment to establish a quantitative baseline for the SONGS radiation monitoring systems. Specific plant components included in this analysis are radiation monitoring systems of the Containment purge isolation signal (CPIS), Control Room isolation signal (CRIS), and the Fuel Handling Building isolation signal (FHIS). Figure 1 provides a simplified diagram of the digital/software based radiation monitoring system for the FHIS. The definition of Acronyms and Abbreviations referred by this study is given in Attachment One.

The major effort of this study is to quantify the software reliability of the radiation monitoring system supplied by the MGPI.

3. ASSUMPTIONS:

a. The assessment of software reliability remains in a state-of-the-art status and significant research and development efforts are currently being devoted to this subject (Ref 1 and 2). Due to the lack of proven methodology and comprehensive data base, there are large uncertainties in the results of software failure rates.

b. "Software defects" in this analysis is defined as: software anomalies identified during the Operating phase of the radiation monitoring system and with criticality in the "Jamming" or "Non-jamming" level. The inclusion of "Non-jamming" is conservative. Software verification and validation records are based on vendor inputs given in Ref 3 (Note 1).

c. No credit is given for train redundancy in the software reliability assessment. All software failures are conservatively modeled equivalent to a hardware system common cause failure such that a defect in one train has the same effects on the opposite train.

Note 1: An (Draft) updated MGPI verification and validation report (Ref 6) with additional software operating history was made available after completion of this study. The latest vendor inputs confirmed that the data provided by Ref 3 is conservative. Software failure rate is expected to be further reduced if more nuclear power plant operational data can be incorporated by future analysis.

d. Software error density reaches an asymptotic constant state after the software is released to the end-users.

e. It is assumed MTBF~ MTTF in this software reliability assessment. This is based on (i) the MTBFs of all software modules analyzed by this study are greater than 100,000 hours, (ii) relationship between reliability parameters is: MTBF = MTTF + MTTR, and (iii) if a software problem disables the radmonitor system, it is expected that MTTR << MTTF. (Per vendor inputs, none of the software defects documented in Table B led to system shutdown.)

f. FHIS, CRIS and CPIS radiation monitoring systems examined by this analysis have a one-out-of-two logic and either train (Train A or B) can generate the required isolation signal.

SONGS Tech Spec allows the radiation monitoring systems to operate with a one-out-of-one logic during power generation. This study compares reliability of digital and analog radiation monitoring systems in both logic configurations.

g. In the CPIS digital radiation monitoring system design, the isolation function is generated by the LPU/SAS only. Based on vendor suggestions, failure contributions from LPU/PIPS of the CPIS are also included in the fault trees to ensure conservatism.

h. Failure of LDU hardware will not affect the generation of an isolation signal for CPIS, CRIS and FHIS.

i. Output of the RDU produces the control relay contact opening to initiate the system isolation function.

j. Reliability data of the analog radiation monitoring system is based on the corrective maintenance records given in Attachment 3 of Ref 4. This reliability data represents all components (pumps, switches, etc.) in each loop of the analog radiation detection system.

The assessment of hardware common cause failure for each radmonitoring system is based on the averaged failure rates of trains A and B. Failure rate for each train of the analog system is derived from Ref 4 and listed in Table 2.

k. Reliability data of the digital radiation monitoring system is based on vendor inputs provided in Ref 5. This MGPI supplied reliability data includes both hardware and software induced failures. It is assumed that the hardware failures provided by vendor only represent unavailability of the corrective maintenance. Plant operation related unavailabilities (e.g. system surveillance, preventive maintenance, and support maintenance) are not accounted for by the vendor data.

l. A mission time of one-hour is used for calculating the failure probabilities of the analog and digital radiation monitoring systems. Hence, the approximate expression of $F(t) = \lambda t = \lambda$ is used for the basic event probabilities in the system fault trees.

4. APPROACH

4.1 Collection of software operating record

First fully tested MGPI radiation monitoring system software was delivered to the end-users in April 1995. By June 1996, this software package has been operating at eight nuclear power stations worldwide. A breakdown of operating history of LPU/Base, DU/Base and Applications, and LPU/(radiation detector) is given in Table A.

4.2 Examination of software defects

Based on the software defect definition given in Sec 3.b, a review of software anomalies and resolutions provided by MGPI's verification and validation report (Ref 3) was performed. This evaluation concluded that there are five software defect records to be accounted for in this software reliability assessment. A summary of these software defects are provided below and a detailed list of these defects is given in Table B.

- One defect in LPU/PIPS
- Two defects in LPU/SAS
- Two defects in DU/Base & Application
- One defect in LPU/Base & Application

4.3 Assessment of software MTBF and failure rate

Using the software operating history generated in Sec 4.1 and the corresponding software defects identified in Sec 4.2, the software module MTBF and failure rate can be established. A step-by-step calculation of the software failure results is presented in Table C. Result for MTBF and failure rate of the software modules is summarized in Table 1.

Per results of Table C and the CPIS, CRIS and FHIS fault trees (Attachment Two), the software MTBF and failure rate of the three SONGS radmonitoring systems can be quantified and the results are listed below:

CPIS software failure rate: $\lambda = 1.8E\text{-}5/hr$, MTTF=55,000 hr
FHIS software failure rate: $\lambda = 1.2E\text{-}5/hr$, MTTF=81,000 hr
CRIS software failure rate: $\lambda = 0.92E\text{-}5/hr$, MTTF=110,000 hr

4.4 Assessment of digital and analog radiation monitoring module/loop MTBF and failure rate

This step assembles results of Sec 4.3, and the digital radiation monitoring system reliability data of Ref 5 to generate software and hardware MTBF and failure rate for each digital radiation monitoring system modules. A summary of the calculation results for the software and hardware system is provided in Table 1. Details of quantification process fo[illegible]rdware failure rate, including the derivation of hardware common cause failure rates for bo[illegible]he digital and analog radmonitor systems, is given in Table D.

The analog radiation monitoring system reliability data was generated by an internal calculation and can be located in Attachment 3 of Ref 4. Results of the analog system MTBF and failure rate (λ) based on records of corrective maintenance are provided in Table 2. Reliability parameters in Tables 1 and 2 form the basis for fault tree quantification.

TABLE 1: Software and hardware reliability parameters of the digital radiation monitoring system

Radmonitor Components	Software		Hardware	
	MTBF(Hour)	λ (/Hour)	MTBF(Hour)	λ (/Hour)
LPU/SAS	176,000	5.7E-6	25,000	4.1E-5
LPU/PIPS	113,000	8.9E-6	29,000	3.5E-5
LDU	451,000	2.2E-6	24,000	4.2E-5
RDU	451,000	2.2E-6	28,000	3.6E-5

TABLE 2: Reliability parameters of the analog radiation monitoring system based on corrective maintenance data (Ref 4)

	MTBF	λ
Containment Trn A airborne (Loop 7804):	290 hr	3.5E-3/hr
Containment Trn B airborne (Loop 7807):	380 hr	2.6E-3/hr
Fuel Handling Trn A airborne (Loop 7822):	510 hr	2.0E-3/hr
Fuel Handling Trn B airborne (Loop 7823):	510 hr	2.0E-3/hr
Control Room Trn A airborne (Loop 7824):	1,200 hr	8.1E-4/hr
Control Room Trn B airborne (Loop 7825):	370 hr	2.7E-3/hr

5. COMPARISON OF SYSTEM RELIABILITY AND CONCLUSIONS

Comparison of reliability between the digital and analog based radiation monitoring systems can be performed by developing fault trees to combine the reliability parameters given in Tables 1 and 2, and quantification assumptions listed in Sec 3. Six separate fault trees were developed and analyzed to assess the reliability of CPIS, CRIS and FHIS for both the digital and analog radiation monitoring systems.(Attachment Two)

Inputs of the fault tree calculation are based on module/loop reliability parameters expressed in terms of failure rates (λ) with a one-hour mission time (Sec 3.l). Result of the fault tree analysis is represented by the integrated system failure probability and is summarized in Table 3.

Review of the fault tree results given in Table 3 shows that an improvement in the system reliability can be expected if the digital radiation monitoring system is chosen to replace the analog radiation monitoring system. By implementation of this radiation detection system renovation, the failure probability of the CPIS could be reduced from about 2.2E-4 to 2.6E-5 (a nine times reduction), the FHIS failure probability could be reduced from about 1.4E-4 to 1.7E-5 (rduced by a factor of eight), and that of the CRIS failure probability could be decreased from 1.2E-4 to 1.5E-5 (an eight times reduction). If mission time chosen for fault tree quantification is not one hour (Sec 3.l) then the failure probabilities given in Table 3 will be different. But the ratio of system failure probabilities between the analog and digital radiation monitoring systems will be maintained and the conclusions described above remain unchanged.

It should be noted that the results in Table 3 is based on the one-out-of-two design logic of the radiation monitoring systems and a one-hour system mission time. As the SONGS Tech Spec allows the radiation monitoring systems to operate in a one-out-of-one logic during power generation, another set of calculations has been performed to compare system reliability under the separate configuration. This study shows that, consistent with findings of the one-out-of-two logic, under the one-out-of-one logic the digital radiation monitoring systems exhibit significantly higher reliability than that of the analog radiation monitoring system. Results and fault trees of this assessment are provided in Attachment three.

However, it should also be pointed out that although this conclusion is based on a set of conservative assumptions (e.g. Sec 3. b and c), there are large uncertainties in the software reliability assessment. The quantification of software reliability remains in a state-of-the-art status and there is lack of proven methodology and a need for a comprehensive data base to reduce uncertainties associated with the software failure rates.

TABLE 3: Comparison of system reliability between analog and digital systems (Based on one-out-of-two design logic)

Radiation Monitoring System	Failure Probabilities (Mission time one hour)
Analog CPIS	2.2E-4
Digital CPIS	2.6E-5
Analog FHIS	1.4E-4
Digital FHIS	1.7E-5
Analog CRIS	1.2E-4
Digital CRIS	1.5E-5

References:

1. NUREG/CR-6465 "Development of tools for safety analysis of control software in advanced reactors" April 1996.

2. SCE calculation J-SPA-279 "FHIS radiation monitor software mode failure evaluation" Dec 1996

3. SCE VPL No. SO123-606-1-367-0 "Software Verification and Validation Final Report" June 1996 Rev A

4. SCE VPL No. SO123-606-1-5 "Radiation Monitoring and Sampling System Engineering Evaluation" Aug 1993

5. MGPI letter from J P Guillemot to D Beauchene of SCE dated Feb 20, 1996

6. "Software Verification and Validation Final Report"(Draft) of MGPI, January 1997 Rev B

TABLE A: Software operation history (Ref 3)

	SOFTWARE MODULES					
	LPU/Base	LPU/PIPS	LPU/SAS	LPU/Si	LPU/IO	DU Base and Appli
CUMULATED EXPERIENCE (# of days/ # hours)	32,678/ 784,272	4695/ 112,680	14,677/ 352,248	12,160/ 291,840	515/ 12,360	37,609/ 902,616

TABLE B: Software defects pertinent to this analysis (Ref 3)

Affected Module	Defect description	Vendor log No.
DU/Base & LPU/Base	Common problem if 2 links are used	349
DU/Application	A DU that reports only channel B initializes itself on channel A	398
LPU/SAS	Spectrum storing overlapping in the database	400
LPU/SAS	Single mode digital input invertion for portable SAS	401
LPU/PIPS	Problem on Beta algorithm if uCi/cc and no filter advance reset	418

TABLE C: Assessment of software failure rate

1. LPU/PIPS
MTTF=112,680 hrs/1 = 112,680 hr
λ = 8.88E-6/hr

2. LPU/SAS
MTTF = 352,248 hrs/2 = 176,124 hrs
λ = 5.68E-6/hr

3. DU/Base & Application
MTTF= 902,616 hrs/2 = 451,308 hrs
λ = 2.22E-6/hr

4. LPU/Base & Application
MTTF=784,272 hrs/1 = 784,272 hrs
λ = 1.28E-6/hr

5. Other software modules do not have failure data

- LPU/Si: Based on the cumulative operational history of this module is similar to that of LPU/SAS (Table A) and has no record of defect, it is conservative to use failure rate of LPU/SAS to represent this module:
λ = 5.68E-6/hr

- LPU/IO: Based on the cumulative operational history of this module is similar to that of LPU/PIPS (Table A) and has no record of defect, it is conservative to use failure rate of LPU/PIPS to represent this module:
λ = 8.88E-6/hr

Per attached CPIS, FHIS and CRIS fault trees, results of the software failure rates are:

CPIS software failure rate: λ = 1.81E-5/hr, MTTF=55,000 hr
FHIS software failure rate: λ = 1.24E-5/hr, MTTF=80,600 hr
CRIS software failure rate: λ = 0.92E-5/hr, MTTF=109,000 hr

TABLE D: Digital Radmonitor Module (Ref 5)

	MTTF	λ
Hardware & Software:	LPU/SAS: 21,657 HR	4.62E-5/hr
	LPU/PIPS: 22,791 HR	4.39E-5/hr
	LDU: 22,408 HR	4.46E-5/hr
	RDU: 26,036 HR	3.84E-5/hr

	MTTF	λ
Hardware:	LPU/SAS: 24,691 HR	4.05E-5/hr(4.62E-5/hr - 5.68E-6/hr)
	LPU/PIPS: 28,571 HR	3.5E-5/hr(4.39E-5/hr - 8.88E-6/hr)
	LDU: 23,585 HR	4.24E-5/hr (4.46E-5/hr - 2.22E-6/hr)
	RDU: 27,624 HR	3.62E-5/hr (3.84E-5/hr - 2.22E-6/hr)

Hardware common cause failure data *

Radmonitor	Common cause failure rate
CPIS - digital	(RDU + LPU/SAS + LPU/PIPS) x BETA = (3.62e-5 + 4.05e-5 + 3.5e-5) x 0.07 = 7.82e-6/hr
FHIS - digital	(RDU + LPU/PIPS) x BETA = (3.62e-5 + 3.5e-5) x 0.07 = 5e-6/hr
CRIS - digital	(RDU + LPU/SAS) x BETA = (3.62e-5 + 4.05e-5) x 0.07 = 5.4e-6/hr
CPIS - analog	Averaged failure rate x BETA = (3.5e-3 + 2.6e-3)/2 x 0.07 = 2.1e-4/hr
FHIS - analog	Averaged failure rate x BETA = (2e-3 + 2e-3)/2 x 0.07 = 1.4e-4/hr
CRIS - analog	Averaged failure rate x BETA = (8.1e-4 + 2.7e-3)/2 x 0.07 = 1.2e-4/hr

* BETA for electronic equipment is chosen at 0.07 (Per Fermi PRA)

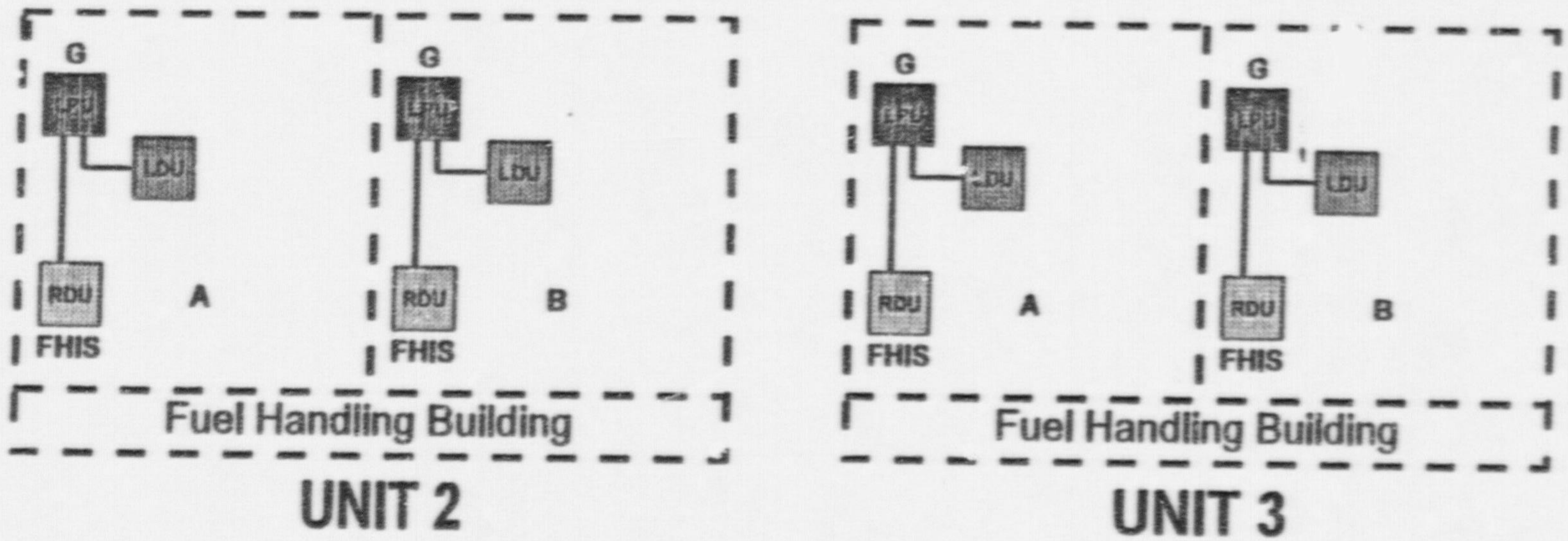


Figure .1 Redundant software channel configurations for RMS Safety Functions

ATTACHMENT ONE

DEFINITION OF ACRONYMS AND ABBREVIATIONS

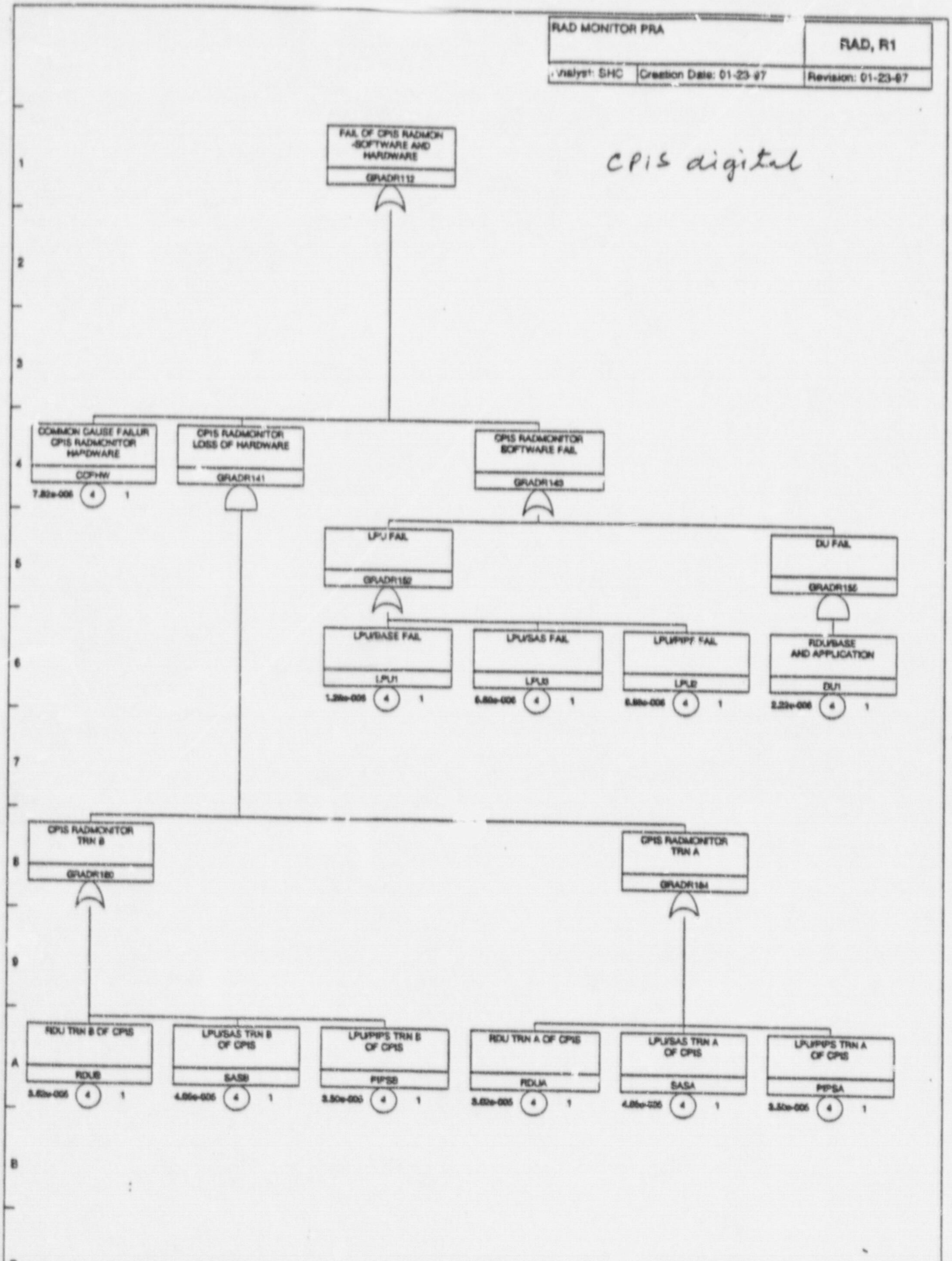
MTTF	mean time to failure
MTBF	mean time between failures
MTTR	mean time to repair
FHIS	Fuel Handling Building isolation signal
CPIS	Containment purge isolation signal
LDU	local display unit
RDU	remote display unit
DU	display unit
LPU	local processing unit
PIPS	passivated implanted planar silcon
SAS	spectrum analyzer system
IO	input output
Si	silcon

ATTACHMENT TWO

FAULT TREES OF CPIS, CRIS AND FHIS

RADIATION MONITORING SYSTEM - DIGITAL & ANALOG

(One-out-of-two logic)


RAD MONITOR PRA
RAD, R1
nalyst: SHC
Creation Date: 01-23-97
Revision: 01-23-97
CPIS digital
FAIL OF CPIS RADMON -SOFTWARE AND HARDWARE
GRADR112
COMMON CAUSE FAILUR CPIS RADMONITOR HARDWARE
CCFHW
7.82e-006
CPIS RADMONITOR LOSS OF HARDWARE
GRADR141
CPIS RADMONITOR SOFTWARE FAIL
GRADR143
LPU FAIL
DU FAIL
LPU/BASE FAIL
LPU1
LPU/SAS FAIL
LPU/PIPS FAIL
RDU/BASE AND APPLICATION
DU1
CPIS RADMONITOR TRN B
GRADR180
CPIS RADMONITOR TRN A
GRADR184
RDU TRN B OF CPIS
RDUB
LPU/SAS TRN B OF CPIS
SASB
LPU/PIPS TRN B OF CPIS
PIPSB
RDU TRN A OF CPIS
RDUA
LPU/SAS TRN A OF CPIS
SASA
LPU/PIPS TRN A OF CPIS
PIPSA
CPRAD WIN-NUPRA 1.0

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Number of Boolean Indicated Cut Sets = 1.500000E+00
Number of MCS in equation file       =            14
MINIMAL CUT SETS SORTED BY UNAVAILABILITY
-----------------------------------------------------------------------
 1.   8.880E-006 LPU2
 2.   7.820E-006 CCFHW
 3.   5.680E-006 LPU3
 4.   2.220E-006 DU1
 5.   1.280E-006 LPU1
 6.   1.640E-009 SASA                SASB
 7.   1.466E-009 RDUA                SASB
 8.   1.466E-009 RDUB                SASA
 9.   1.418E-009 PIPSA               SASB
10.   1.418E-009 PIPSB               SASA
11.   1.310E-009 RDUA                RDUB
12.   1.267E-009 PIPSB               RDUA
13.   1.267E-009 PIPSA               RDUB
14.   1.225E-009 PIPSA               PIPSB
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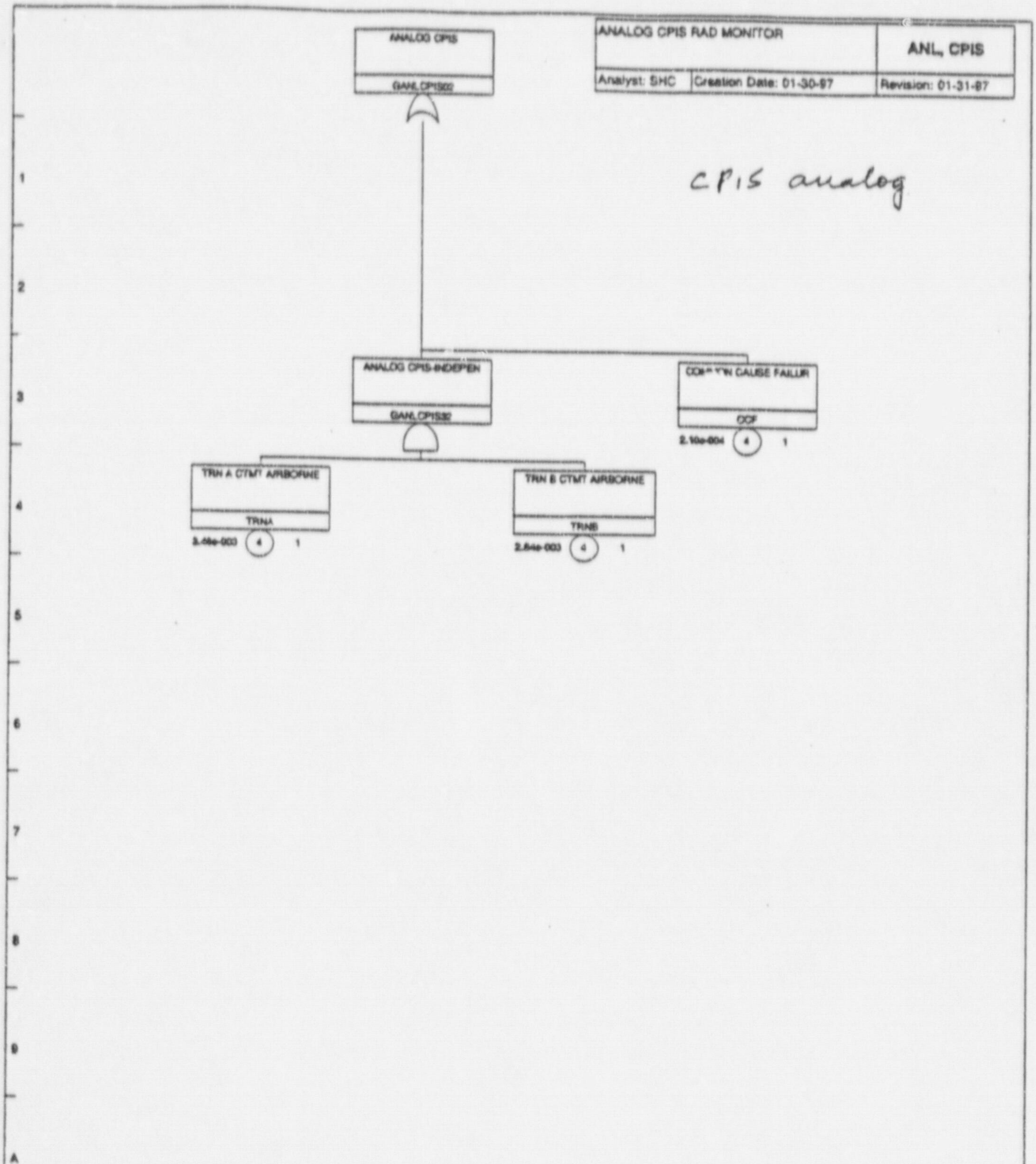
ANALOG CPIS RAD MONITOR
ANL, CPIS
Analyst: SHC
Creation Date: 01-30-97
Revision: 01-31-97
CPIS analog
ANALOG CPIS
GANLCPIS02
ANALOG CPIS-INDEPEN
GANLCPIS32
TRN A CTMT AIRBORNE
TRNA
TRN B CTMT AIRBORNE
TRNB
CAUSE FAILUR
CCF
2.10e-004
2.84e-003
4
1
CPAAL WIN-NUPRA 1.0

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WinNUPRA 1.0  FILE : CPANL.FTP   NURELMCS Solution              ENUS Env

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--------------------------------------------------------------------------
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Number of Boolean Indicated Cut Sets = 2.000000E+00
Number of MCS in equation file       =             2
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 1.  2.100E-004 CCF
 2.  9.134E-006 TRNA              TRNB
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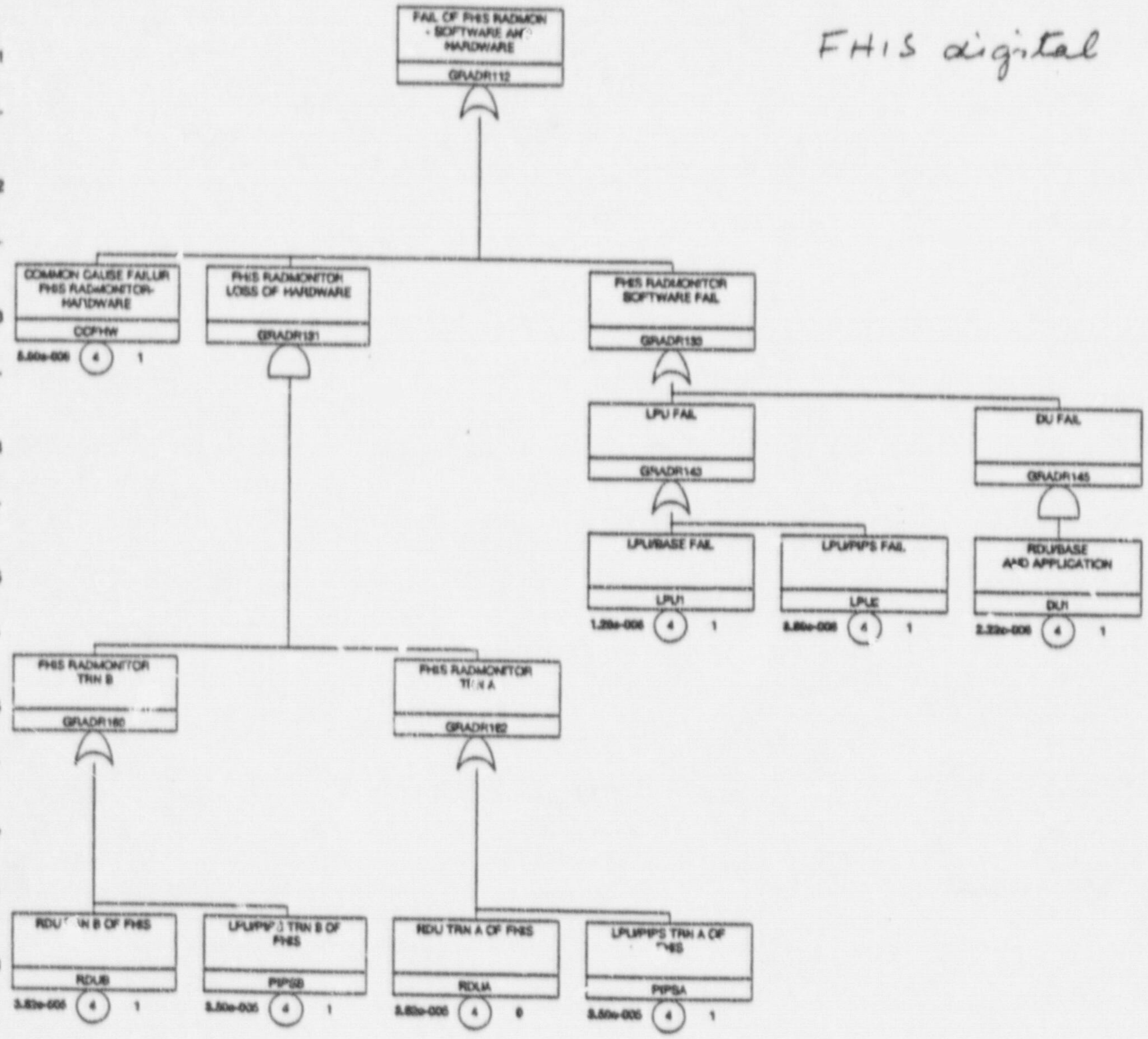
Analyst: SHC	Creation Date: 01-23-97	Revision: 01-23-97

FHIS digital



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---------------------------------------------------------------------
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Number of Boolean Indicated Cut Sets = 8.000000E+00
Number of MCS in equation file       =           8
MINIMAL CUT SETS SORTED BY UNAVAILABILITY
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 2.  5.000E-006 CCFHW
 3.  2.220E-006 DU1
 4.  1.280E-006 LPU1
 5.  1.310E-009 RDUA              RDUB
 6.  1.267E-009 PIPSA             RDUB
 7.  1.267E-009 PIPSB             RDUA
 8.  1.225E-009 PIPSA             PIPSB
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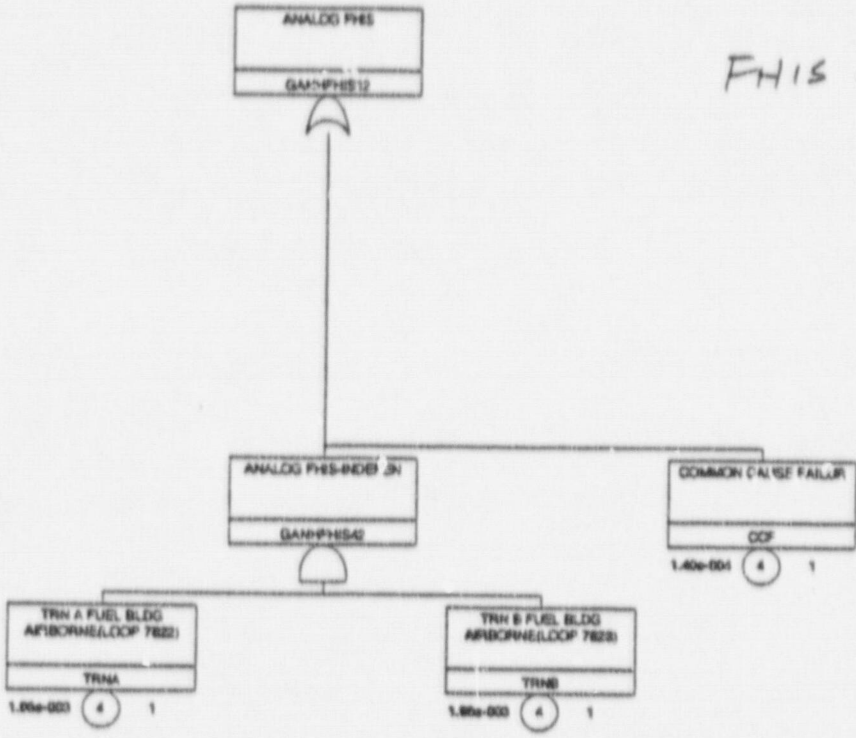
ANALOG FHIC		ANH, FHIS
Analyst: SHC	Creation Date: 02-03-97	Revision: 02-03-97

FHIS analog



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ANALOG FHIC
Top event: GANHFHIS12
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Cutoff value used                    =     1.00E-010
Number of Boolean Indicated Cut Sets = 2.000000E+00
Number of MCS in equation file       =             2
MINIMAL CUT SETS SORTED BY UNAVAILABILITY
 1.   1.400E-004 CCF
 2.   3.881E-006 TRNA              TRNB
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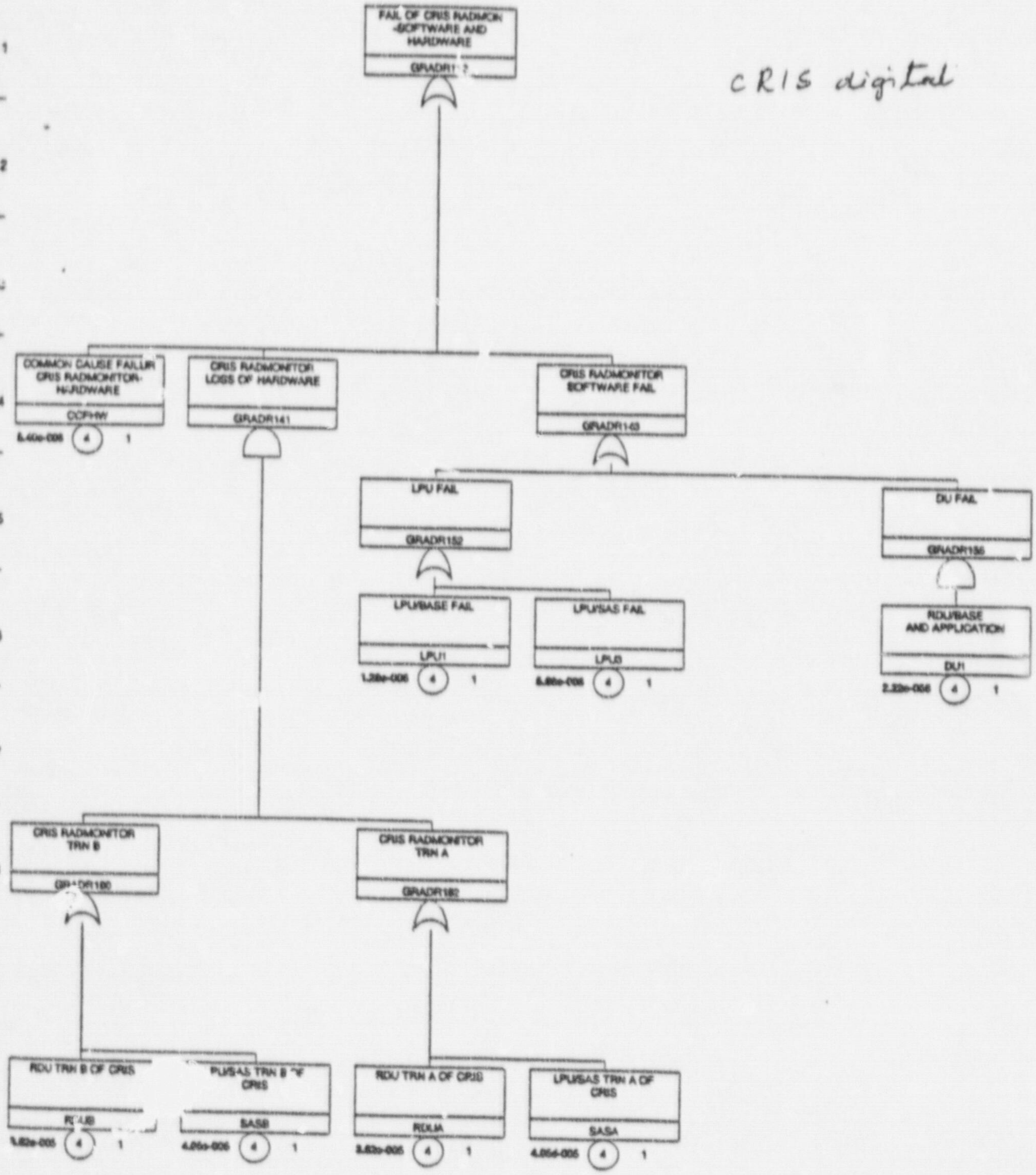
RAD MONITOR PRA		RAD, h1
Analyst: SHC	Creation Date: 01-23-97	Revision: 01-23-97

CRIS digital



CRRAD Win-NUPRA 1.0

WinNUPRA 1.0 FILE : CRRAD.FTP NURELMCS Solution ENUS Env

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RAD MONITOR PRA

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Cutoff value used = 1.00E-010
Number of Boolean Indicated Cut Sets = 8.000000E+00
Number of MCS in equation file = 8
MINIMAL CUT SETS SORTED BY UNAVAILABILITY

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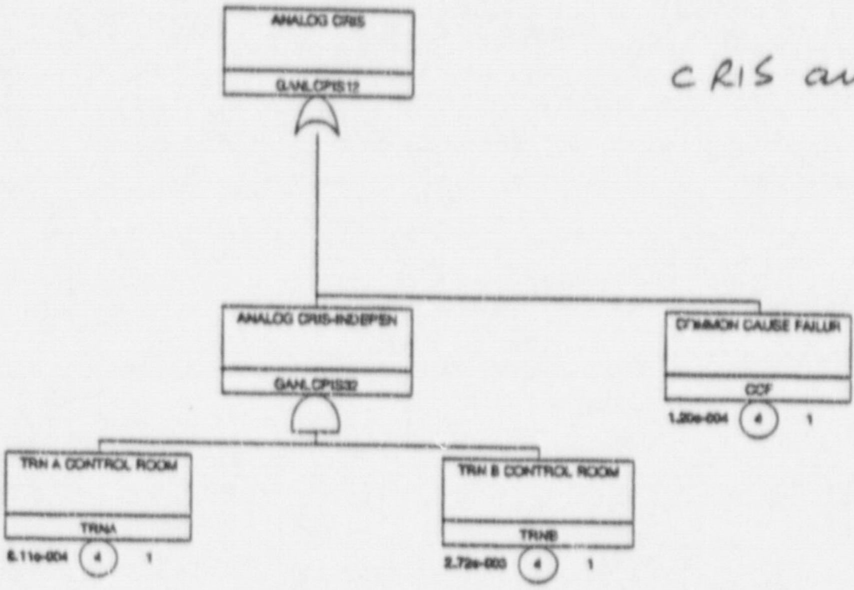
2.	5.400E-006	CCFHW	
3.	2.220E-006	DU1	
4.	1.280E-006	LPU1	
5.	1.640E-009	SASA	SASB
6.	1.466E-009	RDUB	SASA
7.	1.466E-009	RDUA	SASB
8.	1.310E-009	RDUA	RDUB

ANALOG CPIS RAD MONITOR		ANL. CPIS
Analyst: SHC	Creation Date: 01-30-97	Revision: 01-31-97



CRIS analog

©ANL WIN-NUPRA 1.0

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ANALOG CPIS RAD MONITOR

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Number of Boolean Indicated Cut Sets = 2.000000E+00
Number of MCS in equation file   =   2
MINIMAL CUT SETS SORTED BY UNAVAILABILITY

1. 1.200E-004 CCF
2. 2.206E-006 TRNA   TRNB

ATTACHMENT THREE

FAULT TREES OF CPIS, CRIS AND FHIS DIGITAL RADIATION MONITORING SYSTEM

(One-out-of-one logic)

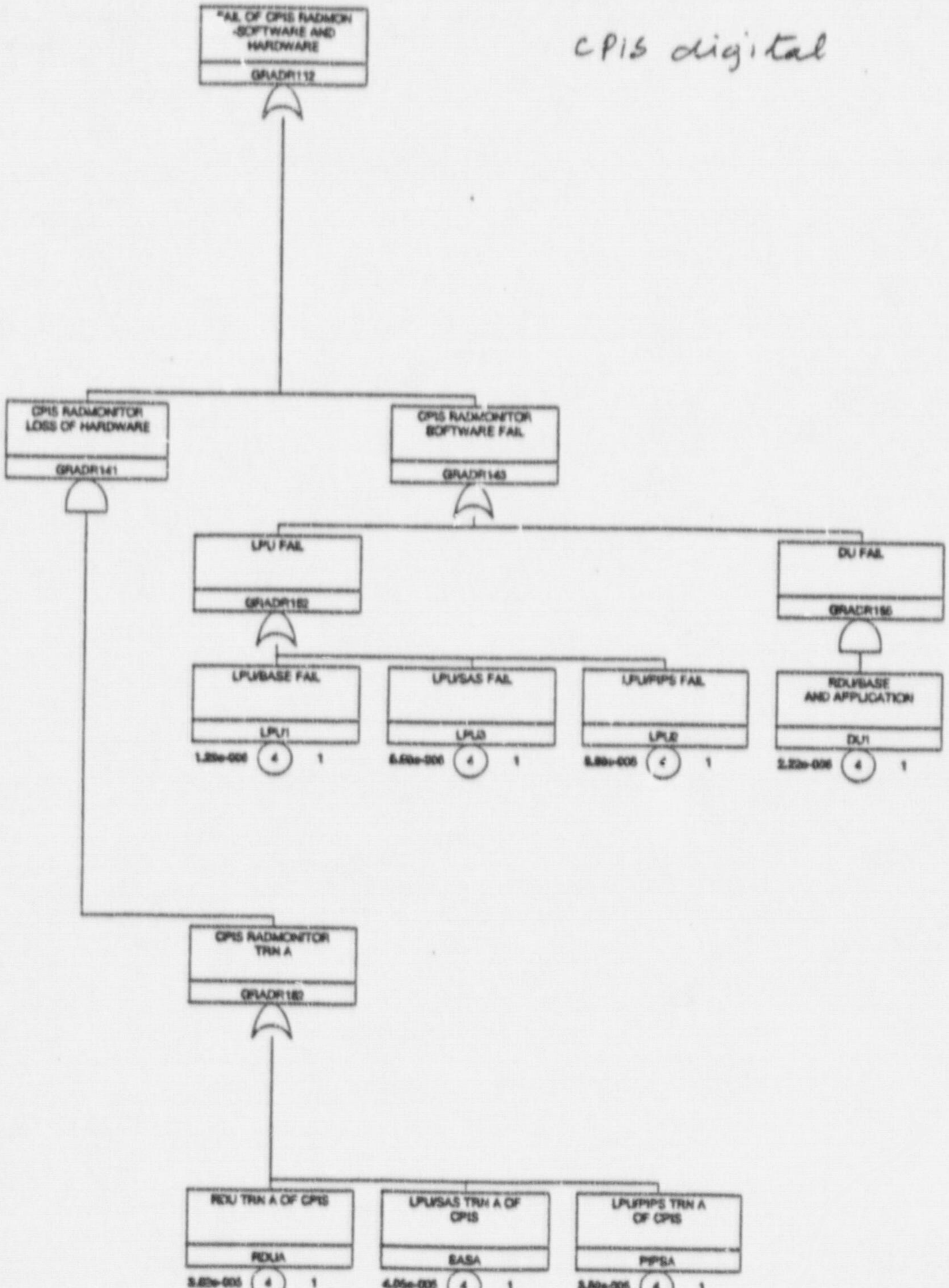
Comparison of system reliability between analog and digital systems
(Based on one-out-of-one logic)

Radiation Monitoring System (note)	Failure Probabilities (mission time of one hour)
Analog CPIS	2.64E-3
Digital CPIS	1.3E-4
Analog FHIS	1.96E-3
Digital FHIS	8.36E-5
Analog CRIS	8.11E-4
Digital CRIS	8.59E-5

Note: Conservatively, the analog trains with lower failure probabilities were selected for comparison.

RAD MONITOR PRA		RAD, R1
Analyst: SHC	Creation Date: 01-23-97	Revision: 01-23-97

CPIS digital



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RAD MONITOR PRA
________________________________________________________________________
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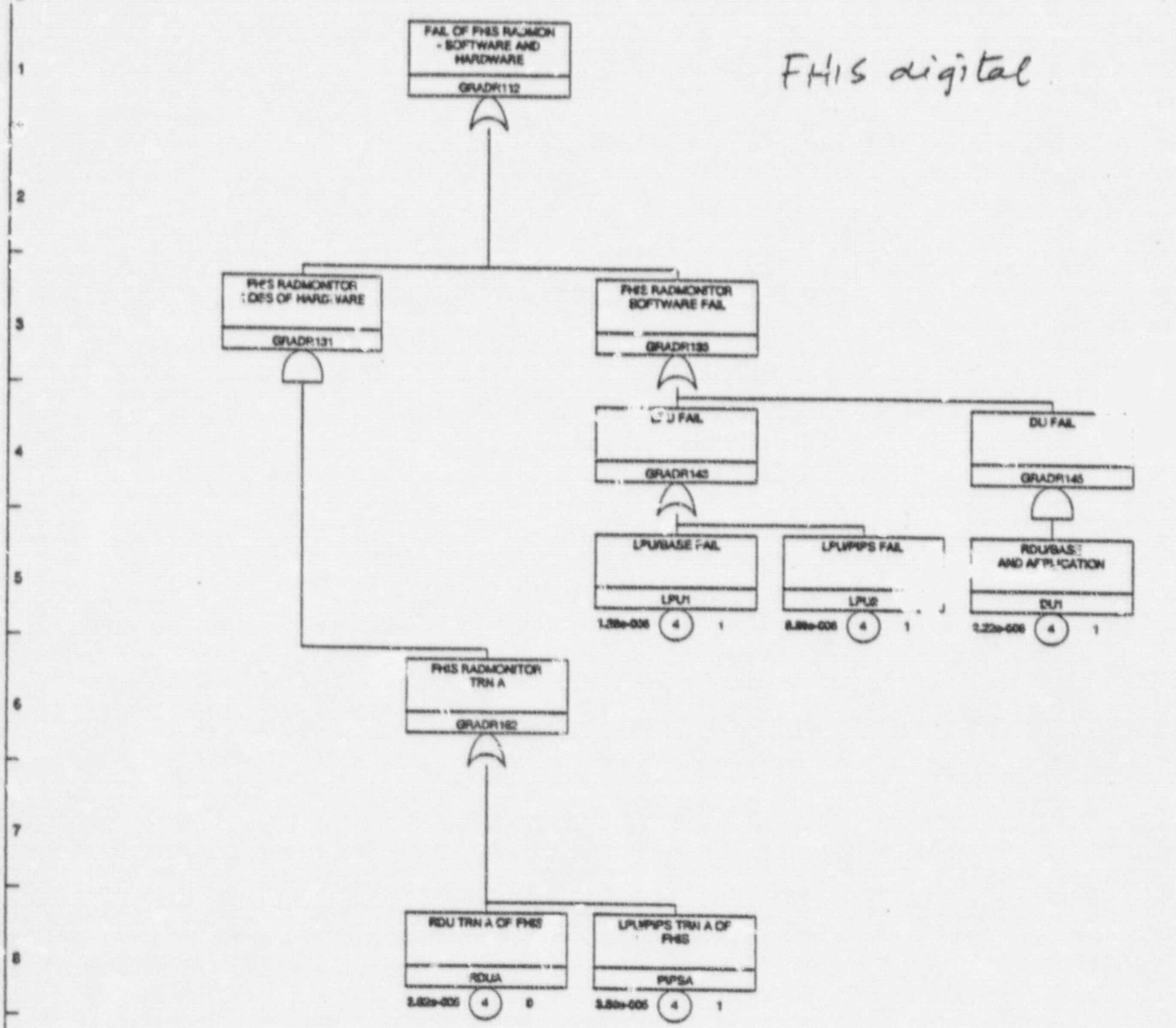
Cutoff value used                    =     1.00E-010
Number of Boolean Indicated Cut Sets = 7.000000E+00
Number of MCS in equation file       =             7
MINIMAL CUT SETS SORTED BY UNAVAILABILITY
________________________________________________________________________
  1.   4.050E-005 SASA
  2.   3.620E-005 RDUA
  3.   3.500E-005 PIPEA
  4.   8.880E-006 LPU2
  5.   5.680E-006 LPU3
  6.   2.220E-006 DU1
  7.   1.280E-006 LPU1
```

RAD MONITOR F..A		RAD, R1
Analyst: SHC	Creation Date: 01-2*-97	Revision: 01-23-97

FHIS digital



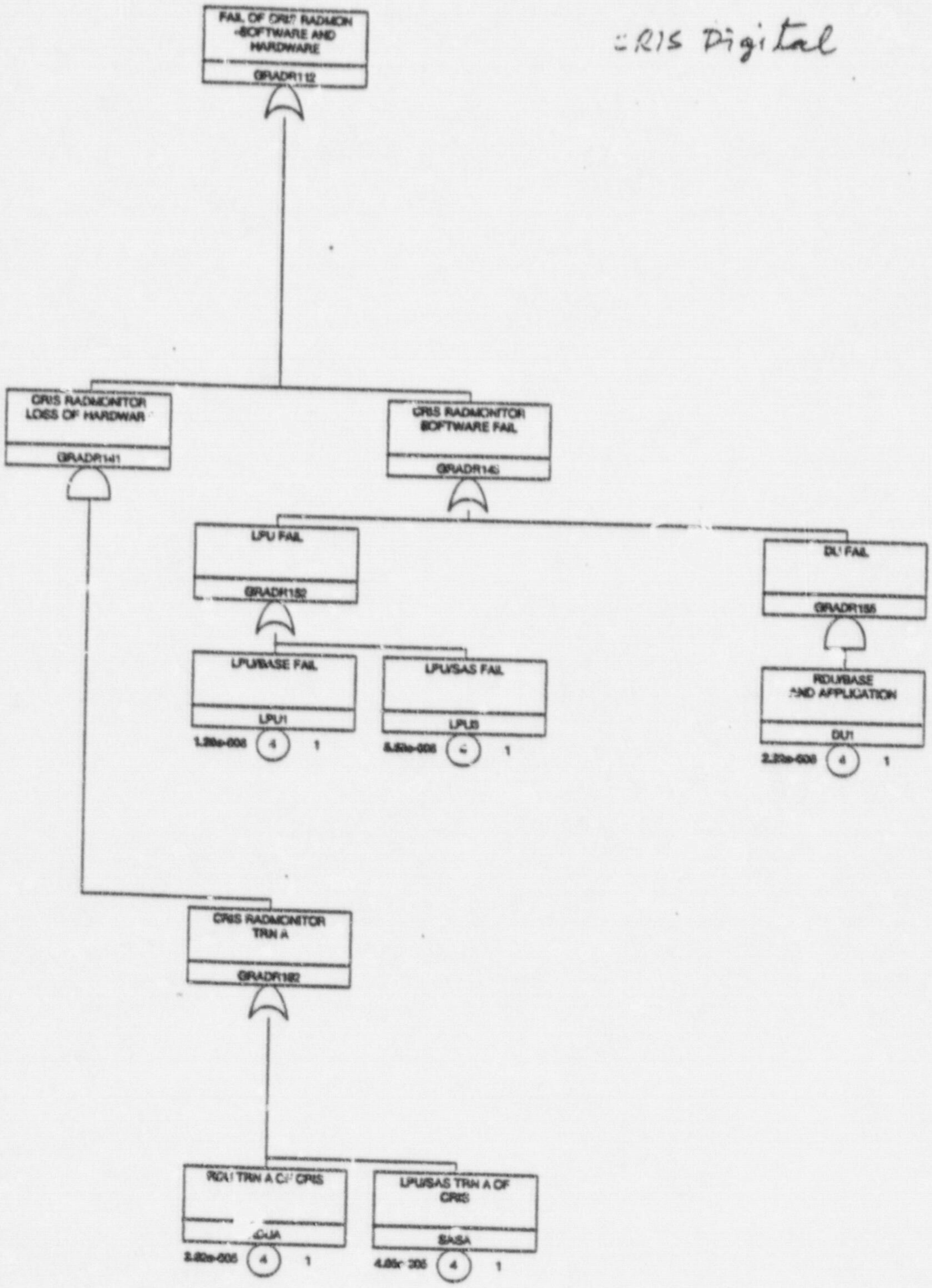
FHRA1 WIN-NUPRA

```
WinNUPRA 1.0  FILE : FHRA1.FTP   NURELMCS Solution           HNUS Env
  Minimum Cut Set Solution for fault tree fhra1   , Serial no.=    19

Performed :    10:16     19 Feb 1997
Cut Set Equation produced in   : FHRA1.EQN
______________________________________________________________________
RAD MONITOR PRA
______________________________________________________________________
Top event: GRADR112
Top event unavailability (r.ev. appr)=   8.358E-005
Cutoff value used                   =     1.00E-010
Number of Boolean Indicated Cut Sets = 5.000000E+00
Number of MCS in equation file      =             5
MINIMAL CUT SETS SORTED BY UNAVAILABILITY
______________________________________________________________________
 1.   3.620E-005 RDUA
 2.   3.500E-005 PIPSA
 3.   8.880E-006 LPU2
 4.   2.220E-006 DU1
 5.   1.280E-006 LPU1
```

RAD MONITOR PRA		RAD, R1
Analyst: SHC	Creation Date: 01-23-87	Revision: 01-23-87

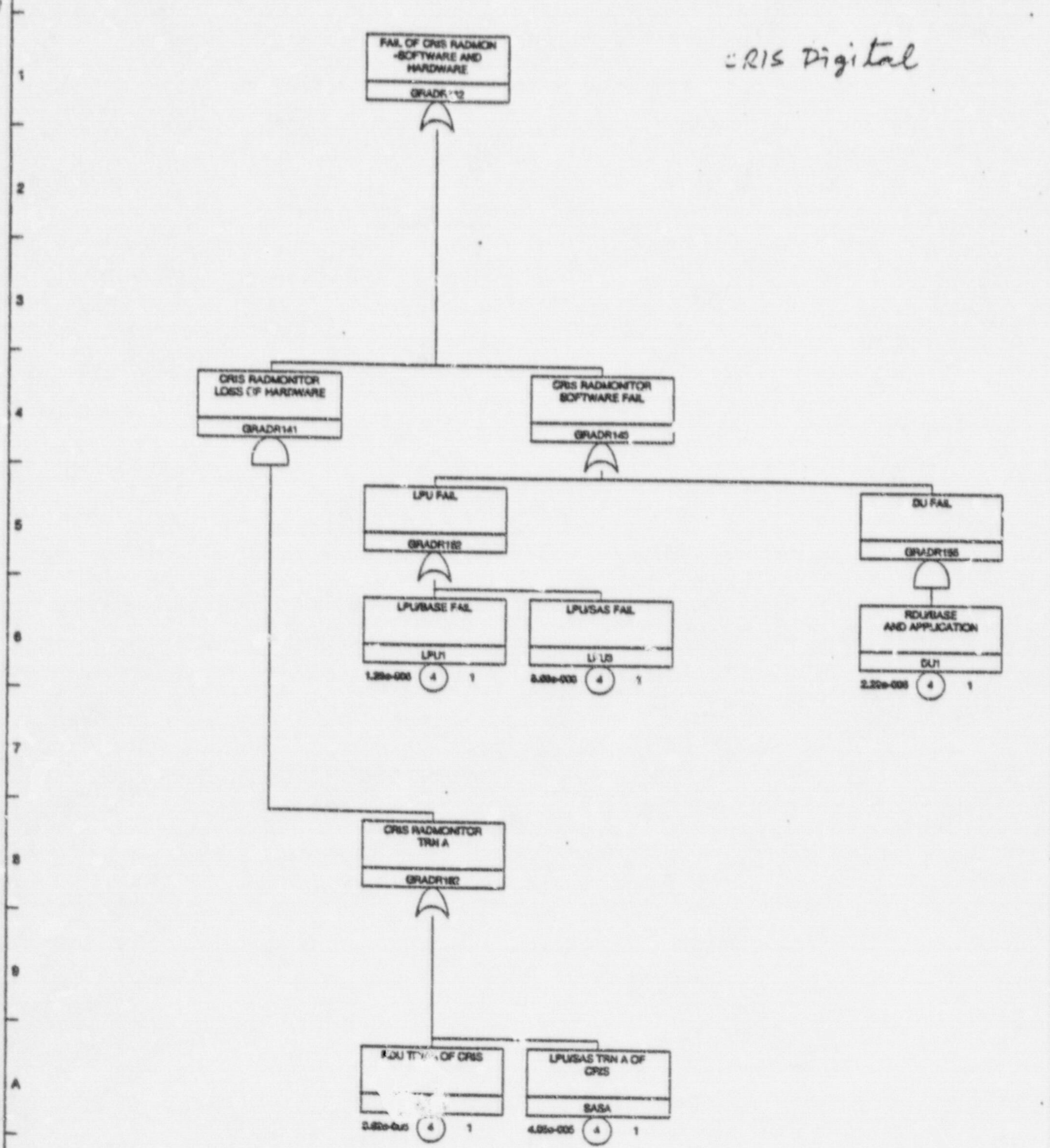
CRIS Digital



CRRA1 WSHKUPRA1.0

RAD MONITOR PRA		RAD, R1
Analyst: SHC	Creat[illegible]n Date: 01-23-97	Revision: 01-23-97

CRIS Digital



CRRA1 WIN-NUPRA 1.0

```
:nNUPRA 1.0   FILE : CRRA1.FTP   NURELMCS Solution            HNUS Env

   Minimum Cut Set Solution for fault tree crral    ,  Serial no.=    18

Performed :   10:..       19 Feb 1997
Cut Set Equation produced is   : CRRA1.EQN
________________________________________________________________________
RAD MONITOR PRA
________________________________________________________________________
Top event: GRADR112
Top event unavailability (r.ev. appr)=   8.588E-005
Cutoff value used                     =    1.00E-010
Number of Boolean Indicated Cut Sets = 0.000000E+00
Number of MCS in equation file        =            5
MINIMAL CUT SETS SORTED BY UNAVAILABILITY
________________________________________________________________________
 1.   4.050E-005 SASA
 2.   3.620E-005 RDUA
 3.   5.680E-006 LPU3
 4.   2.220E-006 DU1
 5.   1.280E-006 LPU1
```