

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

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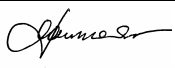
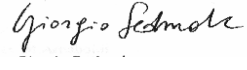
Page: 1 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

VST FINAL DESIGN REVIEW

SECTION 14

MAINTENANCE PLAN & RELIABILITY ANALYSIS

Activities	Persons Involved	
Specification & Functionalities	D. Mancini – ESO	
Document Preparation	M. Brescia – C.Molfese	
Document Supervision & Check	D. Mancini	
Document Approved by	G. Sedmak	
Task Management	D. Mancini	
Documentation Management and Q.C.	V. Fiume Garelli	
Documentation Coordination	V. Fiume Garelli	
All activities Supervision & Coordination	D. Mancini	
Project Responsible	D. Mancini mancini@na.astro.it	Signatures  
	G. Sedmak sedmak@ts.astro.it	
Remarks, Questions & Requests Gateway	D. Fierro – Fierro@na.astro.it	

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: **1.3**

Date: **31.05.2000**

Page: **2** of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

EVOLUTION RECORD

Issue	Revision	Date	Notes
1	0	25/11/1999	First release
1	1	11/02/00	Updating release following ESO RICs, RIQs and RIDs. - Section 14.4 "Reliability Analysis" added - Several minor changes wherever the document
1	2	15/04/2000	Updated Section 14.4.6-14.4.7-14.4.8-14.4.9.2
1	3	31/05/2000	Updated Section 14.4.6-14.4.7-14.4.8-14.4.9.2-14.4.9.3

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 3 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

TABLE OF CONTENTS

14	SCOPE	4
14.1	APPLICABLE DOCUMENTS	4
14.2	FAILURE ANALYSIS	4
14.2.1	<i>Status Monitoring</i>	4
14.2.2	<i>Diagnostics</i>	4
14.2.3	<i>Alarms</i>	4
14.3	FAILURE ANALYSIS	5
14.4	RELIABILITY ANALYSIS	7
14.4.1	<i>List of abbreviations and acronyms</i>	7
14.4.2	<i>Mean System Availability (MSA) and Mean Time Between Failure (MTBF)</i>	7
14.4.3	<i>Individual component MTBF and failure rate</i>	8
14.4.4	<i>MTBF for a system</i>	8
14.4.5	<i>Reliability study</i>	8
14.4.6	<i>Reliability preliminary allocation</i>	10
14.4.7	<i>Reliability assessment</i>	11
14.4.8	<i>Reliability results</i>	12
14.4.9	<i>Conclusions</i>	16
14.4.9.1	<i>Lifetime Conclusions</i>	16
14.4.9.2	<i>Reliability Conclusions</i>	16
14.4.9.3	<i>General Conclusions</i>	16
14.5	PREVENTIVE MAINTENANCE ACTIVITIES	17
14.5.1	<i>Mechanics System</i>	17
14.5.2	<i>Cryogenic System</i>	17
14.5.3	<i>Control Electronics</i>	17
14.5.4	<i>Detectors and Acquisition electronics</i>	17
14.5.5	<i>Overall System Test</i>	17
14.6	SPARE PARTS	17
14.7	MANTENANCE PLAN	18

TABLE

Tab. 1	- Failure analysis of the main VST components and functions	6
Tab. 2	- Reliability allocation criteria	11
Tab. 3	- Reliability allocation results	11
Tab. 4	- Main components failure rate and lifetime	12
Tab. 5	- Subsystem working rates	12
Tab. 6	- VST Reliability Assessment	14
Tab. 7	- VST Reliability Results/Requirements	16
Tab. 8	- VST Sub-system Reliability Conclusions	17
Tab. 9	- The Maintenance plan	18

FIGURES

Fig.9.1	VST System Layout	9
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VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 4 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

14 SCOPE

In this document the maintenance plan of VST is given. VST is designed with the aim to limit maintenance activities to the absolute minimum. This is especially done in order to be able to have the maintenance done by a small number of personnel in accordance with the staffing plans of the VLT observatory.

14.1 APPLICABLE DOCUMENTS

VLT-TRE-ES0-00000-0001, Issue No.4: VLT Maintenance Concept of 14.08.1992.

14.2 FAILURE ANALYSIS

14.2.1 *Status Monitoring*

The HW and SW documents list the status signals which are connected to the LCU digital I/O boards. These signals individually or a combination of these signals allow for the location of a failure. Another possibility to locate failures consists of combining information available from the LCU digital I/O board with other available telescope information.

14.2.2 *Diagnostics*

All active devices will be continuously monitored. Several thresholds will be defined in order to generate alarms when values will be out of range. The control system will validate or not all the diagnostic signals, by monitoring and checking the validity of the diagnostic data.

14.2.3 *Alarms*

Alarm signals will be available on the telescope mimic panels and on the telescope WS. On the telescope the alarms will be audio-visual and on the WS there will be SW alarms. In the detection and location of failures these alarms are helpful diagnostic tool. A preliminary list of alarms is here reported. More details will be added along the project realization.

- a) pressure alarm type
- b) temperature alarm type
- c) cabinet temperature alarm type
- d) motor temperature alarm type
- e) motor overcurrent alarm type
- f) motor overtorque alarm type
- g) overvoltage alarm type
- h) cooling system alarm type
- i) external equipment alarm type
- j) device n alarm type
- k) T B.Added

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 5 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

14.3 FAILURE ANALYSIS

Table 1 reports the failure analysis of the VST telescope. The table reports the action which is required in case of a malfunction. The last column indicates if a spare part is foreseen and the required quantity of spare parts independently if they will be furnished or not by OAC. They can be furnished by OAC as separate supply.

N.	Instrument functions/Equipment/Components	Status information from LCU	Life Time	Action in case of failure	Spare Parts
1.	Calibration lamp	Yes	250h	Replace	Yes,2
2.	Rot/motor	Yes	Indefinite (6)	T.B.V.	
3.	Rot/encoder heads	Yes	Indefinite (6)	Replace/repair (1)	Yes,2
4.	Rot/tachos	Yes (4)	Indefinite (6)	Replace/repair (1)	Yes,1
5.	Adapter/motor	Yes	Indefinite (6)	Replace/repair (1)	Yes,1
6.	Adapter/encoder heads	Yes	Indefinite (6)	Replace/repair (1)	Yes,1
7.	Adapter/tachos	Yes (4)	Indefinite (6)	Replace/repair (1)	Yes,1
8.	All limit switches	Yes (5)	Indefinite (6)	Replace	Yes, several
9.	Probe, objectives, mirrors, slits	No	Indefinite (6)	Repair (2)	No
10.	Guide ESO CCD	Yes	Indefinite (6)	Replace	Yes
11.	SH ESO CCD	Yes	Indefinite (6)	Replace	Yes
12.	CCD ESO controllers	Yes	Indefinite (6)	Repair (2)	No
13.	Corrector ADC motors	Yes (4)	Indefinite (6)	Replace	Yes,2
14.	Corrector Lens exchanger motors	Yes	Indefinite (6)	Replace	Yes,1
15.	All functions from Instrument Group T.B.D.	TBD	TBD	TBD	TBD
16.	Small Step Motors	Yes	Indefinite (6)	Replace	Several
17.	Small DC Motors	Yes	Indefinite (6)	Replace	Several
18.	Instrument outer ring motor	Yes	Indefinite (6)	Replace/repair (3)	Yes,1
19.	Instrument outer ring encoder	Yes	Indefinite (6)	Replace	No
20.	Instrument outer ring resolver	Yes		Replace	No
	Telescope functions / equipment / Components / sensors				
21.	Az/Alt motor	Yes	Indefinite (6)	Replace/repair (1)	Yes,2
22.	Az/Alt encoders heads	Yes	Indefinite (6)	Replace/repair (1)	Yes,2
23.	Az/Alt tachometers	Yes	Indefinite (6)	Replace/repair (1)	Yes,2
24.	Az/Alt drives	Yes	Indefinite (6)	Replace/repair (3)	Yes,2
25.	Az/Alt brake	Yes (5)	Indefinite (6)	Replace	Yes,2
26.	Az/Alt resolver	Yes	Indefinite (6)	Replace	Yes,2
27.	Temperature sensors	Yes	Indefinite (6)	Replace	Yes,5
28.	PT100 to 4-20mA Conditioner	Yes (5)	Indefinite (6)	Replace	No
29.	ESO Cooling unit	Yes	Indefinite (6)	Repair (2)	No
30.	Motor/Cabinet cooling unit valves	Yes (5)	Indefinite (6)	Replace	No
31.	Motor/Cabinet cooling controller	Yes	Indefinite (6)	Replace	No
32.	Water Presence Sensor	No	Indefinite (6)	Replace	Yes,2
33.	M1 active pad motor	Yes	Indefinite (6)	Replace	Yes,2
34.	M1 active pad load cell	Yes (5)	Indefinite (6)	Replace	Yes,5
35.	M1 active pad astatic lever	Yes (5)	Indefinite (6)	Replace/repair (2)	Yes,2
36.	Limit switches for all systems	Yes (4)	Indefinite (6)	Replace	Yes, several
37.	M1 APCS controller	Yes	Indefinite (6)	Repair (2)	No
38.	M1 Active control Cabling	Yes	Indefinite (6)	Replace/repair (2)	Yes,4
39.	Tel/dome bridge cables	Yes	Indefinite (6)	Replace	No

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 6 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

40.	M2 Hex#1 motors	Yes	Indefinite (6)	Replace	Yes,1
41.	M2 Hex#1 encoder	Yes	Indefinite (6)	Replace	Yes,1
42.	M2 Hex#2 piezo/actuator	Yes	Indefinite (6)	Replace	Yes,1
43.	M2 Hexapode controller	Yes	Indefinite (6)	Repair (2)	No
44.	M2 Hex#2 H.V. Power supply	Yes	Indefinite (6)	Replace/repair (1)	Yes,1
45.	M2 Hex#2 feedback controller	Yes	Indefinite (6)	Replace (3)	No
46.	M1 cover motor	Yes (4)	Indefinite (6)	Replace (2)	No
47.	Power Supply VME FPM 1603	Yes	Indefinite (6)	Replace	No
48.	Power PC Motorola	Yes	Indefinite (6)	Replace	No
49.	VMI-VME 3119	Yes	Indefinite (6)	Replace/repair (1)	Yes,2
50.	VMI-VME 4116	Yes	Indefinite (6)	Replace/repair (1)	Yes,2
51.	TIM Board	Yes	Indefinite (6)	Replace/repair (2)	No
52.	MAC4/STEP VME	Yes	Indefinite (6)	Replace/repair (3)	No
53.	ESO VME 4ST	Yes	Indefinite (6)	Replace/repair (2)	No
54.	MAC4/DC	Yes	Indefinite (6)	Replace/repair (3)	No
55.	ESO VME 4SA	Yes	Indefinite (6)	Replace/repair (2)	No
56.	ISER8	Yes	Indefinite (6)	Replace/repair (3)	No
57.	ACROMAG	Yes	Indefinite (6)	Replace/repair (2)	No
58.	Esters Temp. Acquisition Stations	Yes	Indefinite (6)	Replace/repair (1)	No
59.	Kniel Power Supplies	Yes	Indefinite (6)	Replace	No
60.	Heidenhain IK320 board	Yes	Indefinite (6)	Replace/repair (3)	Yes,1
61.	Encoder ERO7001 Reading Heads	Yes	Indefinite (6)	Replace/repair (1)	Yes,2
62.	VME backplane	Yes	Indefinite (6)	Replace	No
63.	ESO backplane	Yes	Indefinite (6)	Replace	No
64.	DIN support Optocoupler	Yes (5)	Indefinite (6)	Replace	Yes,10
65.	DIN support 24V relay	Yes (5)	Indefinite (6)	Replace	Yes,10
66.	DIN support 220V relay	Yes (5)	Indefinite (6)	Replace	Yes,2
67.	380 Power Breacker	Yes (5)	Indefinite (6)	Replace	No
68.	220 Power Breacker	Yes (5)	Indefinite (6)	Replace	No
69.	380 Power Contactor	Yes (5)	Indefinite (6)	Replace	No
70.	220 Power Contactor	Yes (5)	Indefinite (6)	Replace	No
71.	Power Fuse	Yes (5)	Indefinite (6)	Replace	No
72.	Emergency Pushbutton	Yes (5)	Indefinite (6)	Replace	No
73.	Hydrostatic Bearing Support System (7)	TBD	TBD	TBD	TBD

Tab. 1 - Failure analysis of the main VST components and functions

- (1) To be repaired in the Supplier Company
- (2) To be repaired at ESO care
- (3) To be repaired by the manufacturer or by ESO depending on the failure characteristics
- (4) From other info's
- (5) During maintenance
- (6) The mean time between failure is estimated to be much longer than the mean time to repair. The indefinite term means > VST lifetime.
- (7) A detailed analysis will be done in collaboration with ESO.

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 7 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

14.4 RELIABILITY ANALYSIS

The goal is the calculation of the overall reliability and of the overall Mean Time Between Failure (**MTBF**) of each sub-system and of the complete system, and to determine the operational availability of the instrument (**Mean System Availability**) which is deduced from operational time lost due to unscheduled downtime and failure. The requirements on VST reliability and lifetime, considered in the following analysis, follows the standard parameters issued by ESO. For instance, the following parameters will be taken into account on the VST reliability analysis:

Requirement item	value	Remarks/hypothesis
VST Operational lifetime	> 10 years	Including maintenance and spare parts, with a working time of 4760 h/year
Operational time to be lost due to unscheduled downtime and failure	1%	Telescope operational for 54% of the total time. It does not include maintenance periods.
Observing program MTBF	> 1 year	Defined as loss of operation such that the scheduled observing program/back-up program cannot be executed

14.4.1 List of abbreviations and acronyms

MTBF	Mean Time Between Failure (y)
MTTF	Mean Time To Failure (y)
MTTR	Mean Time To Repair (y)
MSA	Mean System Availability
λ	Failure Rate - mean number of failures per time unit for a component or sub-system (1/y)

14.4.2 Mean System Availability (MSA) and Mean Time Between Failure (MTBF)

The MSA is defined on the basis of the following definitions :

MTBF: Mean Time Between Failure (y)

MUT: Mean Up Time (y)

MDT: Mean Down Time (y)

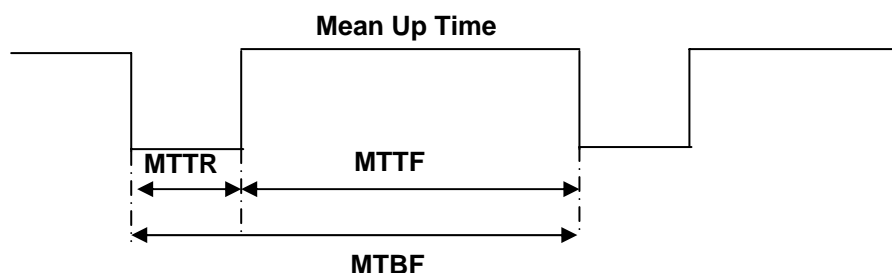
MTTR: Mean Time To Repair \approx MDT (y)

MTTF: Mean Time to Failure \approx MUT (y)

In the study we adopt the following definition about the system availability and MTBF:

$$\text{MSA} = \text{MTTF}/(\text{MTTR}+\text{MTTF})$$

$$\text{MTBF} = \text{MTTF} + \text{MTTR} \approx \text{MTTF}$$



MTBF Definition

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 8 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

14.4.3 Individual component MTBF and failure rate

The **MTBF** calculation is based on the failure rate of a component, expressed in failure/working hour (or failure/working year). The MTBF, i.e. the expected interval during which the component/system will operate reliably is :

$$MTBF = 1/\lambda c$$

with λc : component failure rate

The reliability of each component is characterised by its survival probability which is expressed by:

$$p(t) = \exp(-\lambda c \cdot wt)$$

with **wt**: working time of the component

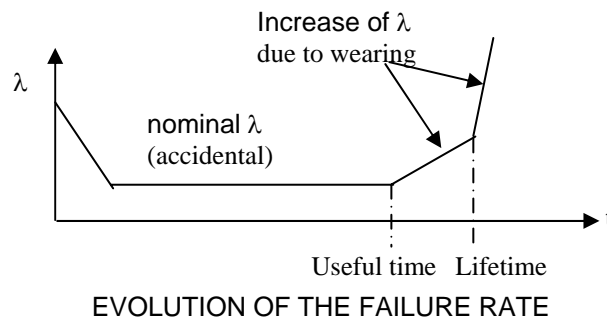
The failure probability is then:

$$1 - p(t)$$

The failure rate value depends on the component characteristics and can be assessed from data provided either by the manufacturer or by a set of formulae elaborated on a number of measurements for similar components. The failure rate has mainly two contributions :

- Accidental failure
- Failure due to wearing

Consequently, the failure rate evolves according to the general curve shown in the following scheme.



14.4.4 MTBF for a system

For a system, i.e. the combination of individual components, the calculation depends if the individual components all contribute to the function, or if there is a redundancy level. If the system architecture is logically sequential, i.e. the system fails whenever one of these components is out of service, and if p_i is the probability of a reliable performance for each component, the reliability of the chain that realize the function is :

$$P_f = p_1 \times p_2 \times \dots \times p_n \quad (n : \text{number of components in the link}),$$

with $p_i = \exp(-\lambda c_i \cdot wt_i)$

The overall failure rate for linked components is calculated by the sum of the individual failure rates, with the ponderation of the actual working use of the sub-system. The calculated overall MTBF is calculated by:

$$MTBF_{\text{subsystem}} = 1/\Sigma(\lambda_i \cdot wt_i)$$

14.4.5 Reliability study

The main steps for the VST telescope reliability study are:

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 9 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

1. **The identification of critical subsystems and components** to be taken into account on the basis of the telescope system layout.
2. **The reliability allocation** which consists to allocate reliability characteristics on the sub-systems on the basis of global criteria and experience.
3. **The reliability assessment** based on actual and assessed reliability parameters.
4. **The reliability conclusions** which goal is to compare the reliability allocation with the reliability assessment and to analyze the impact of local component reliability or redundancy on the overall VST reliability.

In order to cover all telescope potential components, the following type of components have been selected in the reliability study:

- Electro-mechanical components
- Electronic boards
- Cabling

The critical subsystems and the link between them is shown on the next system block diagram. The link is sequential, i.e. VST system degrades if one of the block fails. It means that there is no global redundancy of main functions.

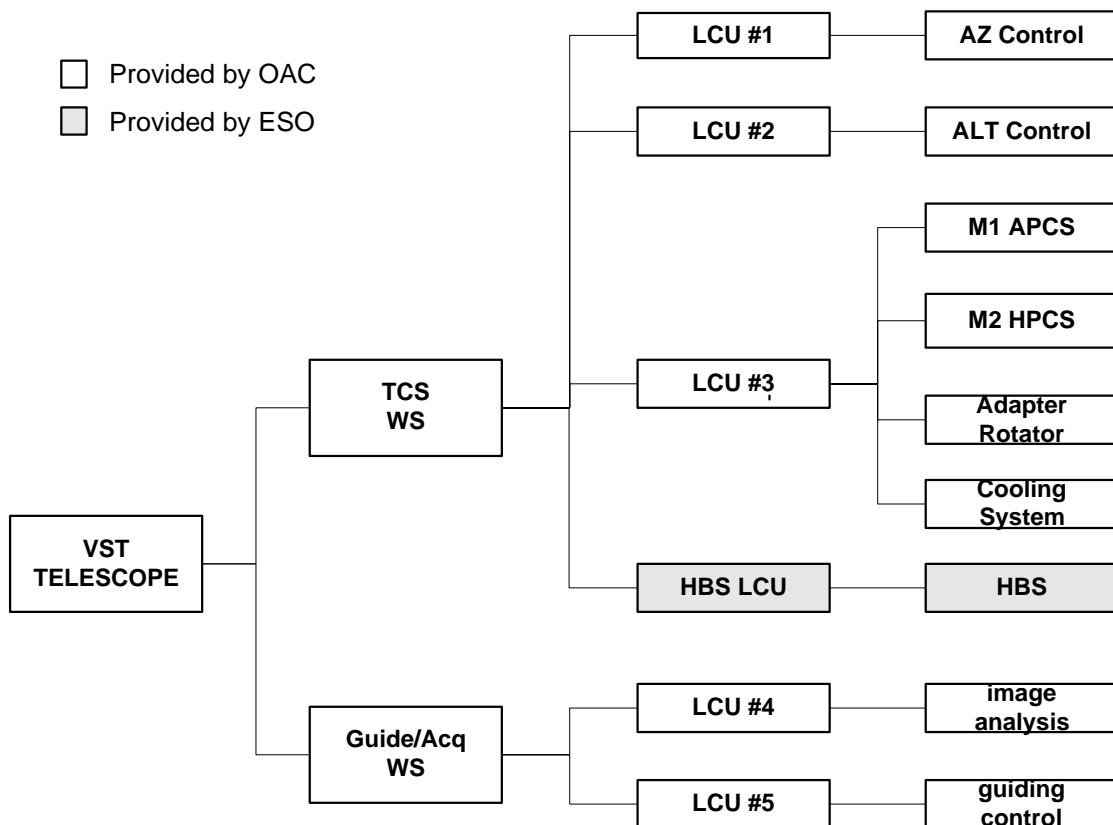


Fig.9.1 VST System Layout

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 10 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

14.4.6 Reliability preliminary allocation

On the basis of the system layout, the aim of the reliability allocation is to determine theoretical failure for each subsystem according to general criteria based on the technical feasibility, and applying a top-down approach starting with the global failure rate goal of the telescope. The goal failure rates are distributed to each sub-system according to its relative weighting. The term λ_{vst} is the goal failure rate for the global instrument expressed as 1/y. It is obtained by means of the following assumptions:

VST MTBF (hypothesis) = 1 (y)

Wt (Working Time) = (14 (h/d) * 340 (d/y)) / 8760 (h) = (4760 / 8760) (y) = 0.54 (y)

MTBF = 1 / (λ_{vst} * wt)

From these equations it is obtained the following value for λ_{vst} :

$\lambda_{vst} = 1 / (MTBF * wt) = 1 / wt = 1.85$ (1/y).

With these assumptions, the failure rate goal for a given sub-system is:

$$\lambda_{ss} = \lambda_{vst} * P_{ss} / P_{vst}$$

P_{ss}: weighting factor for each sub-system

P_{vst}: global weighting factor for the instrument, (expressed as the sum of all P_{ss} values)

λ_{ss} : failure rate allocation for the sub-system, (1/y)

λ_{vst} : failure rate goal of the instrument (1.85 (1/y))

The weighting of each sub-system reliability (**P_{ss}**) is assessed on the basis of the following formula:

P_{ss} = Number of functions * Complexity * Technology level * Rate of utilization * Environment sensitivity

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 11 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

Symbol	Criteria	Function allocation value
N	Number of elementary functions	Number of independant identified functions/components
C	Technological complexity of the functions	Number of interconnected functions or 10: Very high complexity/dependability 7: High complexity/dependability 3: Moderate complexity/dependability 1: Low complexity/dependability
T	Technology Level/Risk	10: New technology or poor quality/intrinsec reliability component 7: Equipment design at known technology limits, or in a field not well known 3: Design based on similar equipment or moderate quality off the shelf component 1: Off the shelf equipment with high quality qualification
R	Rate of utilisation of the function	10: Used continuously with heavy load 7: Used frequently or moderate load on the sub-system 3: Used occasionnaly or low load on the sub-system 1: Used very occasionnaly and low load on the sub-system
E	Environmental conditions of the subsystem	10: Not protected area with a very highly sensitive or poorly tolerant component 7 : Component very sensitive to environment 3: Protected but possible agressions and the component is not very sensitive to environment 1: Protected or the component is very tolerant to environment

Tab. 2 – Reliability allocation criteria

The next table shows the reliability allocation results, based on calculations of above criteria for every sub-system listed in the System lay-out. The last column is obtained as $MTBF = 1 / (\lambda_{ss} wtss)$.

Ranking	Functions	Criteria					Pss	Pss / Pvst	λ_{ss} (1/year)	MTBF (year)
		N	C	T	R	E				
1	Workstations	2	9	1	9	1	162	0,01	0,02	119,3
2	LCUs	44	9	1	9	5	17820	0,92	1,71	1,1
3	M1 APCS	4	3	3	7	1	252	0,01	0,02	76,7
4	M2 HPCS	3	3	3	7	1	189	0,01	0,02	102,3
5	Adapter/Rotator	2	3	3	9	1	162	0,01	0,02	119,3
6	Cooling System	6	1	1	9	3	162	0,01	0,02	119,3
7	HBS	1	3	3	9	3	243	0,01	0,02	79,6
8	AZ Ctrl	1	3	3	9	1	81	0,004	0,01	238,7
9	ALT Ctrl	1	3	3	9	1	81	0,004	0,01	238,7
10	Guiding Ctrl	1	3	3	9	1	81	0,004	0,01	238,7
11	Image Analysis	1	3	3	9	1	81	0,004	0,01	238,7
	VST						19314	1	1,85	1,0

Tab. 3 – Reliability allocation results

The Pvst is the sum of all Pss terms: $Pvst = 19314$.

14.4.7 Reliability assessment

The reliability allocation aimed to allocate failure rate goals according to general criteria and on the basis of the global VST system failure rate/MTBF goal. The reliability assessment starts from individual critical component failure rate assessment to compute the estimated VST failure rate. It is globally a bottom-up approach starting from individual data. The analysis consists of the determination of the individual component failure rates. The effective

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 12 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

working use of the component and then the overall assessment of VST system failure rate and MTBF by sum-up of the individual failure rates. In the following table are reported the VST main components failure rates.

Component Type	Failure rate (1/ year)
Telescope Motors	0,025
Stepper Motors	0,010
Motor Drive	0,020
Encoder	0,010
Limit Switch	0,100
Power Supply	0,01(1)
Maccon motor controller	0,005
MotorolaCPU	0,01(1)
I/O	0,010
Tachometer	0,020
Inductive switches	0,020
M1 active actuator	0,005
M1 load cell	0,005
Connections/Cabling	0,02(1)

(1) obtained by periodical check and substitution of the components

Tab. 4 – Main components failure rate

The reliability of a component and consequently of the related system depends on the working time of the requested function (effective use of the function in term of duty cycles). The working time (**wt**) of a component/sub-system is deduced from the system operation and the related modes. The main assumptions are:

- use of the telescope 340 nights per year.
- 14 hours of telescope total operations per day
- 7 hours of pointing/tracking operation per day

The sub-system working time calculations are described in the following table:

Function/Sub-system	Total Working Time Ratio (working time / year time) * 100	Total Working time hour/year
Workstation	100,0	8760
LCU Unit	100,0	8760
M1 APCS	8,0	701
M2 HPCS	32,0	2803
Adapter/Rotator	22,0	1927
Cooling System	100,0	8760
HBS	100,0	8760
ALT Ctrl	27,0	2365
AZ Ctrl	27,0	2365
Guiding Ctrl	22,0	1927
Image Analysis	32,0	2803

Tab. 5 – Subsystem working rates

14.4.8 Reliability results

The results of the reliability assessment are shown in the following table. The meaning of the columns is :

- Component sub-system component
- No number of operational component
- λr raw failure rate (1 / year). (per single component)

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 13 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

- wt working time (1 / fulltime) (per single component)
- $\lambda\varepsilon$ effective failure rate (1 / year) = $\lambda r * wt * No$
- Tr MTRR: Mean Time To Repair (hours)
- MTBF MTBF (Mean Time Between Failure) = $(1 / \lambda\varepsilon)$ (y)

Sub-System / Component	No	lr	Wt	le	Tr (h)	Mtbf (y)
Workstation Hardware	1	-	1,00	0,024	1,00	41,6667
Workstation Central Processing Unit (1)	2	0,010	1,00	0,020	1,00	50,0000
Workstation Hard Disk (1)	2	0,010	0,20	0,004	1,00	250,0000
Local Control Units Hardware	5	-	1,00	0,332	1,00	3,0120
VME Rack	5	0,001	1,00	0,005	1,00	200,0000
Tim Board	5	0,005	1,00	0,025	1,00	40,0000
CPU Board (1)	5	0,010	1,00	0,050	1,00	20,0000
Digital I/O Board	3	0,010	1,00	0,030	1,00	33,3333
ADC Board	3	0,010	1,00	0,030	1,00	33,3333
DAC Board	3	0,010	1,00	0,030	1,00	33,3333
Serial I/O Board	3	0,010	1,00	0,030	1,00	33,3333
IK320 Encoder Interface Board	6	0,005	1,00	0,030	1,00	33,3333
STP Maccon Controller	2	0,005	1,00	0,010	1,00	100,0000
Stepper Motor Driver	2	0,020	0,05	0,002	1,00	500,0000
LCU Cabinet Temperature Controller	6	0,005	1,00	0,030	1,00	33,3333
Power Supply	6	0,010	1,00	0,060	1,00	16,6667
M1 APCS	1	-	0,08	0,128	1,00	7,8200
M1 active pad motor (2)	81	0,005	0,08	0,033	1,00	30,4832
M1 active pad load cell (2)	84	0,005	0,08	0,034	1,00	29,3945
M1 active control cabling	1	0,020	0,08	0,002	1,00	617,2840
M1 APCS controller (2)	84	0,005	0,08	0,034	1,00	29,3945
M1 APCS Main Control Unit	1	0,005	1,00	0,005	1,00	200,0000
Limit switch (2)	168	0,100	0,001	0,014	1,00	73,4862
Position switch (2)	84	0,100	0,001	0,007	1,00	146,9724
M2 HPCS	1	-	0,32	0,084	1,00	11,9474
M2 stage 1: Hexapod arm DC motor	6	0,010	0,32	0,019	1,00	51,4403
M2 stage 1: Hexapod arm encoder	6	0,010	0,32	0,019	1,00	51,4403
M2 stage 1: Hexapod controller	6	0,005	0,32	0,010	1,00	102,8807
M2 stage 1: Hexapod Power Supply	1	0,020	0,54	0,011	1,00	92,5926
M2 stage 2 : PI Electronics Interface	1	0,005	0,54	0,003	1,00	370,3704
M2 stage 2 : Piezo/actuator	5	0,010	0,32	0,016	1,00	61,7284
M2 stage 2: controller and power supply	1	0,010	0,54	0,005	1,00	185,1852
Adapter/Rotator	1	-	0,22	0,034	1,00	29,7725
Adapter turn/table motor	1	0,025	0,03	0,001	1,00	1481,4815
Adapter turn/table encoder	1	0,010	0,03	0,000	1,00	3703,7037
Adapter turn/table tacho	1	0,010	0,03	0,000	1,00	3703,7037
Adapter turn/table motor driver	1	0,020	0,03	0,001	1,00	1851,8519
Adapter arm stepper motor	1	0,010	0,03	0,000	1,00	3703,7037
Adapter mirror tilt stepper motor	1	0,010	0,03	0,000	1,00	3703,7037
Adapter ADC stepper motor	2	0,010	0,003	0,000	1,00	18518,5185
Adapter lens exchanger stepper motor	1	0,010	0,003	0,000	1,00	37037,0370

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 14 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

Adapter probe focusing stepper motor	1	0,010	0,05	0,001	1,00	1851,8519
Rotator motor	2	0,025	0,22	0,011	1,00	92,5926
Rotator motor driver	2	0,020	0,22	0,009	1,00	115,7407
Rotator encoder	1	0,010	0,22	0,002	1,00	462,9630
Rotator tacho	2	0,010	0,22	0,004	1,00	231,4815
Rotator limit switches	2	0,100	0,002	0,000	1,00	2314,8148
Rotator Power Supply	1	0,020	0,22	0,004	1,00	231,4815
Cooling System	1	-	1,00	0,140	1,00	7,1429
ESO Cooling unit	7	0,005	1,00	0,035	1,00	28,5714
Motor cooling unit valves (1)	10	0,005	1,00	0,050	1,00	20,0000
Motor cooling controller	10	0,005	1,00	0,050	1,00	20,0000
ESTERS temperature acquisition station	1	0,005	1,00	0,005	1,00	200,0000
HBS (TBC)	1	-	1,00	0,060	-	16,6667
ALT Ctrl	1	-	0,27	0,073	1,00	13,6166
ALT motor (2)	4	0,025	0,27	0,027	1,00	37,0370
ALT encoder	1	0,010	0,27	0,003	1,00	370,3704
ALT tacho (2)	4	0,010	0,27	0,011	1,00	92,5926
ALT motor drive	4	0,020	0,27	0,022	1,00	46,2963
ALT motor brake	4	0,010	0,27	0,011	1,00	92,5926
ALT limit switches (2)	2	0,100	0,003	0,001	1,00	1851,8519
AZ Ctrl	1	-	0,27	0,073	1,00	13,6166
AZ motor (2)	4	0,025	0,27	0,027	1,00	37,0370
AZ encoder	1	0,010	0,27	0,003	1,00	370,3704
AZ tacho (2)	4	0,010	0,27	0,011	1,00	92,5926
AZ motor drive	4	0,020	0,27	0,022	1,00	46,2963
AZ motor brake	4	0,010	0,27	0,011	1,00	92,5926
AZ limit switches (2)	2	0,100	0,00	0,001	1,00	1851,8519
Guiding Ctrl	1	-	0,22	0,004	1,00	231,4815
Guide ESO CCD	1	0,010	0,22	0,002	1,00	462,9630
CCD ESO Controller	1	0,010	0,22	0,002	1,00	462,9630
Image Analysis	1	-	0,32	0,003	1,00	285,7796
SH ESO CCD	1	0,010	0,32	0,003	1,00	308,6420
CCD ESO Controller	1	0,010	0,32	0,003	1,00	308,6420
OVERALL VST INSTRUMENT				0,956		1,0462

(1) Value obtained by means preventive maintenance and substitution

(2) Redounded items whose failure do not inhibit the functioning of the telescope

Tab. 6 – VST Reliability Assessment

The computation of Wt values reported in the above table has been carried out taking into account the following hypotheses:

- 1) Only 50% of the total operation time per day (14 hours) is exploited for pointing/tracking operation.
- 2) The pointing/tracking duration ratio is about ¼ (20% of the time is employed for pointing, 80% for tracking)
- 3) Since the limit/position switches are seldom activated, their Wt is actually negligible
- 4) The M1 APCS is activated only during pointing operations
- 5) The M2 HPCS and Adapter/Rotator are activated only during tracking operations
- 6) The actuators of turntable, arm and mirror tilt are activated during the 10% of the pointing/tracking time
- 7) The actuators of ADC and Lens Exchanger are activated during the 1% of the pointing/tracking time
- 8) The motor of probe focusing is activated during the 20% of the pointing/tracking time

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: **1.3**

Date: **31.05.2000**

Page: **15** of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

- 9) The guiding control is activated only during tracking operations
- 10) The image analysis is activated during the 60% of the total operational time

The components or subsystems, whose failures do not impact on the telescope functionality (such as workstation monitors and other peripherals), were not included in the VST Reliability Assessment.

Also the components whose failure can be easily detected via software, such as redundant temperature transducers, do not affect the overall MTBF computation.

The failure rate values of the following components were relaxed: Workstation central unit and hard disks, LCUs CPU boards, cooling unit valves; this is realistic if preventive substitution of the component is done before its lifetime expires.

The reported value of total MTBF equal to 1.04 is conservative, because some components are redundant and the related failure do not inhibit the functioning of the telescope (components marked with (2) in Tab.6). If this kind of components are not considered in the MTBF computation, the more relaxed , but also realistic value of MTBF equal to 1.31 will be obtained.

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 16 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

14.4.9 Conclusions

The aim of this section is to compare the reliability assessment with:

- the VST system reliability requirements.
- the reliability allocation in order to determine the main sub-systems or components subject to reliability problems.

14.4.9.1 Lifetime Conclusions

The VST operational lifetime, including maintenance, spare parts, a working time of 4670 h/year, is > 10 years, that globally corresponds to the VST specified lifetime.

Requirement item	Req. Value	Analysis value
VST operational lifetime	> 10 years	The overall system is designed to be operated during the required lifetime. The components that need to be replaced during the instrument lifetime are specified in the maintenance plan

14.4.9.2 Reliability Conclusions

Requirement item	Req. Value	Analysis value
Operational time to lost due to unscheduled downtime and failure. It is defined as $1 - MSA = 1 - MUT/(MDT+MUT)$	1%	0.012%
Observing program MTBF Defined as a loss of operation such that the scheduled observing program/back-up program cannot be executed	> 1 year	1,04 year (not considering redundancy) 1,31 year (considering redundancy)

Tab. 7 – VST Reliability Results/Requirements

14.4.9.3 General Conclusions

- The overall reliability of the instrument is within specifications
- The reliability can be increased drastically by preventive maintenance. Indeed the failure rate is much below during the usefull lifetime of the component (accidental failure) and then increase drastically when we approach to the theoretical component lifetime (failure due to weariness). One can consider that reliability shall be increased if we replace the components at 75% (for instance) of the theoretical lifetime
- The results consider that the telescope is not operational if one of the listed components fails.
- The main critical subsystem that need to be more followed up regarding reliability problems are shown in the next table. The difference of ranking between allocation and assessment is due to the fact that allocation was based on general criteria whereas the assessment was essentially elaborated on data regarding control system and electronics. Data on mechanism have to be more detailed and justified. This action shall be taken during the manufacture phase of the instrument.

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 17 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

Subsystem	MTBF	Critical Components
Workstations	41.7	CPU, Hard disk
LCUs	3	CPU, I/O boards, Cabling.
M1 APCS	7.8 (151)	Motors, Cabling
M2 HPCS	11.9	Control
Adapter/Rotator	29.8	Adapter and Rotator control
Cooling System	7.1	Cooling control
HBS	16.7 (TBC)	LCU
ALT Ctrl	13.6 (28.5)	Control
AZ Ctrl	13.6 (28.5)	Control
Guiding Ctrl	231.5	Control. CCD control
Image Analysis	285.8	Lenses. CCD control

The values in parentheses take into account the redundancy

Tab. 8 – VST Sub-system Reliability Conclusions

14.5 PREVENTIVE MAINTENANCE ACTIVITIES

Table 1 reports the failure analysis of the main VST subsystems. All the components are grouped in the subsystems recalled in the same table.

14.5.1 *Mechanics System*

The mechanics of VST is designed in order to be expected that no preventive maintenance activities are required.

14.5.2 *Cryogenic System*

These activities are under ESO responsibility.

14.5.3 *Control Electronics*

Time counters are installed for the calibration lamps. If the accumulated operating time of any of the lamps passes the average expected life time, the lamp will be substituted. Once every 6 months a visual check is made of the cabling between electronic racks and instrument. Once every 3 months the cooling liquid piping for the electronic racks, motors and along the telescope is checked visually.

14.5.4 *Detectors and Acquisition electronics*

These activities are under ESO responsibility.

14.5.5 *Overall System Test*

It is planned to have an automatic routine running once every 6 months which checks the overall system functionalities.

14.6 SPARE PARTS

The list of spare parts is given in the last column of Table 1.

VST Project

Osservatorio Astronomico di Capodimonte Napoli

Release: 1.3

Date: 31.05.2000

Page: 18 of 18

File Name: VST_FDR_Maintenance_rel_1_3.doc

14.7 MAINTENANCE PLAN

On the following Table 9 the maintenance plan is given for VST. This plan will be modified and integrated along the project.

N.	Item	Type of preventive maintenance	Interval	Duration	Required parts and components	Required Equipment/ Documents (4)	Required Personnel	Man-hours/level of skill
1	Cables	Visual and manual (1) check of state of electrical cabling	6 months	2 hours	None	None	1	2/technician
2	Cabling of control and acquisition electronics	Visual and manual (1) check of state of electrical cabling	6 months	1 hours	None	None	1	1/technician
3	Cooling system	Visual and manual (2) check of piping inside. outside racks. at bridge level clearing panel. at motor cooling jackets	3 months	1 hours	None	None	1	1/technician
4	Motors. encoders and auxiliaries	Check of motors. visual of pinions (3). gears (3). brake status (dust). Measurement of tacho ripple. resolver phasing. encoder readout signals. preload torque levels. motor power voltaes. generated noise. power drive and power supply status and temperature level at nominal power ecc.	3 months	24 hours	None	4 channels 100MhZ Digital scope. Multimeters. spectrum analyzer. data logger	2	12/trained technicians
5	APCS Overall efficiency test	Test of all motors. signals. applied forces. limit and Pad calibration verification. functionality of the controller and of all active pads in combination. Verication of the noise from the load cell and control loop stability	3 months	6 hours	None	None	2	3/trained technicians
6	HPCS Overall efficiency test	Test of all motors. positions. limit switches Test of all piezo-actuators Test of control loop stabilities Control and measurement of hysteresys and backlash	3 months	6 hours	None	4 channels 100MhZ Digital scope. Multimeters. spectrum analyzer. data logger. dial indicators (resolution 1 microns)	1	6/trained technician
7	Focal Plane (1) Overall efficiency	Test of all motors. encoders. functionalities. control loop moise and stability. backlash. moved components final position. hysteresys	3 months	6 hours	None	4 channels 100MhZ Digital scope. Multimeters. spectrum analyzer. data logger. dial indicators (resolution 1 microns)	1	6/trained technicians
8	Telescope auxiiaries	Test of Mirror M1 cover functionality	6 months	1 hours	None	None	1	1/technician
9	Cabinet electrics	Test of breackers fuses. relay. optocouplers. emergency pushbuttons	2 months	2 hours	None	None	1	2/technicians

Tab. 9 - The Maintenance plan

- (1) Manual check means to verify the continuity of the supply under dynamic and static mechanical stress
- (2) Manual check means to verify the stability of the control signals under mechanical stress
- (3) Mechanical verification of pinion and gear tooth contact surfaces is obtained along line
- (4) A complete set of maintenance procedure will be in the document VLT-PRO-OAC-1000X-0002