Reliability culture at La Silla Paranal Observatory

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ABSTRACT

The Maintenance Department at the La Silla - Paranal Observatory has been an important base to keep the operations of the observatory at a good level of reliability and availability.

Several strategies have been implemented and improved in order to cover these requirements and keep the system and equipment working properly when it is required.

For that reason, one of the latest improvements has been the introduction of the concept of reliability, which implies that we don't simply speak about reliability concepts. It involves much more than that. It involves the use of technologies, data collecting, data analysis, decision making, committees concentrated in analysis of failure modes and how they can be eliminated, aligning the results with the requirements of our internal partners and establishing steps to achieve success.

Some of these steps have already been implemented: data collection, use of technologies, analysis of data, development of priority tools, committees dedicated to analyze data and people dedicated to reliability analysis. This has permitted us to optimize our process, analyze where we can improve, avoid functional failures, reduce the failures range in several systems and subsystems; all this has had a positive impact in terms of results for our Observatory.

All these tools are part of the reliability culture that allows our system to operate with a high level of reliability and availability.

1. INTRODUCTION

As part of the continuous improvement, we designed during the last year our maintenance internal process. In this process, we have included a new group called data analysis or reliability group. This group is in charge of the analysis of data obtained and triggered by the Autonomous group: Preventive Maintenance Optimization (PMO), Root Cause Analysis (RCA) and Predictive Maintenance (PdM) and is also in charge of a reliability project whose goal is to optimize our process and determine how to improve it.

The following paper will show some aspects implemented by the maintenance department in order to establish the culture of reliability at La Silla Paranal Observatory as a manner for increasing the effectively and efficiency of our operations in the astronomic environment.

2. RELIABILITY AS PART OF OUR MAINTENANCE PROCESS

One of the most important steps in the culture of reliability is to define a clear process for all the activities performed by the maintenance department.

Reliability is a vital part of this process as it adds a layer of feedback and allows for obtaining data, doing analysis and improves the process of maintenance in general. For that reason this part of the process should be clearly defined in terms of goals and activities to be done.

Reliability as part of the final part of the process needs:

- Identify the objectives of the organization: KPIs like availability, reliability, costs and safety.
- Priority analysis: ranking of systems or equipment by importance and criticality.
- Strategy to manage the assets: What do we do? How? When?: preventive tasks, predictive tasks, CBM/PdM, condition monitoring, etc.
- Data information from performance of assets: availability, reliability, MTBF, etc.
- Analysis of data: Pareto, Weibull, Jack Knife and statistics
- Eliminate failures and defects: RCA, PMO, new strategy, talk the same language (failures modes, causes, solution, optimization, etc)
- Results: align the results with the objectives of the organization.

The following figure shows the maintenance internal process. This process considers all the activities needed to close the loop including the interfaces with the rest of department and actors of the observatory.

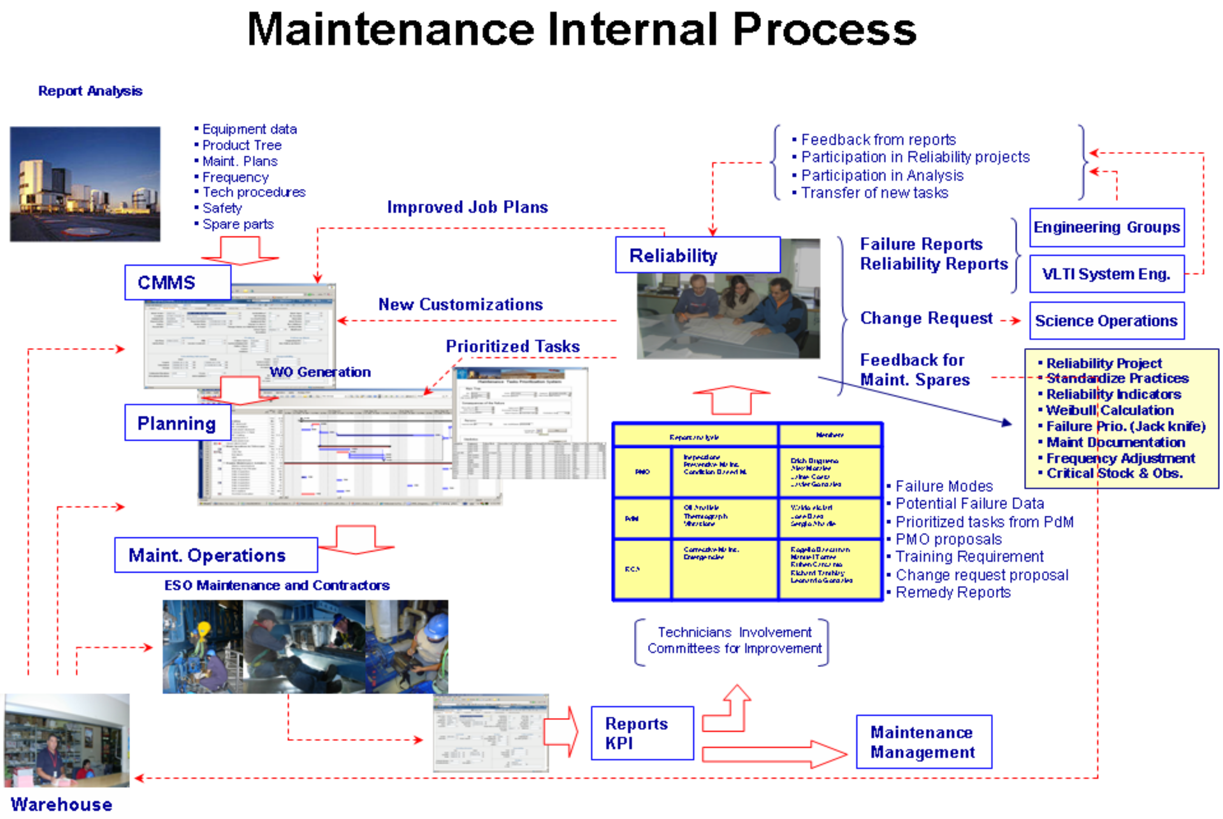


Figure 1: Maintenance Internal Process

3. RELIABILITY TOOLS INCORPORATED AT THE MAINTENANCE DEPARTMENT OF LA SILLA PARANAL OBSERVATORY

3.1. Priority software

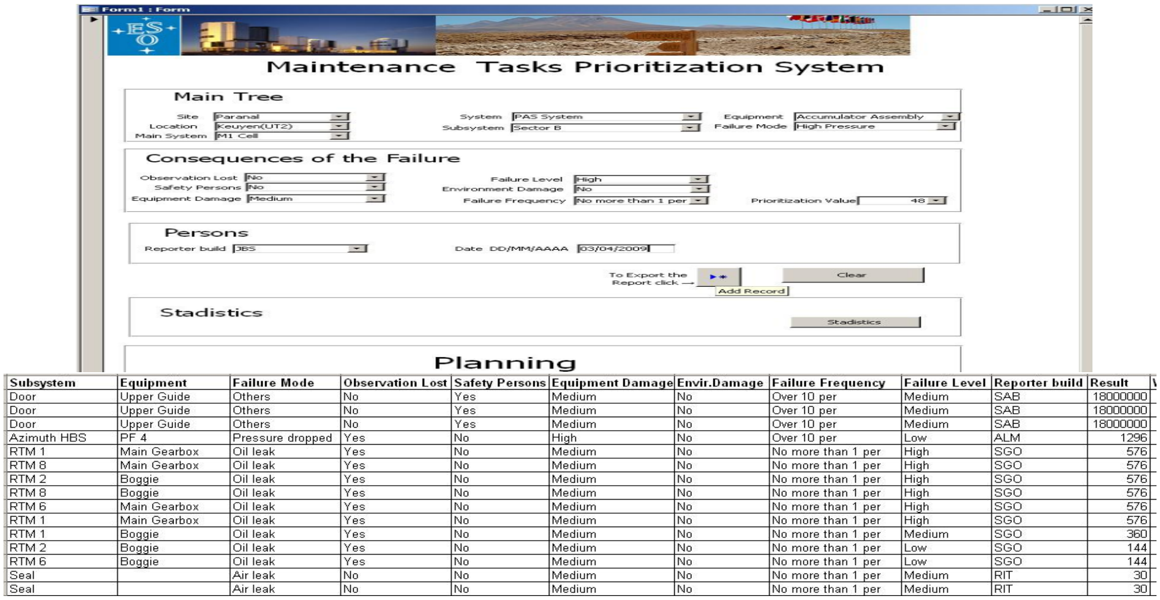
The assignment of the prioritization of the Maintenance task in an objective manner is a fundamental issue for any Maintenance organization in any environment. The Management of the Maintenance activities in our Observatory is not an exception. The Planning of the maintenance tasks is elaborated by taking into account the trigger of the work orders generated by our Computerized Maintenance Management System (CMMS). During the execution of the maintenance activities, a lot of information about the status of our equipment is collected and analyzed according to the different types of maintenance work completed. From the analysis of the information, new maintenance tasks are triggered and delivered to the Planning Group for scheduling. The main issue in this process is: which task has the highest priority? And under which criteria has this prioritization been assigned? Due to these kinds of questions, a priority software was created and is already in use by our department.

During the creation of this software an objective matrix was designed in order to obtain a clear criteria to evaluate if one task should have a higher score than another one. These criterios are:

- Time of observation lost
- Frequency of failure
- Safety of persons
- Level of potential failure
- Damage of equipment
- Damage of the environment

This software is currently used for the prioritization of the maintenance tasks triggered by the analysis executed by the groups of Preventive, Predictive and Corrective Maintenance. In the future, this tool should be capable of triggering a report for the prioritization of the purchase and reservation of the spare parts.

The next figure shows the main page of the priority tool and the result of prioritized tasks waiting for planning and execution.



Maintenance Tasks Prioritization System

Main Tree

Site: Paranal
Location: Keuyen(UT2)
Main System: M1 Cell
System: PAS System
Subsystem: Sector B
Equipment: Accumulator Assembly
Failure Mode: High Pressure

Consequences of the Failure

Observation Lost: No
Safety Persons: No
Equipment Damage: Medium
Failure Level: High
Environment Damage: No
Failure Frequency: No more than 1 per
Prioritization Value: 48

Persons

Reporter build: JBS
Date DD/MM/AAAA: 03/04/2009

Stadistics

Planning

Subsystem	Equipment	Failure Mode	Observation Lost	Safety Persons	Equipment Damage	Envir.Damage	Failure Frequency	Failure Level	Reporter build	Result
Door	Upper Guide	Others	No	Yes	Medium	No	Over 10 per	Medium	SAB	18000000
Door	Upper Guide	Others	No	Yes	Medium	No	Over 10 per	Medium	SAB	18000000
Door	Upper Guide	Others	No	Yes	Medium	No	Over 10 per	Medium	SAB	18000000
Azimuth HBS	PF 4	Pressure dropped	Yes	No	High	No	Over 10 per	Low	ALM	1296
RTM 1	Main Gearbox	Oil leak	Yes	No	Medium	No	No more than 1 per	High	SGO	576
RTM 8	Main Gearbox	Oil leak	Yes	No	Medium	No	No more than 1 per	High	SGO	576
RTM 2	Boggie	Oil leak	Yes	No	Medium	No	No more than 1 per	High	SGO	576
RTM 8	Boggie	Oil leak	Yes	No	Medium	No	No more than 1 per	High	SGO	576
RTM 6	Main Gearbox	Oil leak	Yes	No	Medium	No	No more than 1 per	High	SGO	576
RTM 1	Main Gearbox	Oil leak	Yes	No	Medium	No	No more than 1 per	High	SGO	576
RTM 1	Boggie	Oil leak	Yes	No	Medium	No	No more than 1 per	Medium	SGO	360
RTM 2	Boggie	Oil leak	Yes	No	Medium	No	No more than 1 per	Low	SGO	144
RTM 6	Boggie	Oil leak	Yes	No	Medium	No	No more than 1 per	Low	SGO	144
Seal		Air leak	No	No	Medium	No	No more than 1 per	Medium	RIT	30
Seal		Air leak	No	No	Medium	No	No more than 1 per	Medium	RIT	30

Figure 2: Priority tool

3.2. Weibull analysis

How do we know if our maintenance strategy is right? Currently there are many different types of analysis tools to answer this question. Of these, the maintenance department has recently implemented Weibull analysis.

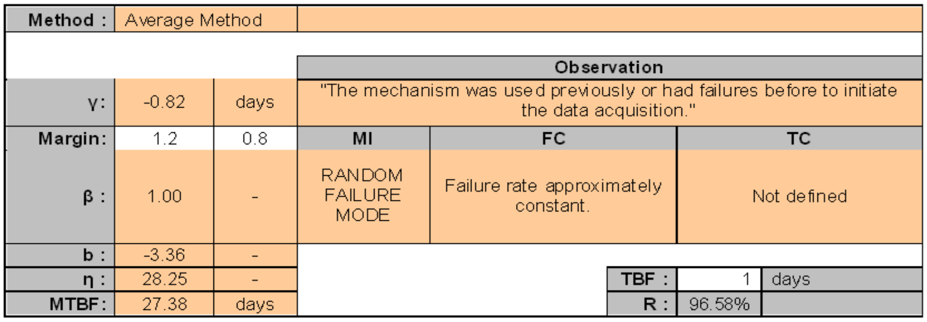
Weibull is a statistical distribution used in reliability studies, especially of mechanical systems. It has the advantage of being very flexible and of being adaptable to a variety of experimental observations. This analysis allows us to determine the failure mode of the system/equipment analyzed, the Mean Time Between Failure (MTBF) and the reliability value considering their individual evolution over time. These results allow us to modify the maintenance strategy, adjust the intervals of inspection or preventive maintenance and to determine what type of reliability value is obtained as final result.

There are several classes of Weibull's Model defined in terms of two, three or five parameters for modeling Exponential and Normal distributions. In our case, a three parameters model is used.

To determine the Weibull parameters (β, η, γ) exist different methods, one of these is the classical Weibull Graph, but due to the systematic analysis it is not useful. Another method is using the statistical knowledge related to Mean Rank and/or Average Rank (Bernard expression).

The next figure shows a case study in one of the system at La Silla Paranal observatory, where the failure mode, Mean Time Between Failure (MTBF) and reliability value were obtained:

Result: (***H:\Weibull-Excel\Results\HBS\UTS-MainStructure-HBS-All-Processed.xls***)



Method :	Average Method					
			Observation			
γ :	-0.82	days	"The mechanism was used previously or had failures before to initiate the data acquisition."			
Margin:	1.2	0.8	**MI**	**FC**	**TC**	
β :	1.00	-	RANDOM FAILURE MODE	Failure rate approximately constant.	Not defined	
b :	-3.36	-				
η :	28.25	-		**TBF :**	1	days
MTBF:	27.38	days		**R :**	96.58%	

Graphic visualization:

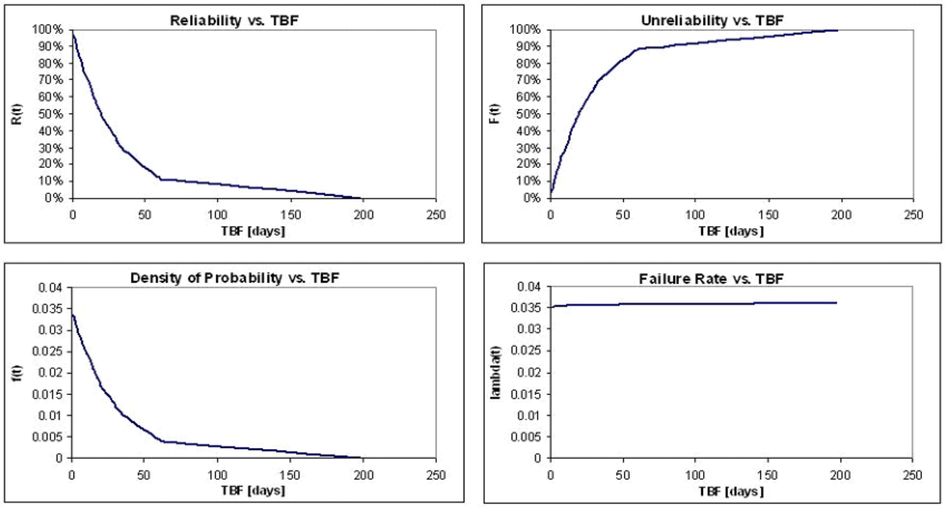


Figure 3: Weibull analysis of UT1-Enclosure-WSC

3.3. Jack Knife

To prioritize the functional failures that occur during regular operation, we have implemented and are currently using the Jack Knife graphics methodology, which is used to identify, classify and prioritize the failure through Graphics, and Logarithmic dispersion. This tool is an evolution of the logarithmic dispersion diagrams used on the priorization, which contains a third axis, Jack Knife it is a tool that it must be complemented with others tools to develop the maintenance management.

To build a diagram, it is necessary to determine certain parameters. For instance, maintenance downtime can be represented by the equation:

$$\mathrm{Downtime}_i = n_i \times \mathrm{MTTR}_i \rightarrow \mathrm{MTTR}_i = \frac{\mathrm{Downtime}_i}{n_i} \qquad (1)$$

Where downtime is the downtime associated with the failure code and ni and MTTRi represent, respectively, the number of failures and the mean-time-to-restore service. A scatter plot is used to plot mean downtime against the number of unplanned failures for each failure code.

The limit determination can either be absolute values determined by organization, or relative values that depend on the relative magnitudes and quantity of data. One approach for determining relative values is to use average values as follows.

The total downtime, D, consumed by unplanned failures is given by:

$$D = \sum_i \mathrm{Downtime}_i \qquad (2)$$

The total number of failures is:

$$N = \sum_i n_i \qquad (3)$$

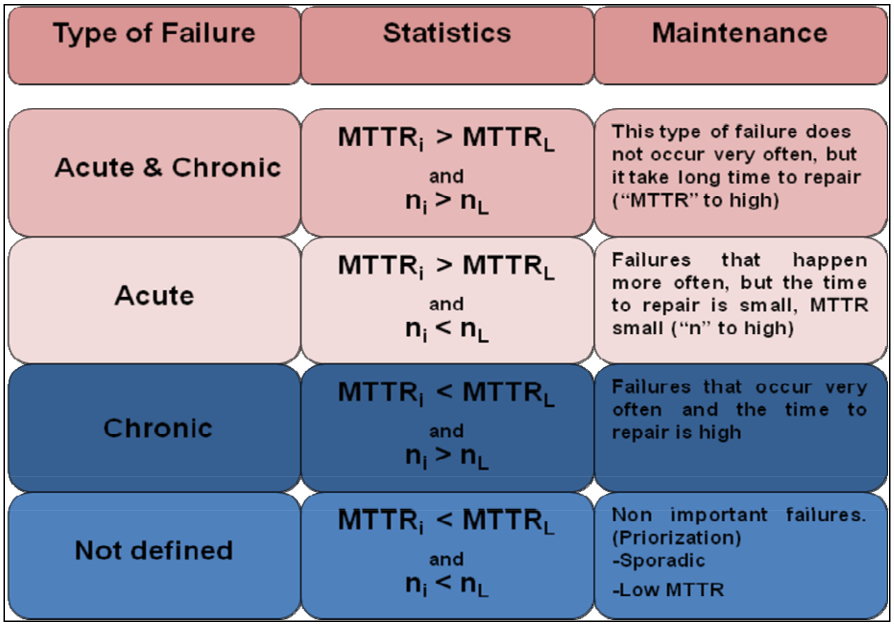
Letting Q be the number of distinct failure codes used to categorize the downtime data, the threshold limit for acute failures can be defined as:

$$\mathrm{Limit}_{MTTR} = \frac{D}{N} \qquad (4)$$

And the threshold limit for chronic failures can be determined as:

$$\mathrm{Limit}_{n} = \frac{N}{Q} \qquad (5)$$

The types of failures are defined as follows:

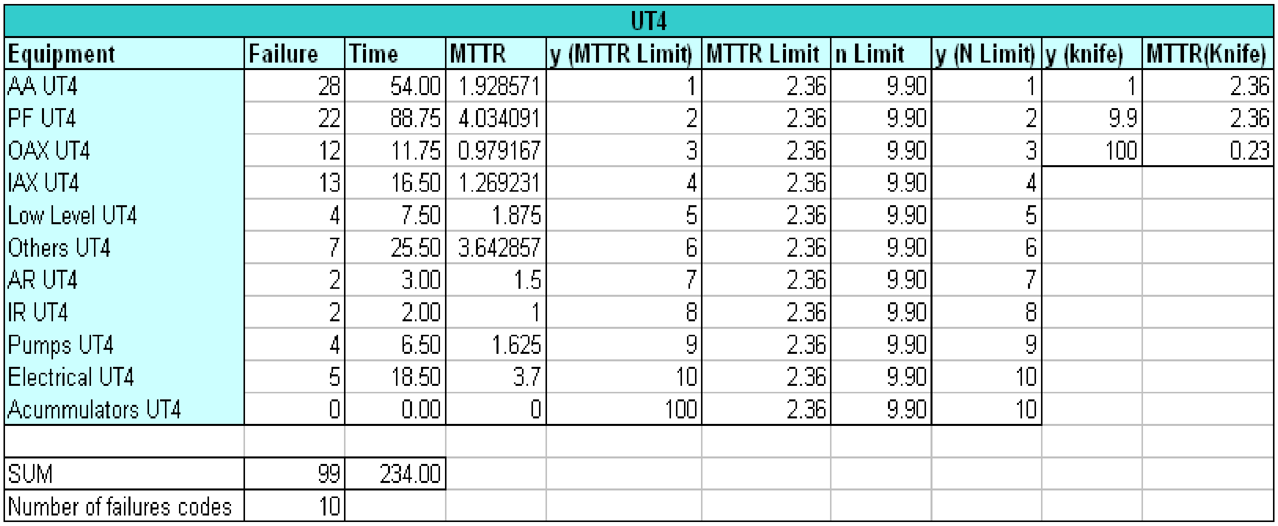


Type of Failure	Statistics	Maintenance
Acute & Chronic	$MTTR_i > MTTR_L$ and $n_i > n_L$	This type of failure does not occur very often, but it take long time to repair ("MTTR" to high)
Acute	$MTTR_i > MTTR_L$ and $n_i < n_L$	Failures that happen more often, but the time to repair is small, MTTR small ("n" to high)
Chronic	$MTTR_i < MTTR_L$ and $n_i > n_L$	Failures that occur very often and the time to repair is high
Not defined	$MTTR_i < MTTR_L$ and $n_i < n_L$	Non important failures. (Priorization) -Sporadic -Low MTTR

Figure 4: Failure Classification.

The chronic failures category can be split into subdivisions – chronic A and chronic B. Failures classified in the chronic A subdivision are those that contain the failure downtime directly superior to the multiple of n and MTTR set up as limit. Chronic b failures are those that require less repair time, but that can hide other costs.

Different problems can be associated to different sections of the chart.
The following figure shows a case study of one important system – the HBS (Hydrostatic Bearing System). For this case, all HBS failures recorded into our Computerized Maintenance Management System (CMMS) were considered as were the time needed to fix them.



UT4									
Equipment	Failure	Time	MTTR	y (MTTR Limit)	MTTR Limit	n Limit	y (N Limit)	y (knife)	MTTR(Knife)
AA UT4	28	54.00	1.928571	1	2.36	9.90	1	1	2.36
PF UT4	22	88.75	4.034091	2	2.36	9.90	2	9.9	2.36
OAX UT4	12	11.75	0.979167	3	2.36	9.90	3	100	0.23
IAX UT4	13	16.50	1.269231	4	2.36	9.90	4		
Low Level UT4	4	7.50	1.875	5	2.36	9.90	5		
Others UT4	7	25.50	3.642857	6	2.36	9.90	6		
AR UT4	2	3.00	1.5	7	2.36	9.90	7		
IR UT4	2	2.00	1	8	2.36	9.90	8		
Pumps UT4	4	6.50	1.625	9	2.36	9.90	9		
Electrical UT4	5	18.50	3.7	10	2.36	9.90	10		
Acummulators UT4	0	0.00	0	100	2.36	9.90	10		
SUM	99	234.00							
Number of failures codes	10								

Figure 5: Jack Knife table

The data was then incorporated into the above table, results were generated and the functional failures were prioritized. Prioritization is very useful for making maintenance decisions and can be complemented with other criteria. These results can identify critical systems that can be further analyzed with techniques such as Root Cause Analysis (RCA). The next figure is the graph resulting from applying this technique to the HBS.

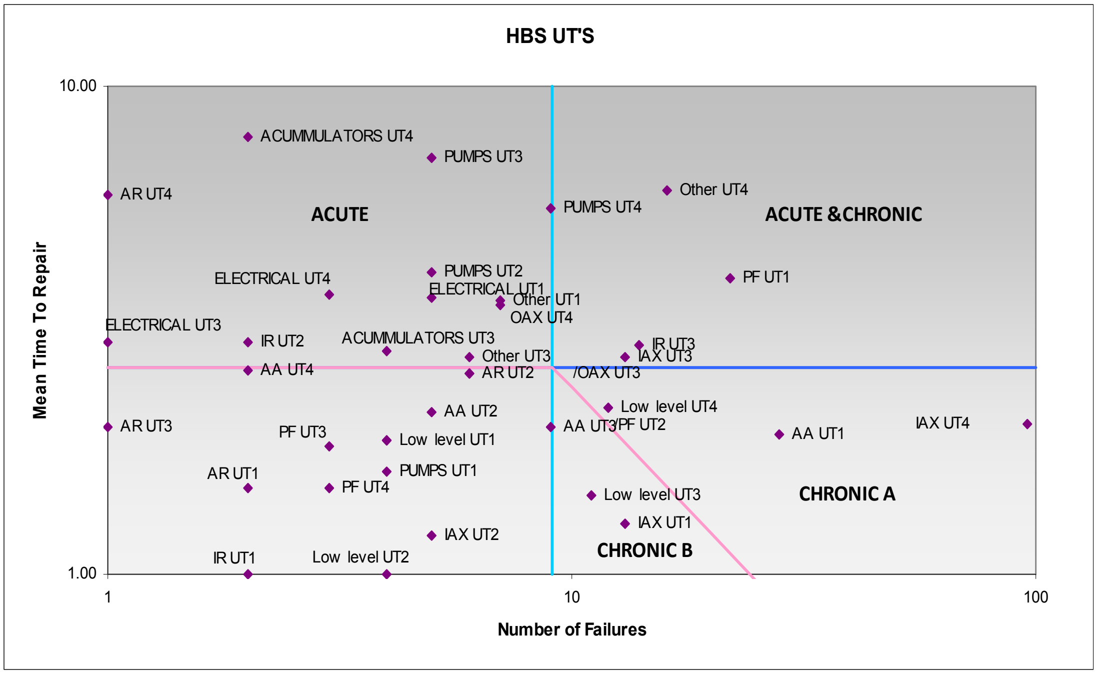


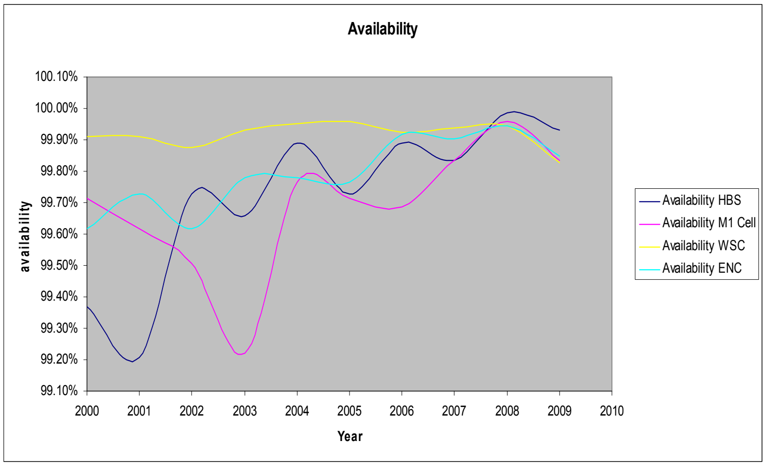
Figure 6: Jack Knife graphic

3.4. Calculate of indicators (KPI)

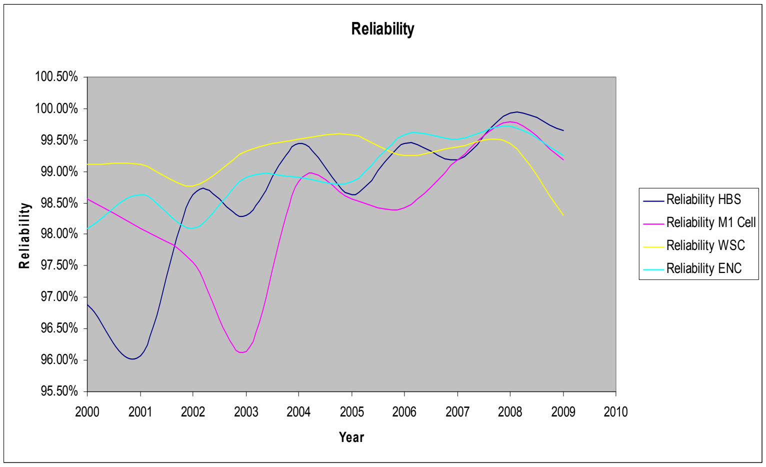
To evaluate permanently the performance of systems, subsystems and equipment under our control, we have included indicators as part of our tools.
Availability, reliability and Mean Time Between Failure (MTBF) are examples of indicators analyzed and evaluated in systems such as the Hydrostatic Bearing System (HBS), the Wind Screen, the Enclosure and the M1 Cell. They were evaluated and some decisions were taken in order to optimize their performance.

The next point will show the basic definition of these indicators and also the analysis performed on the system previously mentioned:

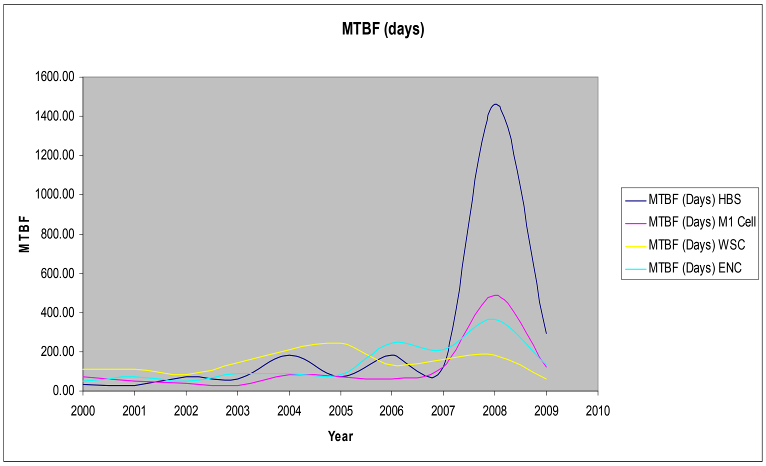
- Availability: The probability that the system is operating properly when it is required for use and means for obtaining feedback regarding the effectiveness of our implemented maintenance strategy at the observatory. The availability indicator should be calculated according to table of critical equipment already designed by our department.



- Reliability: The probability that a system or component performs its required functions under stated conditions for a specified period of time.



- MTBF: How long a machine can be expected to run before it dies or faults.



3.5. Autonomous group

Three autonomous groups were created in order to administrate and handle information used to trigger data for the reliability group.

These groups (PMO, RCA and PdM) concentrate data, analyze and trigger relevant information to be analyzed and approved in turn by reliability group.

Relevant information will be: Failures modes, PMO proposal, Potential failures data, prioritized tasks, training requirement, etc.

- **Preventive Maintenance Optimization**: A technique to modify and optimize the maintenance plans that are actually in operation. Some important aspects are:
    - Establish a methodology for optimization.
    - Acquire knowledge of the equipment and all associated systems, to describe and analyze all the plans to be optimized.
    - Establish criteria for decision-making (with respect to the priority or criticality of the system).
    - Obtain the information from the long description of work order.
    - Monitoring of the optimized plans.

- **Root Cause Analysis:** A technique used for finding the basal cause(s) of a problem. The application of this technique can be done using many tools available, including software packages. For example, the following tools can be used for RCA:
    - Cause – Effect Analysis
    - Fault Tree
    - Kepner-Tregoe
    - Ishikawa Diagram
    - 5 Whys

The application of a particular tool for doing RCA will depend on a problem's complexity

- **Predictive Maintenance Optimization:** A technique that helps to determine the condition of in-service equipment in order to predict when maintenance should be performed. This approach offers cost savings over routine or time-based preventive maintenance as actions are performed only when required. In addition, this technique is less invasive in the long term and therefore provides less risk for harming the equipment or team members.

4. CONCLUSIONS

- Adopting a reliability culture provides a powerful guide for analysis and improvement. However it must be adapted to the real requirement of our internal partners.
- The tools incorporated in our regular tasks should all together support the maintenance decisions. Each tool by itself is part of the culture of reliability, but they must not be considered individually to avoid improper usage of the tool.
- Reliability culture is part of continuous improvement and all tasks, tools and experience obtained must be reviewed continuously in order to detect mistakes and improve our maintenance process.

5. REFERENCES

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