Presenting Reliability Data Effectively

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Introduction

Sourcing, calculating and ultimately providing an interpretation of aircraft, system or component reliability, is considered to be a fundamental part of the aviation reliability exercise. However, it is important to realise that despite all of the hard work in producing reliability data, the exercise becomes meaningless if the data is presented to the managers from within both engineering and maintenance such that, at best, they don't understand it, and, at worst they misinterpret the overall reliability message.

Misinterpretation or plain dismissal of the reliability data would infer a complete loss of control of the effectiveness of the AMP, which would ultimately lead to loss of control of continuing airworthiness. The overall impact to the operator can be severe, both in terms of economic losses as well as the safety of the aircraft for which the AMP is designed to protect.

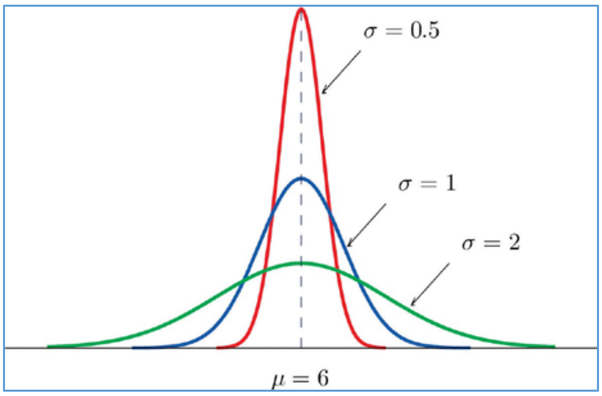
Clear communication of reliability data is critically important. Without unambiguous presentation, engineering and maintenance managers have little or no chance of acting correctly and in the interests of the effectiveness of the AMP, not least other economic or safety issues.

If good reliability data is presented badly, the data becomes meaningless and with it Safety & Airworthiness!!

This paper discusses the various forms of descriptive statistical formats, and makes recommendations as to which format to use for which type of report. Predominantly the paper discusses varying graphical and tabular presentation formats, and will not discuss Reliability Reporting structure and any associated guidance. This will be presented in a separate white paper.

Graphical Displays

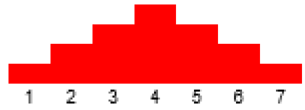
Graphical displays are predominantly useful, in order for the reliability engineer and the engineering managers to be able to immediately discern a distinct pattern in the data provided. These patterns are commonly described in terms of their center, spread, shape, and other unusual features. There are also common terms to describe certain distributions such as symmetric, bell-shaped, skewed, etc.



The following discusses terminology that is utilized to describe distributions similar to those opposite.

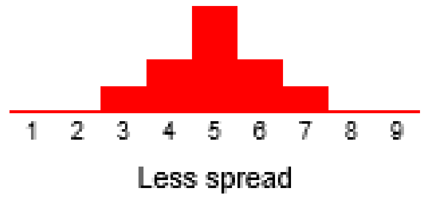
Centre

The **centre** of a distribution is located at the median[1] of the distribution. This is the point in a graphic display where about half of the observations are on either side. In the chart to the right, the height of each column indicates the frequency of observations. Here, the observations are centred over 4.



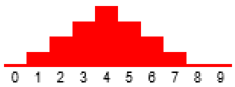
Spread

The **spread** of a distribution refers to the variability of the data. If the observations cover a wide range[2], the spread is larger. If the observations are clustered around a single value, the spread is smaller.



Shape

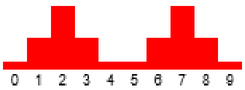
The shape of a distribution is an altogether more complex issue to describe. There are a number of characteristics that need to be discussed as part of the description.



Symmetric, unimodal, bell-shaped

Symmetry - When it is graphed, a symmetric distribution can be divided at the center so that each half is a mirror image of the other. Hence the name.

Number of peaks.



Symmetric, bimodal

Distributions can have few or many peaks. Distributions with one clear peak are called **unimodal**, and distributions with two clear peaks are called **bimodal**. When a symmetric distribution has a single peak at the center, it is also referred to as **bell-shaped**.

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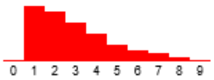
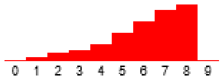
[1] The median is a simple measure of central tendency. To find the median, we arrange the observations in order from smallest to largest value. If there is an odd number of observations, the median is the middle value. If there is an even number of observations, the median is the average of the two middle values.

[2] The range is a simple measure of variation in a set of random variables. It is the difference between the biggest and smallest random variable.



Skewed right

Skewness - Some distributions have many more observations on one side of the graph than the other. Distributions with fewer observations on the right (toward higher values) are said to be **skewed right**; and distributions with fewer observations on the left (toward lower values) are said to be **skewed left**.



Skewed left

Uniform

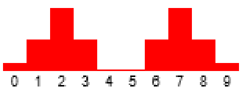
Uniform - When the observations in a set of data are equally spread across the range of the distribution, the distribution is called a **uniform distribution**. A uniform distribution has no clear peaks.

Unusual Features

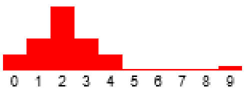
If skewing left and right is not unusual enough, sometimes reliability engineers also identify extreme values, no data, or just a plain lack of the same. These features are usually referred to as either Gaps or Outliers.

Gaps - These areas of a distribution where there are no observations. However, the reliability needs to be very careful, as no observations may actually mean observations might exist but have failed to be reported. **ENSURE THAT THE GAPS ARE 'NO OBSERVATIONS' RATHER THAN NON REPORTED.**

Outliers - Sometimes, distributions are characterized by extreme values that differ greatly or are completely out of step from the other observations. These extreme values are called outliers.



Gap



Outlier

Understanding and communicating data in terms of centre, spread, shape and symmetry, not least discerning clear trends is the starting point to an effective communication of just what is happening over a period of time to our aircraft, systems and components.

Investigations on the part of Engineering & Maintenance managers are usually triggered by such data, so it is important that reliability engineers are capable of providing everybody else with a clear unambiguous interpretation, and explain to the managers, just what the data is telling them.

Failure to get this bit right will almost certainly send any investigation off on the wrong tangent, worse still produce wrong or misleading results which may make the reliability situation worse.

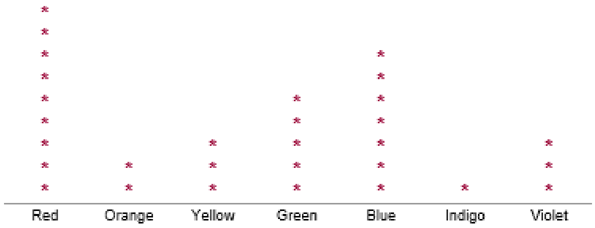
Graphical Display Options

Up until this point, this paper has merely discussed the means by which trends and distributions may be described, and the reader will note that histograms have been utilized to demonstrate the varying features and characteristics. However, not all reliability data will lend itself to just one display option. These are as follows:

- Dot Plots, Scatter Plots, Line charts
- Bar-Charts & Histograms

In the main, most published reliability reports tend to utilize a combination of Line & Bar Charts together with tabular displays. However, and for the purposes of completeness, this paper will provide a brief insight into all graphical display options as listed above.

Dot Plots



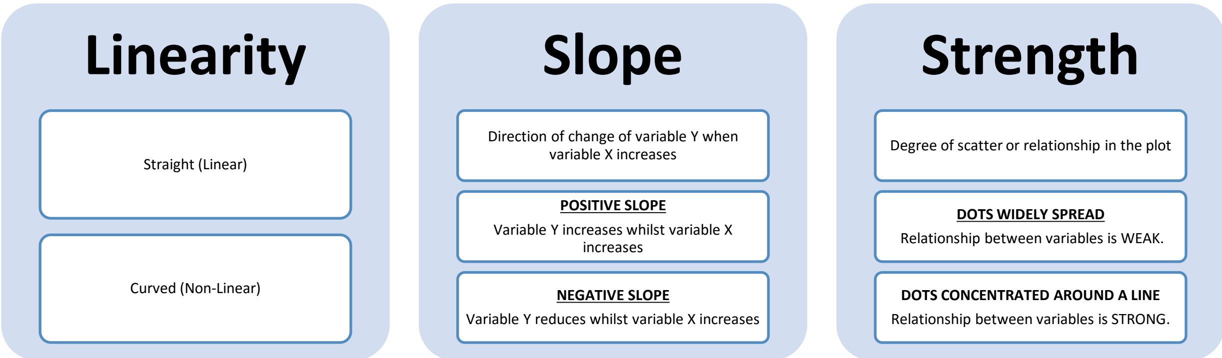
Dot plots are utilized to compare frequency counts small categories or groups of data. For example, a Dot Plot can be utilized to demonstrate failure frequency of say the Top-5 PIREPS by ATA Chapter.

In this way, categorized data is useful, as it provides and immediate indication of where issues are taking place, and allows the reliability engineer to alert the relevant departments that correspond to those ATA chapters.

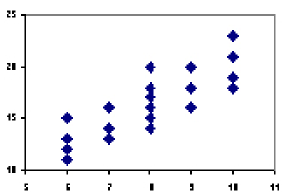
Scatter Plots

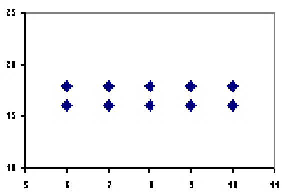
Scatter plots are utilized to display the relationship between two quantitative variables. For example, the number of specified component failures over a period of time (Flight hours or calendar days). Generally, each dot represents one observation from a particular data set and is positioned utilizing an X and Y co-ordinate on the chart, or ‘Bivariate data’.

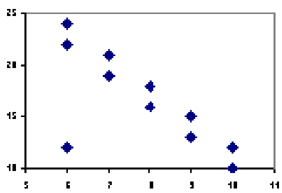
Because scatter plots utilize Bivariate data (X,Y Coordinates), reliability engineers have to employ a different set of characteristics to describe these patterns.

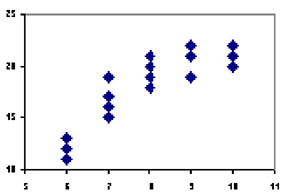


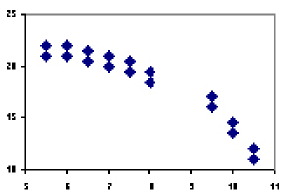
Typically Scatter plots tend to look something like the diagrams below.

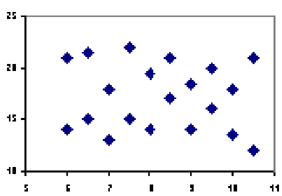

Linear, positive slope, weak


Linear, zero slope, strong

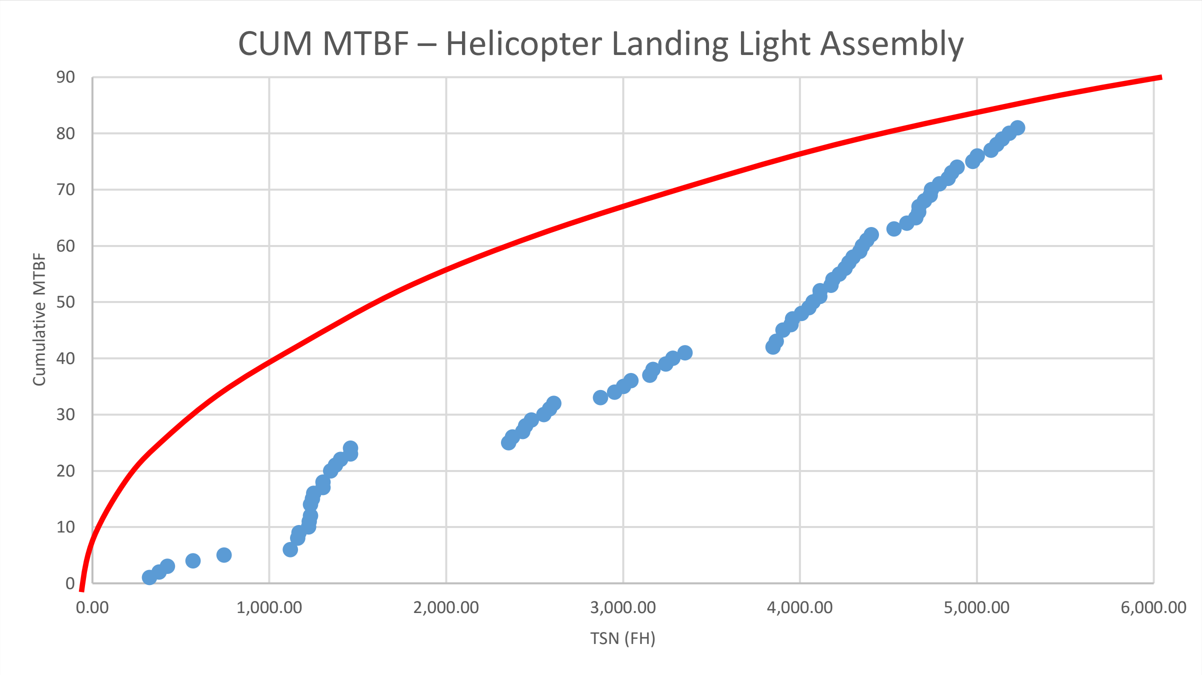

Linear, negative slope, strong, with outlier


Nonlinear, positive slope, weak


Nonlinear, negative slope, strong, with gap


Nonlinear, zero slope, weak

On its own, Scatter plots can be meaningless, however, if the reliability engineer introduces some form of recognized aviation standard against which the data can be compared, the reliability engineer and the engineering managers can discern how a system may be performing. Consider the example below which plots Cumulative MTBF against TSN.

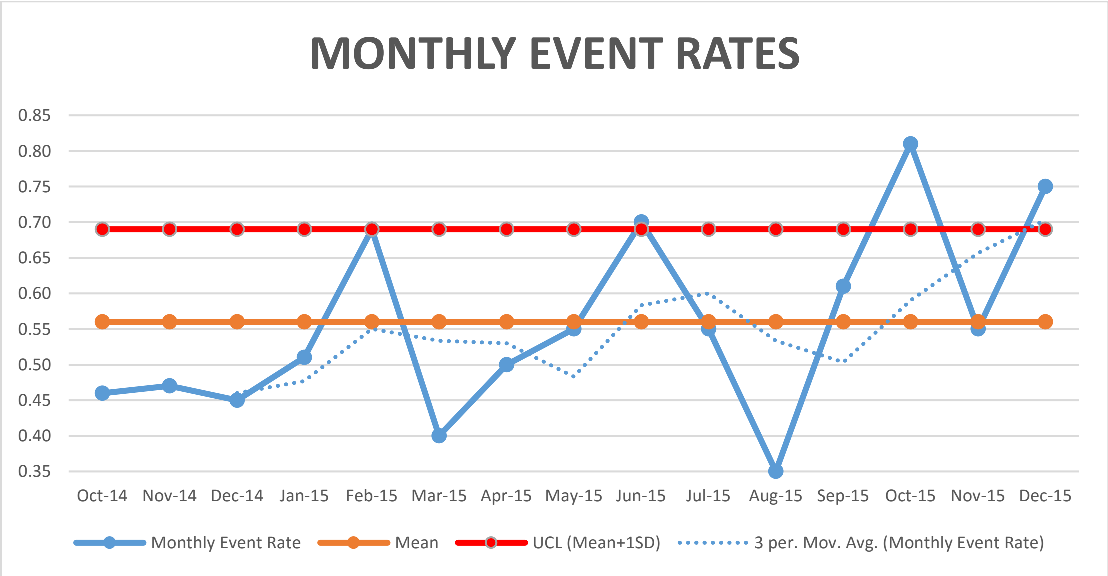


Red Line = Estimated MTBF per the Crow AMSAA model for repairable systems

Here we may suggest that the data is demonstrating a positive non-linear trend which in isolation may suggest a strong relationship between data point. However, the variance in the data in relation to the Crow AMSAA curve (Possible the OEM's projected Cumulative MTBF) demonstrates causes for concern particularly during the systems 'mid-life' phase.

Line Charts

Frequently, reliability engineers introduce trend-lines, or physically 'Join-the-dots' to provide a demonstration of variability for a single system or component. See the example below.

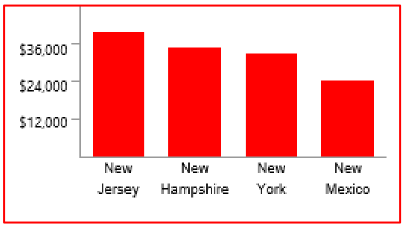


In connection with other standards like the Upper Control Limit (UCL)or the 3 month moving average, line diagrams provide an indication of performance of a specified system, and in the above case when and by how much the system has exceeded a particular control. The three month moving average can even be replaced with a linear or non-linear curve as a means of forecasting when an exceedance might occur.

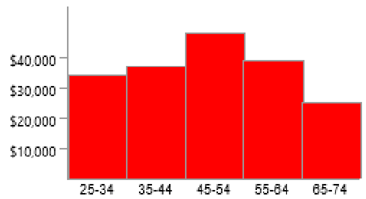
The purpose of this paper is to demonstrate display options, and not to discuss setting and adjusting Upper Control Limits, and trend lines. Please refer to the author’s white-paper on reliability reporting.

Bar-Charts & Histograms

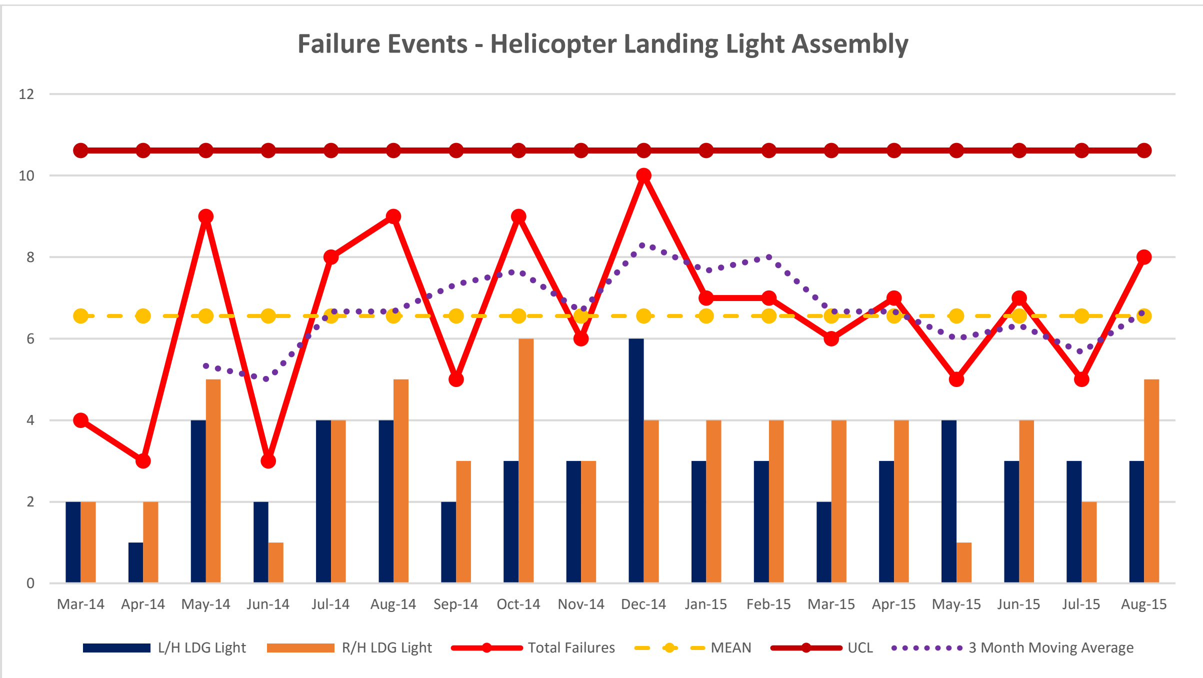
In much the same way as Dot Plots, Bar-charts and histograms are used to compare the sizes of difference groups. Rather than stacked dots above the particular category bar-charts are simply columns. The height of the column represents the size of the group. See opposite.



Histograms work differently, as the X-axis categorizes quantifiably (Number groups), with the distinguishing visual format of no gaps between the columns, and has the added advantage of allowing the introduction of bi-variate data into the analysis. However, much of aviation reliability data is categorized under particular ATA chapters, and further under simple sub-categorisations such as Left-Hand, Centre or Right-hand. To this effect the bar-charts are preferred in comparison to histograms.



In the diagram below, a bar-chart has been incorporated into the overall analysis in order to provide a ‘real-numbers’ indication of Landing light assembly failure between the left and right-hand sides of the helicopter. We might draw a conclusion that the right-hand side of the aircraft may be experiencing more events over the sample period, which may lead to deeper investigations of those helicopter landing-light assemplies.



Tabular Presentations

You may have noticed from the last diagram, that the chart has begun to look more and more complex and difficult to read. This tends to draw the conclusion that graphical presentations also have their limitations, and to a certain extent, it is better to move back to a textual format.

It is without doubt, that all Aviation Reliability reports also include numerical data in a tabulated format. This data can either be mono-variate or bivariate in nature, however most reports utilise tabulated formats to present qualitative data in a structured and easily digestible format. A case in point usually includes PIREPS data.

ATA Chapter	System	PIREPS	June-99	July-99	August-99	Three-month average	UCL	Mean	Alert status
21	Air conditioning	114	3.65	3.77	3.80	3.74	3.75	2.70	YE
22	Auto flight	43	1.80	1.48	1.45	1.58	1.39	1.21	WA
23	Communications	69	3.44	2.75	2.33	2.84	2.80	2.30	CL
24	Electrical power	29	1.15	0.87	0.98	1.00	0.94	0.60	AL
25	Equip/furnishings	104	4.17	3.69	3.52	3.79	5.43	4.38	
26	Fire protection	30	1.80	1.30	1.01	1.37	2.19	1.14	
27	Flight controls	48	0.99	3.07	1.62	1.89	1.94	1.26	
28	Fuel	36	0.65	1.16	1.22	1.01	2.32	1.27	
29	Hydraulic power	17	0.73	0.43	0.57	0.58	1.58	0.82	
30	Ice & rain protection	12	0.61	0.65	0.41	0.56	0.72	0.56	
31	Instruments	49	1.76	1.48	1.66	1.63	2.46	1.66	
32	Landing gear	67	2.41	2.06	2.27	2.25	2.72	1.76	
33	Lights	72	3.48	3.15	2.43	3.02	3.32	2.42	
34	Navigation	114	4.81	6.62	3.85	5.09	5.58	4.70	
35	Oxygen	19	0.31	0.67	0.64	0.54	0.41	0.23	YE
36	Pneumatics	25	1.11	0.80	0.85	0.92	1.19	0.77	
38	Water & waste	16	0.42	0.36	0.54	0.44	1.10	0.56	
49	Aux. power	42	1.41	1.48	1.42	1.44	1.63	1.38	
51	Structures	0	0.00	0.00	0.00	0.00	0.16	0.09	
52	Doors	31	1.41	1.05	1.05	1.17	1.62	0.92	
53	Fuselage	0	0.00	0.00	0.00	0.00	0.33	0.02	
54	Nacelles & pylons	1	0.00	0.00	0.08	0.03	0.22	0.10	
55	Stabilizers	0	0.00	0.00	0.00	0.00	0.16	0.09	
56	Windows	0	0.00	0.04	0.00	0.01	0.09	0.06	
57	Wings	0	0.00	0.00	0.00	0.00	0.33	0.15	
71	Power plant	11	0.65	0.54	0.37	0.52	1.30	0.91	
72	Engine	4	0.31	0.29	0.14	0.25	0.47	0.22	
73	Fuel & controls	17	0.96	0.47	0.57	0.67	0.84	0.61	
74	Ignition	11	0.08	0.40	0.37	0.28	0.46	0.30	
75	Air	53	1.52	1.63	1.79	1.65	1.11	0.66	RA
76	Engine control	3	0.23	0.14	0.10	0.16	0.33	0.15	
77	Engine indicating	22	0.53	0.76	0.74	0.68	0.96	0.68	
78	Exhaust	3	0.50	0.43	0.10	0.34	0.90	0.64	
79	Oil	5	0.19	0.22	0.17	0.19	0.83	0.48	
80	Starting	3	0.27	0.29	0.10	0.22	0.28	0.17	CL
	Total	1070							

NOTE: Alert status codes: CL = clear from alert; YE = yellow alert; AL = red alert; RA = remains in alert; WA = watch. (Kinnison)

Generally referred to as a 'One-way' or 'Relative Frequency' table. The tabular equivalent of bar-charts, one-tables display categorized data in the form of Frequency counts (Events) or relative frequencies. In the above example, Tabulated data is categorized into ATA chapter, showing the most recent 3 months of reliability observations.

Conclusion

- Even good reliability data if presented badly, becomes meaningless along with Safety & Airworthiness.
- Graphical Displays help Reliability Engineers and Manager discern distinct patterns or behaviours associated with aircraft systems and components.
- Operator reliability reports tend to utilize a combination of Line graphs, bar-charts together with tabular displays of data.
- With large volumes of data graphical displays become over complicated and difficult to interpret. Sometimes it is better to utilise tabular formats as the simplest means of presenting categorised data.