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Shooting the Rapids

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Abstract

"Water, water, everywhere, nor any drop to drink".

(This is the lament of the Ancient Mariner when stuck in the middle of the sea; the water is salt and unfit for consumption – from the Rime of the Ancient Mariner by Samuel Taylor Coleridge.

1. Introduction

Robert Butler [1], probably like many others, has drawn an analogy between water and data in that there is enough to drown in but none that can satisfy our thirst. He recognises that we have a thirst for data but without the ability to make proper use of it. From personal experience I can agree with Robert. The thirst for data is one that cannot easily be quenched, regardless of the climate; there seems to be an assumption that the more we have the better able we will be to control our systems and processes. But, in the maelstrom of data, he is coming from the perspective of someone whose aim is to bring calm by delivering analytical product.

Why would we want to enter the maelstrom in the first place? Simply put it is very often the case that we are searching for what some regard as the Holy Grail of IT – Organizational Transformation through the application of Information Technology – to become effective and efficient. But why exactly? We live in a competitive world where it is no longer enough to have a business strategy of being a low cost producer/service provider or maintaining one's market share. Today it is also the ability to respond quickly to opportunities and threats, to reduce time to market, to improve customer service, and to improve the quality of our products and services, particularly in a climate of tighter and reducing Resource Control Totals. Organizations recognize past failures and/or inefficiencies and they know that they can do better. IT is the enabler for making sense of their considerable data resource and the answers lie in the maelstrom of data. However, we must recognise as others have done that IT in itself cannot bring about organisational transformation.

2. Organizational Transformation

In 1985, Porter [2] suggested that a company has a chain of activities which create value and which are 'performed to design, produce, market, deliver and support its product'. Porter also pointed out that each activity employs purchased inputs, human resources and some form of technology. Saunders [3] said that "A business strategy needs to give direction to these activities and to ensure that the interrelationships between them are taken into account. Thus, the strategies for these activities should support the overall strategy of the business with regard to mission, objectives, competitive scope and competitive advantage." Saunders is clearly advocating an integrated strategy that permeates all elements of the business and thereby enables these elements to positively contribute to product value.

Galliers and Baets [4] effectively agree with Porter and Saunders, and many others for that matter, e.g. Dutta & Doz [5], Jordan and Tricker [6], Ward and Peppard [7], in this respect. Galliers and Baets [4] describe this in a “Circle of Forces”, which is illustrated below.

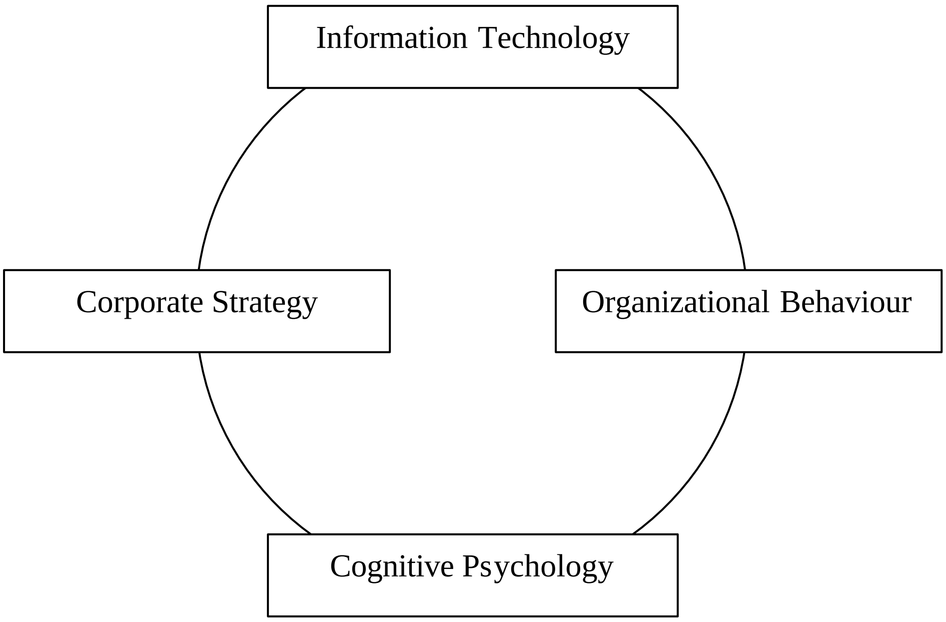

Figure 1
Circle of Forces
(Galliers and Baets [4])

3. Data

But whatever the Corporate Strategy, insofar as most organizations are concerned, they are driven by outputs and require data to produce, support and validate them.

Robert Butler [1] acknowledges that “Data elements are often defined incorrectly, stored incorrectly, not updated, and the data of interest hidden among masses of irrelevant data." He makes an armchair empiricism that “The result is that typically, 90% of an analyst’s time is spent organizing data and only 10% performing analysis with it.” Whilst I would not agree or deny his acknowledgement or armchair empiricism, it does bring into question the quality, meaning and utility of the analytical product that is delivered in relation to the information that is required by the customer. If the customer knows what s/he wants and can recognise it when s/he sees it, it follows that they will have shot the rapids together, hopefully without spills, and end up in a benign flow where steering is easy; everything behind is understood and the way ahead makes predictable sense.

Many organizations particularly the larger ones have vast quantities of data flowing in various directions. I have certainly seen the trend appearing whereby there is an increasing will to bring the data into a pool where it can be more readily managed; a data warehouse. I am neither an advocate particularly for data warehousing or against it. Indeed there are strong arguments both for and against their use. Two of the many opposing views are reproduced from LGI Systems [8] below.

For: “To make it easier, on a regular basis, to query and report data from multiple transaction processing systems and/or from external data sources and/or from data that must be stored for query/report purposes only.”

> ”For a long time firms that need reports with data from multiple systems have been writing data extracts and then running sort/merge logic to combine the extracted data and then running reports against the sort/merged data. In many cases this is a perfectly adequate strategy. However, if a company has large amounts of data that need to be sort/merged frequently, if data purged from transaction processing systems needs to be reported upon, and most importantly, if the data need to be "cleaned", data warehousing may be appropriate.”

Against: “Data warehousing can become an exercise in data for the sake of the data.”

> ”Organizations find that there are unlimited opportunities to add data to their data warehouse. Data warehouses, like most other complex systems, take a life of their own. Unfortunately, adding data without questioning the business value of the data can lessen the business value of the data warehouse and quickly increase the cost of maintaining the data warehouse.”

Whatever your personal view, I can tell you that I have been known to make what I feel are appropriate observations on almost any subject under the sun. Donald Rumsfeld [9] famously but not quite succinctly said, “there are known knowns”, etc. However, it is arguable that, at the end of the day, Mr Rumsfeld can be excused for being unclear and perhaps uncertain because he is only human after all; he is not a professional engineer or logistician. He acts out of conscience; he knows what he knows.

> **Conscience.** What is conscience? As *science* means *knowledge*, *conscience* etymologically means *self-knowledge* . . . But the English word implies a moral standard of action in the mind as well as a consciousness of our own actions. It is also concerned with duty [10]; we do what we think is right because we are responsible and it is our duty to be effective and efficient.

But is it enough to have a conscience? I have one I am told, but that, in itself, can only make me act out of good intent for the benefit of all; it doesn’t mean that when I act out of conscience, knowing what I know, that I will always be right in all respects; in fact I could be totally wrong at times. However, if I apply my scientific knowledge properly I can be certain to some predictable extent that my expectation will be met because I am using empirical truth.

> **Science.** As seen above, science means knowledge; it comes from the Latin “scire”, to know. But science is more than knowing, “it is the systematic study of the nature and behaviour of the material and physical universe, based on observation, experimentation and measurement, and the formulation of laws to describe these facts in general terms. [11]

So where does that leave me? Well, fortunately, I am a professional engineer and logistician. Therefore if I do know something, I should act out of conscience based upon science.

4. My Problem

Having been party to many discussions in particular about equipment reliability and availability and their contribution to the planning for and conduct of required tasks/operations, it has long been clear to me that the understanding of the terms Reliability and Availability vary dramatically among the people employed within organizations. This is quite understandable because these terms have multiple definitions that tend to be applied within discrete areas of authority, responsibility, and specialization. Therefore we should not be surprised to find that there is misconception and misunderstanding when these terms are employed routinely without definition agreement and/or qualification where necessary. I have seen these terms used in a variety of contexts and sometimes interchangeably.

The assumption seems to be that we are "comparing apples with apples". If we are then that is fine. But it is not enough because when making comparisons we need to ensure that not only are we comparing apples, but that the variety of the apples under consideration is known to enable us to draw reasonable conclusions; whether comparing Cox's with Cox's or two different varieties to understand the differences.

The matter is made more difficult because there is a felt need to express equipment reliability and availability in a precisely quantitative "measured" manner, usually Mean Time Between Failures for Reliability, or, Availability as a percentage of the fleet, that is, has been, or will be available. A single figure can speak volumes to some people without any absolute understanding of how it came to be. It is authoritative because it is deemed to have numerical certainty and a foundation in reality because it purports to reflect that which has been reported, analysed and scrutinized. Therefore it is the mathematical truth.

However, measurements are well and good. But it is unreasonable to assume that just because you start out with a measurement of something it means that you have control of it and it will never vary. If we deem a process or activity to be of sufficient importance that we would wish to control it, then it follows that we must conduct analysis to understand in absolute terms the significance and utility of the measurement(s) in relation to managing it.

In an ideal world systems would never fail. However, we live in an imperfect world where chemistry, the laws of physics and even nature are conspiring against the ideal. A simple example of this is bird strike causing an aircraft engine to fail. Whilst this is a relatively rare occurrence, we accept that equipment does fail for a variety of reasons. It is widely acknowledged that fatigue is a primary cause of equipment failure in mechanical equipment. More recently the Computer Aided Life Cycle Engineering (CALCE) Electronic Products & Systems Center of Maryland University [12] physics of failure analysis has shown that this is also the case in electronic products. Whatever the cause, in the real world we accept that equipment isn't absolutely reliable, that failures do occur and consequently that maintenance is necessary, even for relatively simple equipments, therefore it cannot be available at all times.

Stevens et al [13] talk about "coping with risk and change". They say that risk and human fallibility are constants in system development and operations. "The perfect design is beyond our reach, reason has its limitations, and life is not predictable". On the face of it, this seems to acknowledge not only the physical constraints of the natural world but also Simon's notion of bounded rationality (1957). Additionally they say "Although systems engineering is about prediction and direction, the future is only partially discernible." This seems to acknowledge the uncertainty and in so far as the user in a non-profit organization is concerned this will likely manifest itself as an inability to accomplish its mission in the manner and/or with the resources it should reasonably expect to employ; in essence, reduced availability. Interestingly, in their book, Stevens et al [13] make no specific reference in the index to operational availability or availability of any sort and therefore not surprisingly neither does it feature within the glossary of terms.

5. Reality

Arguably this type of bounded rationality perspective may in part explain why the noted physicist and academic Professor Arie Dubi [14] has come to form the view that "System Engineering was, for many years an art composed of an eclectic collection of methods and procedures. A vast array of excuses ranging from lack of data to excessive unnecessary complexity was used to justify semi heuristic solutions based on uncontrolled approximations." In his experience, exponential distributions are assumed in almost all cases of reliability and availability analysis, detaching the problem from ageing and maintenance issues. Where maintenance is required, immediate repair is assumed. In spare part models homogeneous Poisson processes are assumed and no relation is established between resources (such as spare parts) and system performance. "Most categories of system engineering are treated as independent subjects, such that Availability analysis is done as if no spare part problem exists. Maintenance analysis is executed with no relation to resources and performance and non-Markovian analysis is almost unheard of."

Whilst this may seem like someone "taking a pop" at systems engineers, the view expressed by Arie Dubi is absolutely representative of my experience to date.

Dubi's view is effectively supported in Engineering Reliability whereby Richard Barlow [15] questions whether the use of classical statistics is logically tenable. He contends that classical statistics is based on deductive analysis (the logic of mathematics), whereas statistical inference and decision theory are concerned with inductive analysis (probability judgments). He quotes Basu [16] who said, "It took me the greater part of the next two decades to realize that statistics deals with the mental process of induction and is therefore essentially antimathematics. How can there be a deductive theory of statistics?" Therefore the ability to forecast availability goes beyond statistical analysis of the reported times between failures, the corrective and preventive maintenance times and the logistic delay times. However it is dependent upon the empirical data provided by such reporting and therefore the two are inextricably linked. Forecasting examines empirical data, building a picture of individual equipment and fleet behaviours that can be scientifically analysed to mathematically express observed relationships between reliability, operational availability and support factors to calibrate the probability of future operational success and cost impact.

So, why am I particularly concerned about Availability? Why not Reliability to the same extent? Well I am concerned about Reliability but it comes from the abstract world of design. In Reliability Simplified: Going Beyond Quality to Keep Customer for Life, Harrington et al [17] make the case that Intrinsic Reliability is defined by the design. I wholeheartedly agree.

We know, particularly for complex items, that although an item is a function of system design, the item does not generally of itself constitute a system [18]. Additionally, the probability that an item will perform its required functions for the duration of a specified mission profile is dependent upon its use up to the point that it embarks on the mission, and the availability and opportunity to apply the resources required to maintain it for the period between that point and the planned mission completion. Therefore in itself, the suitability and usefulness of reliability as a measure of effectiveness is limited.

People also use the terms Intrinsic and Inherent Reliability, probably because if we consult most dictionaries the terms Inherent and Intrinsic are regarded as wholly interchangeable. I take a different view in this respect because I have always regarded that something Intrinsic has purity, the essence of something, rather than Inherent, which is closely connected with, stems from, or holds onto the Intrinsic nature but does not necessarily perform or react exactly as expected in terms of the Intrinsic value. The difference between the two terms is borne out in various etymological dictionaries. Therefore, I consider that insofar as Inherent Reliability is concerned, we have crossed over the line into the domain of Availability.

Simply put I live in the real world, the physical world, where I have to deal with the physical truth, the practical consequences of Reliability, Availability, because I want to make an effective and efficient contribution to the outputs of my organization.

Availability can be defined as the probability that the system is operating properly when it is requested for use (Instantaneous or Point Availability). That is, availability is the probability that a system is not failed or undergoing a repair action when it needs to be used.

But the definition of availability seems to be flexible. As a result, there are a number of different classifications or types of availability; Inherent, Achieved, Instantaneous, Steady State and Operational as examples. The different classifications are largely based on the type of downtime one chooses to consider in the analysis.

Blanchard [19] says that Availability is viewed as "the measure of the degree a system is in the operable state at the start of a mission when the mission is called for at an unknown random point in time. This is often called operational readiness." In fact it can be termed in many different ways. For example Airbus use the term Operational Reliability [20] to describe what in essence is Availability." Like James V Jones [21], I am of the view that "The mere fact of possessing a system provides no value to the owner. The value of possessing a system comes through the ability to actually use it. Therefore the ability to use a system becomes the final gauge of its value to the owner. The most common term for this value of a system is availability, or the ability to use a system when required." He makes the point that conceptually it is not enough to own a car; it is the ability to have it provide transportation upon demand. If the car is inoperative, unavailable, because of some failure, or has no fuel or tyres, or driver for that matter, then it cannot provide its necessary value contribution to transportation capability. Therefore it can be argued that the concept of availability has been developed as a gauge of the value and a measure of the effectiveness of a system. Availability is a metric; it is a performance criterion for repairable systems that accounts for both the reliability and maintainability properties of a component or system.

What is consistent and clear from the multiplicity of classifications and definitions, other than Point Availability, is that Availability is concerned with probability. From the users' perspective perhaps the most important of the classifications and types is Operational Availability because at this stage we are delivering our Capability for a purpose, as a means to deliver outputs.

6. Capability

Reality, because of its complexity, can be limiting in practical and analytical terms. Figure 2 below is used in some arenas as an illustration of the contracting solutions for equipment procurement and support, progressively leading to acquisition of capability.

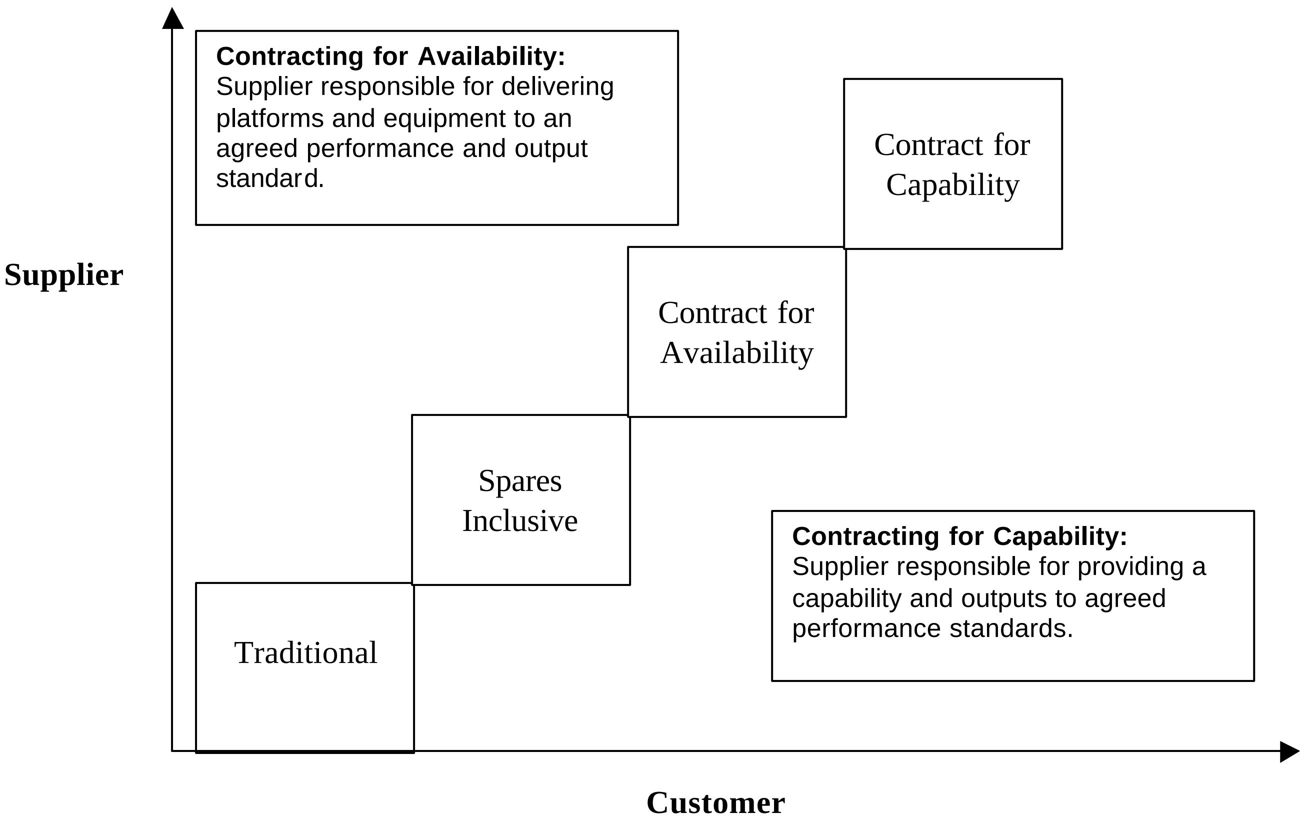

Figure 2
Transformation Staircase
(UK MOD Acquisition Management System, 2005 [22])

Some take the view that the illustration is a display of absolute intent because the progression appears to be onwards and upwards, as if a staircase to better things, which may or may not be true. It is true however that it is recognized that there cannot be a 'one size fits all solution. Developing strong and healthy Customer/Supplier relationships is key in this as a means of achieving value, being output rather than input focused, forging the value chain, and taking a whole-life perspective. Consequently there is a declared intent to have more and improved strategic, professional partnering arrangements, in the public, private and public/private arenas. Although the idea of partnering and collaboration with key suppliers is not new in itself, in this sense it requires a cultural shift to "an approach with an attitude and a management ethos, (towards selected suppliers) of openness, effective communication, close collaboration and co-operation, trust, honesty, transparency, sharing and mutual benefit." CIPS [23]

Clearly, it is accepted that there must be greater involvement between Customer and Supplier to make transformational progress. What is not always so readily recognised is that Customer and Supplier sophistication must also be improved if there is to be a real chance of the Customer properly articulating expectations and the Supplier meeting them. They must understand the outputs and the means to deliver them. Ultimately this means entering the maelstrom together to make sense of the data whirlpool.

"Capability" is easily defined, but it is not simple. For example, it can be defined as follows [22]:

> **An operational outcome or effect that users of an equipment or service need to achieve. (Sense One)**

It can also be defined as:

> **The operational need which is satisfied by the deployment of an operational system integrated with other cooperating systems. (Sense Two)**

"Effect" can be defined [11] as: 1. "Something that is produced by a cause or agent; result. 2. Power or ability to influence or produce a result. 3. The condition of being operative."

It is obvious that we cannot guarantee that users could or would achieve or influence the required operational outcome or effect; we either do or we don't. If we do, we don't necessarily know if we are being efficient. If we don't, we don't necessarily know that we are being inefficient. Therefore it is unreasonable to attempt to measure Capability in this sense.

However, if we consider Capability in terms of Sense two, then it may be possible to consider the value contribution of the deployment of an operational system to output effectiveness.

There are broader views of effectiveness. Jane Ellis cites Seashore and Yuchtman [24] who define 'effectiveness' as 'the ability of an organisation to exploit its environment in the acquisition of scarce and valued resources to sustain its functioning'. Martin Christopher [25] supports Seashore and Yuchtman in their assumption about scarce resources and develops it further; "Since we can assume that money spent on service is a scarce resource then we should look upon the service decision as a resource allocation issue." In both cases efficiency and effectiveness are inextricably linked to outputs.

If we can understand the contribution of our resources to our output, potential and/or actual capability, and the end to end efficiency of our processes, we can begin to recognize their value contribution and make allocations appropriately. We should separate the tangible from the intangible and have real performance measures that can be seen to relate to product or service value and effectiveness [26]. These metrics should be the drivers for decision making both from the operating and operating cost perspectives. Easier said than done!

Recently I was party in a discussion with representatives of a global consultancy firm who had been engaged to improve availability in a specific area. When I asked them what their definition of availability was, I got a slightly pained and unclear response; but I am certain they went away somewhat better informed. Also recently I was party to discussion with a major prime contractor who was similarly looking to improve availability in a different, but related, area of business. Therefore it seems that there is recognition that availability of some sort is key to delivering outputs but there is uncertainty about the understanding of exactly what and how. It also confirms Stephens et al's view that "overall behaviour emerges only when the complete system can be seen as an entity." I interpret this to go beyond the systems engineering environment because if we accept that complexity is a key issue, then we should accept that there is also uncertainty, even beyond the point of acceptance that cannot be quantified without empirical data. Furthermore, Stevens et al [13] define a system as "A human-made entity with a distinguishing and defined purpose that draws on integrated, constituent parts, each of which does not individually possess the required overall characteristics or purpose." Whatever, the elements forming an entity are interrelated, interdependent or interacting and it is only when a system is brought into use that comparison between the design abstraction and the physical reality can be properly made; how does the actual failure rate compare with the output design failure rate.

But how often are we the architects of our own downfall because we have accepted what we are told by the designers and manufacturers, its reliability? Do we really understand what our expected value of availability should be? Do we ever quantify it in any truly meaningful way? Is it appropriate to plan based upon a negative exponential distribution and expect that reality will match that expectation?

Albert Einstein [27] said that "As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality."

The shape of the curve which is a function of the actual failures cannot be deemed to be a product of an exponential distribution unless analysis reveals it as such. Just because three objects have the same surface area does not mean that they are the same shape. It only takes one parameter, the radius, to calculate the surface area of a circle, whilst for a rectangle it takes two, length and height, and for a trapezium it takes three, lower length, upper length and height. Therefore it is unreasonable to summarize the shape of a curve unless there is sufficient information to properly describe its attributes.

It is the ability to characterise the distribution of failures mathematically as a function of the observed failures in finite populations against a time related independent variable and approximate these to infinite population conditional probability models that enables probability analysis to begin. The measures of location and of spread or variability can be determined and these in conjunction with the characterization can describe the curve under consideration and enable the calculation of probability of failure and conversely survival. Barlow [15] offers a definition of probability as "a degree of belief held by an analyst or observer". He says "The idea here is that probability is an *analytical tool based on judgement useful for making decisions*. Of course we are free to adopt observed frequencies as our probabilities if we are consistent, but observed frequencies are not otherwise probabilities according to this definition."

It is interesting to note that in consideration of the maelstrom, organisational transformation, partnering and the various views of reliability and availability that Reliability Centred Maintenance is in vogue and seen by some as medicine for making things better.

Reliability Centred Maintenance (RCM) is a "method for establishing a scheduled (preventive) maintenance programme which will efficiently and effectively achieve the inherent reliability and safety levels of equipment. It is methodology which can be applied to the development of a preventive maintenance programme and results in improved component reliability and minimised overall programme costs. The intended end result is improved overall equipment safety, availability and economic operation." ARMP [28]

RCM as a methodology takes a Physics-of-Failure perspective including root-cause analysis, and evaluation of the impact of defects and stresses on product reliability. Based on the analysis, the failure is eliminated, or abated, by re-engineering the design and/or the production, assembly, and/or support processes.

But is RCM as an oxymoron? If we accept that RCM can improve the operating reliability of equipment and consequently increase availability, then by that acceptance are we not denying that failure is generally exponentially distributed?

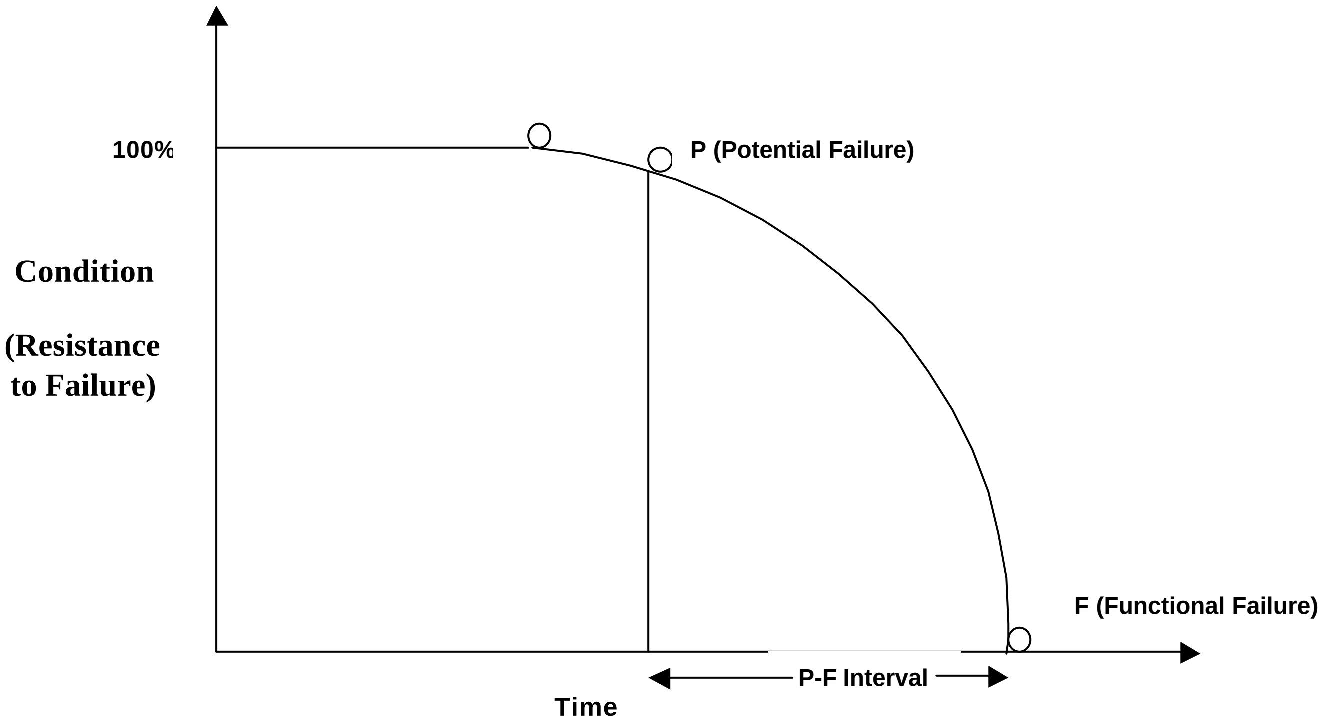

Figure 3
The P-F Curve
(Adapted from Cranfield University, RMCS, 2004)

If failure is exponentially distributed, through RCM, broadly speaking, we must be aiming to increase the Mean Time Between Failures and/or decrease costs. However the P-F Curve above belies the exponential failure of an item under consideration because, although only an illustration, it does characterise the LRU/component under consideration as having a minimum period of time before it will degrade and ultimately fail; the distribution of failures is not exponentially characterised. This begs a number of questions.

a. If the support system is functioning as designed, does the empirical data indicate a correlation relationship between the failures of the LRU/component under consideration and its B_{10}, B_{50}, B_{90} lives?

b. Will the re-design or re-engineering of the LRU/component positively affect the Mean Time Between Failures of the system such that availability improves?

c. How would we know that availability has improved?

I am not going to speculate on the first question because that is a matter for analysis. On the second, I only want to say that it is not necessarily the case that redesign or re-engineering will actually improve availability. It may be the case that we are using less of the component under consideration, but how has that impacted upon the overall system availability? In his book "System Engineering Science" [29], Arie Dubi shows that it is scientifically possible that an LRU/component with a higher failure rate can produce a higher overall availability of a system. My third question is largely unanswered, in my opinion, because of the lack of understanding of availability.

7. My Concern

So what is my point in all of this? I am certainly not taking a pop at RCM, although it does concern me that it will be used for cost saving, not to improve availability (it may not in any case) unless safety or lives are at risk.

In his book [29], Dubi makes the observation that we use the throw of a die in a 'statistical experiment' to demonstrate the meaning of probability. He goes on to explain that each throw is slightly different; the angle of the throw, the position of the die, the velocity etc. He asks whether there are "true" statistical experiments and if there can be a "unique deterministic" future.

My concern is that we don't understand availability and consequently the data associated with it.

What is availability?

What do we measure?

What data is required?

How do we interpret the data?

Key to answering these questions is the deterministic view of the quantitative, empirical, data that is currently taken by many professional engineers, even though there is evidence to dispute this view.

Dubi, Knezevic, Basu and Barlow essentially agree that classical statistics are logically untenable when it comes to predicting the future. Therefore application of statistics can only give a deterministic view of the historical availability up to a point in time and cannot give a probabilistic perspective with any level of confidence or regularity of availability at any future point in time. Therefore until we change the culture that largely prevails, we will remain in the maelstrom.

Finally the foregoing begs me to ask this last question.

If we understand science, shouldn't we have the conscience to use it?

"Fare il vino e semplice ma non facile"

(Making wine is simple but it's not easy)

- Italian Proverb

Or the British version.

"You can't make an omelette without breaking a few eggs"

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