An Etiological explanation of WHEN logic in Classic FAST.

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ABSTRACT.
This paper compliments another paper by the same authors at this conference that explains teleological functions in the HOW-WHY major logic path of Classic FAST (Berawi & Woodhead, 2004). The focus of this paper is on the vertical arrangement of functions in the WHEN direction. The reason such articulation is needed is to enable the use of Classic FAST to be taken into High Technology projects that require greater alignment of engineering and scientific knowledge. The paper examines the use of WHEN in the Classic FAST and argues that it is inappropriate as it implies both causality and time-sequence. As such it leads to a level of ambiguity that undermines the value Classic FAST can provide to scientists and engineers working in High Technology. The failure to make the difference between functions in the HOW-WHY and the WHEN logic explicit, leads to inconsistency with respect to intentional-functions, causal-functions, co-incidental-functions, processes and activities. Whilst this ambiguity may be of little concern to those that see FAST as simply a means to stimulate ideas, it is an impediment to the role Value Engineering can play in High Technology such as drug development.

This paper views the HOW-WHY logic as purposive and as such it is teleological and intentional. However, the focus of this paper is on the etiological functions that are found in the context of causal relationships and so represent a way in which scientists can become involved in the development of the way functions in nature can be used to support the intentionality of engineers. Just as unprotected steel can be used to form a roof in a wet climate, it will rust because of the etiological functions related to the causal account of oxidisation. The paper concludes that 'WHEN' should be replaced in a new version of Classic FAST with the logical operand "IF-THEN".

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INTRODUCTION

This paper is part of a continuing theme that seeks to develop greater use of Function Analysis (Miles, 1972) in the context of science (Paley, 1999). Let us begin by introducing two very old words that may be new to many VE practitioners. The first one comes from Aristotle and is a word used to convey the 'joined up' consideration of a functioning system that has a purpose and operates within goals in a means-ends type of 'being'. The word is "Teleology" and is used in this paper in the intentional sense a designer would think about doing X to achieve Y in order to get Z. The second word, still common in some healthcare contexts, is "Etiology" (See also Aetiology) which refers to the causal history of how an effect today has been arrived at. So, that someone's poor spectacles led to even worse eyesight would be a causal account of an etiological type within this paper.

Rather than explaining what Classic FAST is so as to enable newcomers to engage with our paper we must concede to brevity and ask that they become familiar with Classic FAST and the difference between this approach and others commonly used in VE practice (See Kaufman, 1990; Woodhead & Downs, 2001, Woodhead & McCuish, 2002 for examples of Classic FAST; see Fowler, 1990 for examples of Customer FAST; see Snodgrass& Kasi, 1986 for examples of Technical, Task and Customer FAST; see Miles, 1972 for example of Function Analysis)

This paper is aimed at experienced VE practitioners wanting to use new forms of VE in Knowledge Industries and high-tech firms in such industries. It sets out to explore and expose ambiguity practiced in the identification, naming and representing of functions in the WHEN direction of a Classic FAST diagram. It will argue the case for another approach to modelling functions in the WHEN direction by replacing that operand with " IF-THEN ".

As VE is often seen as a ‘project improvement toolkit’, one amongst several competing methodologies, many VE practitioners are forced into a ‘do it quickly’ culture by clients wanting to minimise the cost of consultancy fees in relation to project budgets. This undermining cycle of trying to 'perform' VE more and more quickly runs contrary to our aim where we seek to increase the truth-value of a functioning representation to help scientists, engineers, business managers and investors gain reliable and penetrative insights that feed breakthrough innovation. A few days spent saving several years, as we check our claim that the function of a 'thing' is really the thing's function, seems a worthwhile investment in the context of Research and Development (R&D) projects. Our vision for new approaches growing out of VE is radically different to the interventionist attitudes of *'get in quick, get done quick, get out quick, get paid quick'* forced by task oriented Project Management cultures where getting a deliverable *'on time, in spec, under budget'* takes priority over the deliverable's contribution to sustainable growth in 'value-added'. We see VE as offering far more than quick fixes that are often trapped within the project they were applied in, but also accept that's where the main market for VE is today. The key to this new capability is to develop an approach that opens the door for scientists and engineers collaboration in ways that are not yet common.

In this paper we argue for new ways of developing Classic FAST models that lower ambiguity so that R&D such as drug development can enjoy greater levels of systematically realised innovation. We see the major logic path (Kaufman, 1998) as being a way in which managers and engineers set out their intentions. However, for such intentions to become reality we must also have a means of linking in non-intentional functionality, such as the function DNA has in triggering certain developments in the growth of a human embryo. Consider the internal

combustion engine in which the engineer needs to create turning motion and so takes the expanding properties of ignited petrol as the driving force on a piston and through connecting rods to a rotating crankshaft. The piston, connecting rods and crankshaft are designed to function in such a way that the engineer's intentions are achieved. This means-ends view is achieved by the effect of ignited petrol in the confined space of the cylinder. Petrol does not exist in order to combust at a specific moment in a specific place though. Engineers use spark plugs to cause this effect. Petrol burns because that's what petrol does; it's one of its properties. There is no intentionality within petrol as it is a mindless material; the intentionality is in how we use its properties for our own ends. Diesel engines use the Universal Gas law (Derived from Charles' and Boyle's Laws) and the fact that increasing compression raises temperature to such a point that injected diesel oil combusts in what is known as a "Compression Ignition". Again the practical ingenuity of the engineer borrows understanding made by science. To be able to model our intentions and what we want mindless 'things', such as petrol or diesel, to do, is to help scientists and engineers to collaborate in new ways.

We will argue that the WHEN logic provides a way of combining a science-knowledge to underpin engineering's practical intentionality and in so doing provide a way of seeing FAST models developed from a technology base rather than craft base.

It is important that we see the difference in teleological and etiological functions if we are to devise a way of using Classic FAST to help high-tech firms and their R&D projects. One only has to consider the cholera ridden streets of London in the mid 1800s to understand clearly why functions in the HOW-WHY (Berawi & Woodhead, 2004) must be conditioned by causal functions as suggested by the causal-WHEN direction of Classic FAST today. The initial assumption was that cholera was airborne and so prospective 'airborne' solutions sought to deal with that assumption. If we had built a major logic path under such assumptions we might have suggested a function such as "Clean Air" and whilst conforming to the rules of FAST have modelled worthlessly. Dr Snow deduced cholera was waterborne by studying cases that spread from the use of a particular water pump in Soho; a notion of functioning was drawn from the observation and interpretation of real-world data. The functionality that was actually happening was therefore different to the functionality people thought was happening. Therefore, there are at least two different ways in which we can think of functionality. For Classic FAST to become useful in high-tech situations we need to develop a capability to join actual functional causality to intentional functionality so that our FAST models correspond or reference to an external reality.

The HOW-WHY is more about the way an engineer might approach problem solving than say a scientist looking down a microscope to singularly understand how a cell reacts to a hormone with no other motive in mind. The engineer has practical ambitions whilst the scientist has theoretical ambitions.

In this paper we want to concentrate on the way a scientist might find usefulness in a Classic FAST model. Let us accept that the horizontal HOW-WHY logic is about linking purpose with functional intention in what is referred to as a teleological explanation. Let us concentrate on the WHEN relationship in a Classic FAST diagram.

Here we might be dealing with co-incidental or accidental functions such as having to cope with the unwanted heat generated by a light inside a projector. Similarly we might be dealing with

some requisite function that enables another function on the major logic path to be performed; for example, the relationship between 'Illuminate Bulb' and 'Connect electric supply'. Because common practice uses the functions to stimulate creativity in hurried sessions lasting no more than a day, the imperative is simply to get the secondary functions placed somewhere on the FAST so they can be used to brainstorm. We want to move beyond this view so as to use a FAST not merely as a stimulus for 'haphazard' creativity but as a way to represent a functioning reality in order to build a deep and shared understanding as we believe that to try to improve something without understanding how it works brings a short-term attitude to innovation that may actually be counter productive. Our vision of a more powerful VE is heading towards an approach that searches beneath superficial understanding to explore fundamental problems and opportunities in a developmental, rather than interventionist, use of thinking methodologies[1].

THE CURRENT USE OF WHEN

The major logic path is about how we want a 'thing' to function and intentionality is justified in terms of 'why'. Kaufman (1998) advocates a process whereby the context for a Classic FAST is established in the Pre-Event. Following this it is common to cite components or equipment and in a process known as "Random Function Determination" to establish their 'stand alone' function; for example, a sieve might be cited as a component and its function determined as "Separate particle sizes". This approach is close to the method set out by Larry Miles in that the search for function is derived from phenomena which are things that exist and can be perceived. That is, to ask the question "What does it do?" requires 'it' to exist in an irrefutable way.

In Classic FAST the functions are then laid out on a horizontal major logic path in a means-end logic represented in the HOW-WHY direction. However, there is a subtle change in the style of thinking when we move from asking "What does the object do?" to a logically constructed chain that explains How and Why various actions (i.e. verbs) on things (i.e. nouns) have some coherent interdependence. This is why we see HOW-WHY as being more about intentionality than actual causality; it is also heavily influenced by the mental models (Senge, 1990) of those people that craft the FAST and so their biases and limited knowledge must be dealt with in high-tech applications. The functions in the HOW-WHY are not so much about what real things do *'in of their self'* anymore, but what we want them to do to achieve a progression through means-ends methods that operate within goal-orientations and in order to achieve a purpose.

THE CONFUSIONS IN THE USE OF WHEN

The most common difficulty with the term WHEN is that to many it implies both sequence and time rather than causality. In figure one we have a HOW-WHY major logic path for a compression ignition engine such as a diesel engine[2]. In this hypothetical example we also have four functions that need to be 'unambiguously' positioned in relation to the HOW-WHY logic

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[1] We wish to acknowledge Andrew Garnett (also known as Alf) a freelance consultant <agarnett.ptc@virgin.net> for his work in articulating the difference between intervention, development and how they can be used to leverage organisational wisdom by asking fundamental questions in a collaborative inquiry.

[2] To aid readers we have used "Rotate Crankshaft" and "Move Connecting Rods" as functions when they are really specific processes. The distinction between functions and processes will be shortly published in SAVE International's "Value World" within a paper titled "Is Drink Beer a Function" by Woodhead, Kaufman and Berawi.

path. Under the WHEN rule we could place them above or below any function and argue "WHEN we do X we also do Y" and for most VE workshops in time constrained Project Management contexts such an approach is satisfactory as that quickly sets them up for creativity later in the Job Plan (Woodhead & Downs, 2001). In R&D contexts, where we really need to understand functioning more accurately, such an approach would not necessarily force us to develop keener insights into how a system 'actually' works.

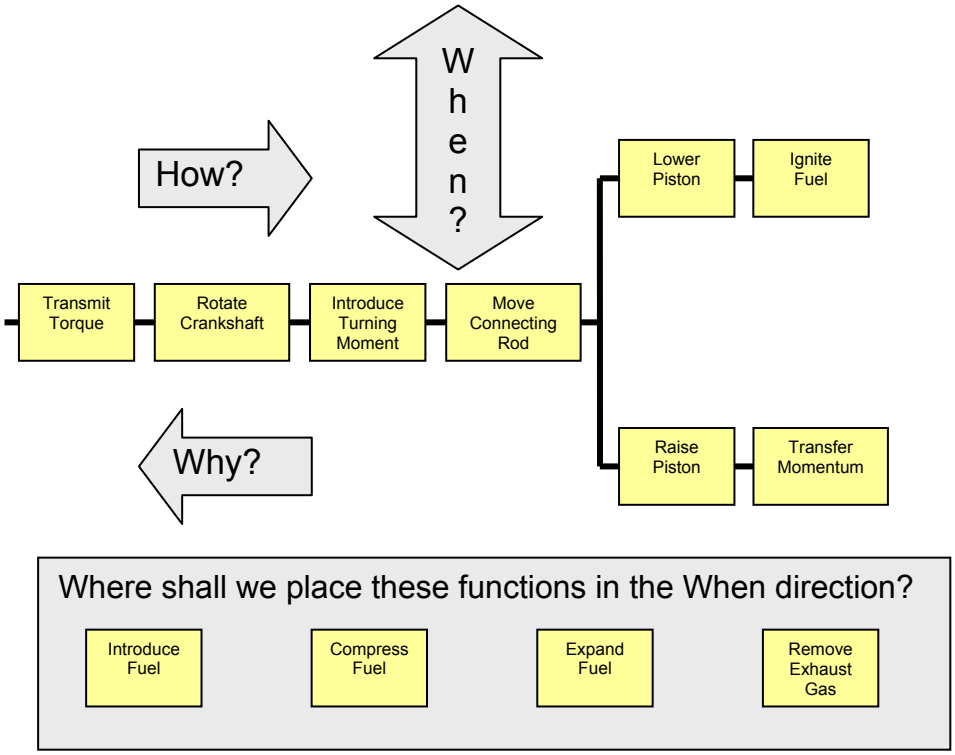

Figure 1. Functions in a compression ignition engine

The distinction between the intentional-teleological world we socially construct and the natural world we exist within becomes mixed and confused as we stick functions anywhere without any guiding rules to force us to think very clearly. In the case of the 1800s cholera epidemic in London, an alternative approach grounded in the culture of scientific investigation, would force us to test our assumptions and in so doing realise our problem was not airborne but waterborne. A function in the WHEN is supposed to be in a causal relationship. In the current approach to WHEN, functions are not related to each other and their position in the vertical can simply be a matter of chance. They are in a relationship with the intentional functions on the HOW-WHY logic path.

THE BENEFITS OF CLARITY

If we can become sensitive to the different thinking styles at play as we consider intentionality and causality then we can use both of them to develop representations of 'real' functioning and in so doing gain insights into how things work. Such an approach would bring a new capability to high-tech industries as they grapple with the cutting edge of what is known.

We want to develop FAST models that will allow scientists to model real systems, such as cancerous cells growing in a lung, so as to make the objective knowledge explicit and enable 'informed creativity' to be simulated.

The question, “What is a FAST diagram?” is an important one. Practitioners offer explanations as to what it might achieve but few state a theory of what it actually is. For example, we have heard it described as a way of getting *"everyone on the same page"* in an act of collaborative learning, but such truisms also fail to encourage explanations that distinguish a 'good' FAST from a poor one. To achieve a measure of how good a FAST is we must set out to remove ambiguity. For us, a Classic FAST diagram is a logical representation of reality that aids our ability to diagnose where best to innovate in a complex system.

TOWARDS A CONSISTENT THEORY OF CAUSAL REPRESENTATION

We will now outline a theory for the WHEN direction that is markedly different from the teleological use of function in the HOW-WHY direction. This theory is etiological and it operates at the causal level; Darwin’s theory of evolution is an example of an etiological explanation of functional adaptation. Another logical operand that could be swapped for ‘WHEN’ is ‘IF-THEN'. The ‘IF’ refers to a link between the function and if it is performed. The ‘THEN’ refers to a causal corollary that links the interconnectedness of one function to another.

Larry Wright (1973) described functions as having distinctive explanatory consequences. The ascription of a function to a feature explains both its utility and its etiology. He argues that the function of X is Z means:

a. X is there because it does Z, and
b. Z is a consequence (or result) of X’s being there.

It is important to distinguish this use of function from that in the major logic path. X is not there 'in order' to Z in some purposive or designed sense; it's simply there and whilst there it coincidently enables Z. The reason the distinction is important is because this is how many scientists use the word function and it is also very close to the word function in mathematics. It's about cause and effect mappings. Furthermore, Wright indicates that it is the nature of the etiology, the history of effects discussed through their causation that determines the validity of a functional explanation. The function of 'X is to do Z' means that X is there because it does Z with no further qualification by explaining how X came to be there; it's just the way it is.

There are two aspects we need to elaborate for etiological accounts of functional explanations. First, the object must have the capacity and/or disposition to function under appropriate circumstances; for example, diesel oil must combust under intense compression for it to function in a diesel engine. Second, the history of the object determines which of its capacities/dispositions account for its being there. That diesel oil can be used in other ways, such as a fuel for heaters, because of its 'other' properties, is irrelevant when our practical ingenuity considers what we want to happen inside an engine. The history of why we have traffic lights at highway intersections is causally linked to the history of Henry Ford inventing mass produced cars; one innovation created a problem that begat a further innovation. This is important for it allows us to understand how systems forcing decisions can be seen as etiological and so other traffic flow solutions such as the roundabouts of England and the un-invented external control of a car's speed via microwaves at junctions never emerged from the causal

history that gives us traffic lights at intersections in North America. The way we can view Darwin's theory of evolution is also an etiological explanation. Those creatures that lacked the ability to adapt, lacked the functionality to survive and that is why they are no longer with us. The missing ingredient from Darwinian type adaptation is 'choice'. We argue it is *'the ability to choose'* that is absent from truly etiological considerations; clouds do not choose to rain they simply play a part in the causal explanation. We could look at explanations of human development and the ability of hands to manipulate, combined with brains that could imagine uses, as examples of etiological functioning; the source of the capability to invent, that is the actual possession of a thinking brain, is etiological but what is done with that functionality is the act of inventing which is a product of choices guided by intentionality; the two are different but inseparable in their co-existence.

The first part of Wright's explanation displays the etiological form of functional ascription:

a. X is there because it does Z, and

The second part distinguishes functional etiological from teleological theories:

b. Z is a consequence (or result) of X's being there.

Furthermore, part 'a' can be seen as that the function of something has to do with what something does. That is, some performance in which it is involved. This performance can be either active (such as a car's engine to produce torque, or a cigarette lighter to produce a flame, etc) or passive (such as the chair not yet sold being able to support a person sitting on it). The 'passive' functionality may not be in use as in the case of a chair not yet sold, and so this view of function requires a specification of capacities or dispositions to be performed under appropriate circumstances.

We must not forget co-incidental or accidental functions when thinking about making the FAST more useful to scientists. Whilst the beating of a heart is about blood circulation the co-incidental fact that it makes a noise is used in a scientific way to judge the health of the heart inside a person (Mahner & Bunge, 2001). We must be sure not to confuse proper functions with co-incidental ones. We must avoid being distracted from the proper function which for Miles flows from his view of the customer determining value. Thus, the engine in a car has function, not because it makes a noise, but because it produces torque, which allowed it to power motion. That petrol ignites and 'unknowingly' expands to push a piston down in an internal combustion engine is not driven by intentionality (i.e. teleological function) but by causality (i.e. etiological function) brought about through the conditions created by the engineer with an intentional ambition.

We see this as a need to distinguish etiological from teleological explanations and that the logic of the HOW-WHY is markedly different to that used in the causal sense of WHEN. This distinction establishes the basis to achieve a combination of functional explanation types in the act of modelling Classic FAST.

From an etiological perspective functional explanations help us to understand causal mechanisms. Combined with the HOW-WHY the role they play also directs our engineering creativity when considering which materials to use, or chemicals to suppress, etc. When Miles began with retrospective Value Analysis and the identification of a function for a part that

already existed he was conceiving function in this etiological sense. His analysis was connecting function ascriptions to performances that account for why the thing existed in the first place.

Replacing WHEN

The term WHEN is inappropriate because the temporal-causal ambiguity misleads. What we are trying to talk about are etiological relationships that have as their purpose a function on the HOW-WHY major logic path. The purpose is that which we give to some 'usefulness' we see in nature that can be adapted for our benefit; such is practical intelligence. That is, in order to achieve the intentionality within the HOW-WHY major logic path we are conditioned by our often inadequate ability to control etiological functions because of ignorance; for example, the school boy's puzzlement that given hydrogen mixed with oxygen combusts, why can't the fresh water (H_2O) of Lake Ontario be burned? This realization of different types of functional explanation provides an explicit means to combine how engineers think with the way scientists think. For this reason we argue WHEN should be replaced by 'IF-THEN' so that the ambiguity is reduced. The positioning of causal functions is now logically coherent in terms of relationships between other causal functions and other intentional functions.

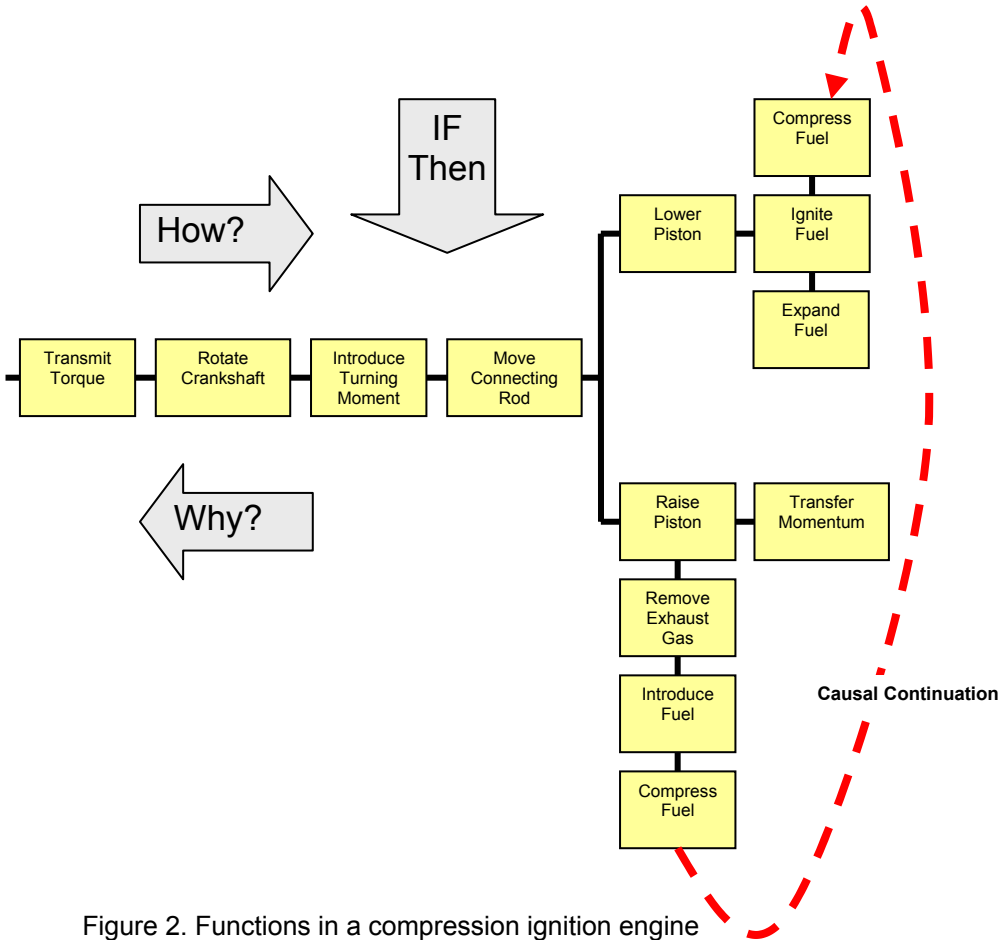

Figure 2. Functions in a compression ignition engine

Figure two shows how the problem of figure one is unambiguously addressed. The previously unattached functions have a logical place on the Classic FAST model that can be refuted on the basis of how a 'thing' really functions as opposed to how we 'think' it functions. Furthermore we can link causal continuations and see that to get rid of such functions we must look to the left of them and realize that the function "Move Connecting Rod" (*see foot note 2*) in order to

"Introduce Turning Moments" is the focus of innovation that would lead us to consider alternative functioning-causality such as that embedded within an electric motor.

CONCLUSION

Clients in Project Management contexts play a critical role in limiting the capability of VE but may not realise it because they are uninformed. In attempts to lower consultancy budgets clients place time constraints on the act of FAST and so practitioners use their ingenuity to try and give the best they can under those 'limiting' conditions.

In the case of Research and Development contexts the time constraints must be seen in terms of 'days saving years' with the aim to produce insights that lead to significant innovations and new products. The goal of breakthrough innovations requires an approach to VE that seeks the best possible outcomes for each stage of the Job Plan regardless of how long it takes. The justification for such an approach is that the methodological structure underpinning VE will lead to significant reductions in development time.

To get outstanding ideas we need accurate representations of how things really work. This requires us to model intentions such as strategy and then to condition such ambitions with causal realities; we must combine teleological and etiological functions in our Classic FAST models. This cannot be done adequately with the "WHEN" rule and so this paper concludes that for R&D projects additional time is needed to build clearer understanding of functionality using the logical operand "IF-THEN".

This paper makes the case for a new mode of engaging the underpinning truths upon which VE is founded; all things function whether that be intentional or etiological functioning.

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