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Co-evolution and Contradiction: A Diamond Model of Designer-User Interaction

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Abstract

This paper explores how the Engineering Design process might balance conflicting constraints of technical product design and the social demands of users. Building on a generic 2D map for innovation in design from the author's previous work, a prototype 3D Diamond Model is presented to help structure conversations between Designers and Users – or indeed any other group with apparently opposing aims. In theory, the model draws on the structure of Buddhism (in particular the Mandala of the Five Buddha Families) and managerial cybernetics (in particular Beer's Viable System Model and his Team Syntegrity protocol), to establish how one's worldview might evolve and how a common worldview for two teams can be determined. In practise, a Facilitator or Researcher helps Designers and Users achieve their respective aims, and develop a common one. When a common worldview is achieved, conversations and activities can become mutually informing, co-evolving and emotionally satisfactory at both the individual and team levels.

Keywords: Innovation, co-evolution, Buddhism, phenomenology, cybernetics, VSM, Team Syntegrity

Background and Aims of this Paper

Our Starting Position

This paper presents part of a programme of work, which has been ongoing in the Department of Mechanical Engineering at the University of Bath since 2001, and prior to that, also in Australia. This research aims to investigate existing methods and synthesize new methods, which can systematically enhance creativity and innovation in individuals and teams in early phases of engineering design and product development. In particular, it is concerned with (i) the streamlining of unstructured information or knowledge, (ii) the rapid integration and subsequent transformation of multi-disciplinary information with existing patterns of thinking, (iii) the liberation of engineering designers from a worldview of 'problem-solving', to one of 'solution-finding' (these terms are in general use by engineers) – especially one where the solution has been inherent in the system resources all along.

Following investigation of tens of thousands of examples of the processes of 'creating' and 'innovating' in the literature and practise of many disciplines (the difference between the two terms will be clarified in the sections on 'Contradiction', and 'The Generic Process of Creating'), we abstracted and synthesized their common steps. This allowed us to develop a 2D map and a generic model for innovation in design (A-K. Pahl, Newnes, & McMahon, in press), to be briefly discussed below, which is arguably the most comprehensive model for innovation currently available. In its current form, it is bearing fruit in a test in Aerospace design.

We need now to admit however, that while the efficacy of the model is dependent on using the language of Western scientific reporting (in particular from the domains of study we loosely call 'Engineering Design' and the 'Psychology of Creativity'), the strength of the model is based on its foundation in Eastern scientific reporting (in particular from the view of 'Mahayana' and 'Vajrayana' Buddhism).

We did not originally intend to make this foundation explicate in a peer-reviewed paper, but early comments by reviewers of Informing Science Journal rightly forced our hand, and eased our reservations. We

cannot, of course, introduce this material in a way that befits a serious researcher in Buddhist Studies. Nevertheless we hope that explaining some core elements of Buddhist Meditation will help make the application of our Diamond Model easier for designers who wish to consider their own point of view as part of a larger, informing system.

On the Difficulties Entailed in Reporting

At the outset, we would like to point out that both our language and 'representation' (this term will be further discussed below) of the conceptual domains, which are considered in this paper are incomplete. This is not just because we cannot simultaneously be experts in all of the domains we draw upon, and must rely on our language and understanding of the accepted axioms and propositions of the three domains of Engineering Design, Psychology and Buddhism to co-evolve. It is also because our evolution of thought is currently largely independent of the input of other researchers. We expect this will evolve as others join our discussion. To that extent, the problems we face in multidisciplinary reporting are obvious.

However there are additional factors to consider. Needless to say, prior to our study and field tests of our proposed generic model for innovation, a coincidence of the domains of Engineering Design, the Psychology of Creativity and Buddhist Meditation (as defined above) has not previously been considered useful. Not only that, the possibility that it might be useful is emotionally loaded. There are many who would prefer that creativity and innovation remain intuitive or mysterious, lest a systematic approach take the fun or birthright or spontaneous experience from the act of creation. And there are many who would prefer to keep religion and science separate, lest the presumed belief of one impinge on the supposed non-belief of the other. We asked ourselves many times: do we have a right to trespass that space? Do we have a right to systemically unpack creativity or scientifically examine the tools of what many perceive to be a religion? In the past, these hindrances have kept us from exploring the useful connections as much as we might.

We here propose, however, that Mahayana and Vajrayana Buddhism are actually more science than religion, in the sense that they proceed in the same manner as Western science. To be exact, both Western science and Buddhism: (1) aim at a goal for the benefit of humanity, (2) define their starting axioms, (3) encourage practitioners to make hy-

potheses about reality, and (4) give repeatable methods for testing whether the hypotheses and experience of reality match. What is more, when the latter do not match, Buddhists change their assumptions about reality just as Western scientists do, rather than dogmatically insist that things must be a certain way. The historical Buddha Shakyamuni himself encouraged his followers and colleagues to do this many times during the course of his life, pointing out that, 'Just as a learned one tests gold by burning it and rubbing … so should my statements be accepted after examination and not (merely) out of respect for the guru' (Dighanikaya, ii ; Tattvasamgraha, 3588; Visuddhimagga Vii).

We also point out that the methods for testing 'how things really are' (here we use this concept loosely – it is defined more rigorously in 'Backgrounds to Meditation') differ in all domains in any case. Thus Buddhism cannot be excluded from being a science, by having methods that differ from physics, for instance. In fact, it is not the existence but the nature of the starting axioms and nature of the goal of the Eastern and Western sciences that differ. Buddhism has as its starting axiom an assumption that the nature of both space and mind are quintessentially creative, integrative and non-dualistic. Western science on the other hand, is mostly based on Aristotle's premise that the universe is composed of separate, non-integrable parts and cannot be experienced as 'mind' (please note also that how psychologists speak of mind is not how Buddhists think of mind). The only other slight difference between the Eastern and Western approach to investigation of reality is that the goal of Buddhism is also linked to its starting axiom. Thus, on reaching the goal one no longer assumes, but actually completely knows or experiences the starting axiom to be true. Such conviction is not possible in Western science, due in part to a disparity between the starting point and an unknown finish.

In any case, it is in the context of Buddhism as science – not Buddhism as an adjunct to, or foreign discipline to science, that we have been given permission from Buddhist Lineage holders to deal with this topic here. In that respect, we say nothing about the core experience of living Buddhism, which must be transmitted first by the oral teaching of a qualified Lama, and second realised by one's own meditation. In that respect also, we limit ourselves to merely exploring the structure of the formal meditations, which are widely available without undertaking initiations, and which can be regarded impartially as 'Creativity tools' and

'Innovation tools' (this distinction comes from A-K. Pahl, 2006b) for both individuals and teams.

In addition, we need to consider a word limit for this paper as well as the predisposition of a modern Western public to receiving information in rather smaller intellectual chunks than might have been the case 100 years ago. Thus we did not wish to reproduce any written Buddhist explanations in the complexity in which they were originally given, or translated from the Indian or Tibetan into English. Rather than deal with the patterns of Buddhist meaning layered in such texts, we instead prefer to deal directly with the geometric pattern of the formal meditation practises. After all, the latter were designed to cut through the psychological baggage that accompanies the use of over-familiar terms. They were designed to liberate one from any kind of 'fixation' (this term is from Eckert & Stacey, 2001, 2003) on concepts and enable a continuously fresh view and experience of one's 'world' (this term from Gero & Kannengiesser, 2004, inclusive of both a physical space and Boden's, 1992, 1994a, 1994b, 'conceptual space'). And this is exactly why we believe that examining the mechanics of meditation is of benefit for the social and psychological space of design. Of course, we cannot avoid language in reporting, nor in placing ancient knowledge in a new context. Thus we must partially invent a language, which integrates the three domains we wish to connect and whereby we can talk about things, which should not be named at all, if they are to be understood as originally intended. We are likely the first to attempt this and trust that the reader will bear the inadequacy of our language in mind, as he proceeds.

Having said we will focus on the geometry of the formal meditation practise, rather than on the concepts accompanying them, one issue does, however, stand out as needing special introduction for our model in general and this paper in particular. That is the issue of 'representation', which we alluded to, in the beginning of this section. It has been pointed out that often this term is understood as implying the existence of a 'pre-given', objective, observer independent, physical reality, which can be consensually talked about (see e.g. Maturana & Varela, 1992, pp. 129-134). Of course many modern philosophers and scientists are aware that a physical 'reality' is not necessarily as it seems, but instead much influenced by our perceptions and communicative abilities and the construction of Boden's (1992, 1994a, 1994b) conceptual spaces, and we do not wish to imply otherwise. However, for the sake of sim-

plicity and pedagogy in this paper, we will assume that this insight is not yet a complete understanding shared by all who call themselves scientists, researchers or designers. Thus we take the approach of explanation in our paper, which is also taken in Buddhist teachings, whereby even advanced students always successfully start from the simplest possible starting point.

Incidentally, we will use the term 'pre-given' to refer to the kind of world most non-meditators would consider themselves familiar with, for the same reason. In Buddhist terms, this is a basic starting point. The thorough examination of a pre-given world may or may not lead to acquiring true knowledge (of reality). Acquiring knowledge, as Maturana and Varela (1992) also pointed out, is not an action 'of acquiring features of a pre-given world'. However it is self-evident that any act of human experiencing, which leads to knowledge of what is truly real does still take place in a social world. In such a world, all individuals are influenced by the building blocks and methods of others (we return to this concept in 'Preparing for Meditation', below). These building blocks include knowledge both presumed (received second-hand from others) and experienced for oneself, which is accrued in both physical and conceptual spaces of all scales and perspectives. For differing reasons, building blocks become accepted as facts and passed on as common knowledge to peers or those coming afterward. But at each stage of passing knowledge on, we feel we must, as researchers, assume that any pre-given world (and any linguistic term used to describe it) acts as a reference frame and is therefore quasi-concrete. In other words, the issue of acknowledging one or more (albeit incompletely specifiable) kinds of pre-given world cannot be avoided in the issue of any representation of a world.

To be exact however, in this paper, we employ the term 'representation' not only for the pre-given world of Westerners and non-meditators but also for the world of the Buddhas. In short, it is employed in the same way as in the practise of meditation. In that sense, the reality (the 'existence' or 'non-existence') of the object or event represented as a concept is not questioned – nor indeed relevant to the representation. Having this attitude toward using maps of invisible conceptual spaces is useful, because it allows for at least two extreme scenarios of experiencing reality. These are, albeit, not mutually exclusive. These are that the object or event represented is: (i) an internally experienced and non-shareable reality i.e. not a pre-given reality, and (ii) an externally inde-

pendent and/or consensually experienced (thus pre-given) one. The practical advantage of having the attitude that a map may represent either or both of these realities (and one does not really mind which is true), is that in early stages of use, the map is not confused with the reality. In other words, if no questions are asked about the truth or validity of the conceptual object or event behind the map, one is released from doubt as to the truth or validity of the map, which is intended to lead to finding and seeing the reality it represents. In Buddhist meditation that means one simply goes ahead and acts as if an independently existing 'divine' (this term is from Beyer, 1973) reality were pre-given by the map. At the same time, one does not lose touch of the pre-given reality, which also has its own implicit map.

That said, the point of meditation practise is not, of course, to introduce multiple new worlds and see them as separate from each other, but to superpose the map and experience of the divine world with the map and experience of the pre-given one, so that a transformation of both occurs. This will be discussed further in 'Mandalas for Engineering Design'.

On top of this, we are very much aware, as Vajrayana practitioners generally are, that the creation of maps and the naming of worlds to designate fields of perception or concepts is entirely fabricated. Such worlds do not exist in or of themselves. In other words, we are improperly naming things, which do not exist to be independently named in any case! However, it is crucial to our argument and hopefully evident to readers that researchers need a reference framework or measuring stick. There is no other means with which to discuss and test what elements in a given world are real, consensual or pre-given, as opposed to merely theoretical.

Now, it is not our intention to delve more deeply than this, into what can sound like very weighty intellectual philosophy. Our intention is rather to delve as deeply as we can into the simple geometry upon which such weighty statements are arguably based. For it is precisely because Western science lacks any kind of map for the conceptual space of design and innovation, and a reference model for the experience of it, that we feel we cannot do other than borrow the Buddhist representations of such spaces, and see whether they help us too.

Aims of this Paper

As mentioned in 'Our starting position', we did not make any background reasons for establishing a generic process of creating, explicate at the time of first publishing that model, because it was beyond the scope of that particular paper. Nor did we explain why we proposed a 2D Diamond Model of innovation. However, for those interested in, and familiar with, multidisciplinary research and the above fields, as is likely the case in this special issue, we here aim to extend our model for co-evolution and contradiction in the context of discriminating three main behaviours.

We consider these behaviours in the form of archetypal people we call the 'Designer', the 'User' and the 'Researcher' (capitalized for the remainder of this paper). By these terms we hope to include not just engineering designers, but designers in all other fields also. Along the way, we introduce reference to other authors and concepts loosely grouped under the headings of Buddhism, phenomenology and cybernetics – fields in which we are not expert and can only hope to scratch the surface to provoke discussion.

First we provide a background of meditation and Engineering Design, including a summary of our previous work on the process of creating and innovating in Engineering Design. In this paper, we focus primarily on extending a small part of the 7-step process we identified there and previously in A-K. Pahl (2005a, 2005b). In particular, we deal with the fifth step, in which a complete system is described. Detailed knowledge of the whole map is not necessary to understand this.

To facilitate conversations between the Designer and User, who each partially understand the system, and can only together build a complete system description, we propose using the structure of a Buddhist 'Mandala' (defined in the section 'The Mandala of the Five Buddha Families' below). We link our exploration of this structure with Stafford Beer's (1984, 1985) Viable System as well as drawing on the protocol of Beer's (1994) icosahedral 'Team Syntegrity' model. We suggest why a three-dimensional version of a two-dimensional map might be useful for discussion of complex topics in teams who apparently oppose each other. This is what we call the 'Diamond Model' of Designer-User interaction. Last, we consider how to establish a combined purpose for stakeholders using our model.

Backgrounds of Meditation

Preliminary Thoughts

Preparing for meditation – Establishing the view

Engineering Design has traditionally focused on immediate action and product generation, with little regard for longer-term reflection or feedback on the consequences of that action. However psychologists since Osborn (1953) proposed that 'reflection', in the sense of 'contemplation' or 'rumination', is intrinsic to the process of creating. Rumination of course also requires time for mental incubation of problems (though the scale of this can range significantly). To be more pedantic, the process of rumination and feedback on any theme must also have an aim, if it is ever to have an outcome. To that end, we can add the biologists Maturana and Varela's (1992, p. 24) definition that 'reflection is the process of knowing how we know'.

There exist very few methods, which can facilitate the process of achieving perfect, early stage feedback in Engineering Design. The soft science of 'Action Research' (Heron & Reason, 1995; McTaggert, 1996; Reason, 2002; Schön, 1983, 1987; Wadsworth, 1998) is perhaps the only validated method currently available to Western researchers, to facilitate cycles of action and reflection in teams. Since its relatively recent inception, however, said method has not been widely accepted in the hard science, and it has not evolved much detail. In respect to engineering needs, it is certainly too general and unsystematic. It has no structure to help identify or incorporate common and necessary elements of conversations of teams of Designers and Users when there are conflicting viewpoints. The formal structure of Buddhist meditation, on the other hand, can fill this gap. The 2500 year old methods are designed to make reflection on complex sets of actions with one or multiple stakeholders systematic.

We must now digress for a moment to point out we use the term 'meditation' in this paper in two senses. One is the sense that there is a formal structure, which provides a 'mirror' (this term is from Vajrayana Buddhism) and therefore also reflection on one's action and purpose. The other is that it is a complete ritual and a complete experience, which encompasses both the action of being and its reflection as well as the awareness (which we will later in this paper call 'knowledge') of the co-existence of the two. The insider Buddhist definition of meditation

as an 'effortless resting in the way things are' (Seegers, 2007) refers to the experience of aware co-existence of the two worlds (but see also Prebish & Keown, 2004). However, since the latter is considered an advanced realisation, it is the first sense of the term that is most generally used. In order to distinguish the two senses, we capitalize the formal Meditation practise, which is structured as a map or method, for the remainder of this paper.

Intrinsic to reflecting on one's actions, is knowing one's reason, purpose or motivation for even wanting said reflection. This is especially important, when one is using a ritual, map or method for reflection. It is less beneficial to follow someone else's footsteps blindly. The preparation for Meditation therefore, requires one first to contemplate the situation where one actually is right now, and why one might want to be somewhere else. Buddha's first teachings, known as The Four Noble Truths, generally provide an impetus for refining one's wish to move towards another more ideal state of existence. The wish to move includes a wish to employ methods that lead to an understanding and experience of a world where action and reflection are unified in a continuous feedback.

The Four Noble Truths are ordered in a way, which Westerners and Theravada practitioners would generally recognize as coming from a problem-space or problem-oriented view. In short, they acknowledge (i) we experience problems in our existing world, because we do not understand the natural order of things (ii) there is a cause for our problems in that we want things to be a certain way, which is not in their nature (iii) there is a solution to our problems, in allowing things to be as they naturally are (iv) there are methods to reach the solution and we should use them.

We can also consider a similar set of pithy truths starting from the viewpoint of the solution-space. This is the Vajrayana practitioner's view. In this case, we establish our motivation via the basic thoughts that (i) we have a great opportunity facing us in our existing world (ii) problems do not last, just as joy in material things does not last (iii) we are responsible for changing our view and handling of problems to seeing only solutions (iv) knowing that we do not yet see only solutions in our existing world, we want to learn from those who can do so.

The basic thoughts of The Four Noble Truths and other Buddhist Meditation are incidentally identical with considerations reported by

engineers and young people (A-K. Pahl, 2006b) in early stages of determining their problem-space and goal of innovation. They also make up the first four steps of the complete 'Diamond Map of Design' (as we have called it), a brief summary of which is included in the sections on 'Contradiction' and 'The Basic Generic Model of Creating' (a thorough elucidation is beyond the focus of this paper).

These simple thoughts cover the lengthy Buddhist teachings on impermanence, karma, interdependent origination and emptiness. A thorough exploration of those topics is traditionally carried out in monastic teaching situations lasting twenty or more years, and can be interesting for those disposed to analysis. A deep understanding of those topics is said to lead to liberation from the perception and sensation of being trapped in a problem-oriented view of the world. However, to enable Designers to streamline their thought processes without lengthy study on these topics, we summarized the mechanics of these teachings in a map for innovation in design (A-K. Pahl, 2005b), just as we now summarize the mechanism of using that map, and in particular, of discussing its fifth step with two teams.

The need for maps and methods

As mentioned in the section 'On the difficulties entailed in reporting' and in 'Preparing for Meditation' above, the authors of this paper believe that modern design cannot progress without some generic reference frame. This must first describe its existing world and thenceforth help make decisions on new input and directions for innovation. In other words, we propose that a Designer needs a map and method(s) to express his inner experiences and external material considerations in conversations with others involved in product innovation.

To some extent, this is already done. There are of course, accepted sequences in which engineering design is taught and talked about. G. Pahl and Beitz' (1984) system is perhaps the most widely taught and accepted standard in the UK. Furthermore, designers have always made ad hoc individual maps, trying to capture their thinking, intuition and design decisions.

So why do we suddenly propose to make more maps, when the existing ones seem to have worked perfectly well to date? To answer this question, we need to consider that there is not just one direction or level of action between an individual and his world. Yet to date, engineers have maps going in only one direction if in any at all (see 'Contradiction',

below). The problem with such a map is not that it is too simple (for we also consider our map and model to be simple), but that it is inadequate. The existing maps and any discussion, which refers to these conceptual spaces, make no systematic link between the different worlds that co-exist and co-evolve (for example between a Designer, and a User). Suffice to say that this view of a system is incomplete and thus ultimately confusing.

When a situation is confusing, it helps to have a map. This should not, of course, materialize from thin air. It should be relevant both to the individual and to the collective pre-given world. And for this kind of coincidence to happen between the individual and the collective, there must be a coincidence of external elements of the world, which are shareable and can be agreed upon, with the internal elements of the intellectual world, which is arguably non-shareable. There must, in other words, be a relationship between the inner and outer organization of the space one perceives

This is, in any case, what Buddhism considers to happen. Buddhism equates the organization of the thinker's awareness and the organization of his senses and his perceived and pre-given world.

This is not dissimilar to the realisation of the Chilean biologist Humberto Maturana, as popularised in 'The Tree of Knowledge' (Maturana and Varela, 1992, pp. 24-27). There, the authors discuss the shortcoming of Western culture not to acknowledge the fundamental circularity of living, acting and knowing. This, as they state (p. 27), entails both the individual and the social level.

A classic way in which the issues of individual perception and social organization are related in Buddhism is given in Table 1, summarized from two approaches of the Indian philosophers Vasubandhu and Sthiramati (Beyer, 1973, p. 97-98). 'Reality itself' is about the kind of awareness that perceives directly, without labels or interpretation of any kind. It is the equivalent of the 'divine' (explained below). In a pre-given world, this is given two labels, depending on the extent to which one is aware of oneself and one's surroundings, and makes a distinction between the two. The 'underlying awareness' of reality includes awareness of the physical ground one stands on and all physical objects in it. It includes an ability to make mental connections and inferences of relationships between objects, based on reason and experience. An 'evolved awareness' includes awareness of one's own thoughts and their

effect on one's perception of other objects and beings. In other words, it includes awareness of the interrelationship between one's inner senses and their projections on the pre-given world. A hierarchy of awareness could be construed (obvious from top to bottom in the right-most column), moving from physical concerns to concerns of (self-) esteem and self-actualization. Though Buddhism does not identify or condone this hierarchy, the divisions implied are not dissimilar to the well-known 'Hierarchy of Needs' identified by Abraham Maslow (1943), and similar observations made by many other modern thinkers.

Certainly in Buddhism it is not enough to make philosophical correspondences (or hierarchical diagrams) between one's perception and the organization of the inner senses or outer realities one perceives. Buddhism also requires that a coincidence of one's perception and reality be known from experience.

Buddhist maps, methods and rituals were created in order to provide a starting point for this experiment in one's life.

To be completely clear, Buddhist maps are not provided as a kind of theory of alternate worlds. They are provided in part due to the observation that human beings are predisposed toward understanding their world by grasping external objects. Indeed even the evolved awareness makes objects of intellectual concepts if none are physically available (this is a different angle on the researcher's need for a reference frame we previously discussed above).

On top of that, however, a paradox exists. The maps provided in Meditation are supposed to be structuring for the mind, but at the same time also liberating from fixation on objects.

How is this possible – to provide a structure and yet be simultaneously be free of structure?

This is the very question Designers face for, ideally, innovation will produce a result which is close enough to a standard set of rules to be recognisable, and yet far enough away from them, to be exciting or profitable.

Table 1: Summary of classic Buddhist teaching connecting the focus of awareness and organization of a pre-given reality.

Organizational System describing perception and experience	Predominant function of Sub-systems of an ideal whole				
	Sub-system 1	**Sub-system 2**	**Sub-system 3**	**Sub-system 4**	**Sub-system 5**
Mandala of The Five Buddha Families	East - Identification	South - Equality in Diversity	West - Discrimination	North - Overall accomplishment	Centre - Ultimate reality
The Five Skandhas of Buddhist philosophy	Form, structure, body, sense objects	Perceptual stimulus, feeling, sensation	Cognition, recognition mental processing of sensory stimuli	Mental habits, thoughts, ideas, relationships, associations, volitions	Conscious awareness of self, others and cosmos
Viable System Model of Stafford Beer	Implementation, initial direction	Coordination or information	Internal control	Integrated & externalized intelligence	Intention, Policy, overall command

To achieve this end of freedom inclusive of structure, formal Meditations, and Mandalas in particular (defined in 'the Mandala of the Five Buddha Families' below) focus the mind on a world, which is stripped of any but the most fundamental pre-given conceptions or rules. This world is liberated from the confusion that results from not having any kind of template at all, to establish the way things naturally are. But it is precisely because any given Mandala is only a template that it allows room for change. It provides no predictable events that need to meet one's expectations.

Formal Meditation thus offers something similar to what Schutz would have called 'the life world' –a world, which is pre-structured for the individual, who is actually trying to construct his own world, but cannot do so in isolation from the building blocks and methods offered to him by others (Schutz, 1972, as cited in Wagner, 1974). Schutz's concept was, of course based on observation of human society, whereas Meditation is based on the observation of Buddha nature (defined in 'Geometric Structure' and particularly in 'The Mandala of the Five Buddha Families' below). However the concept of offering a pre-given world to help those who come after us is the same in both cases.

Some particularly well-constructed Meditations have additional functions, other than offering a map and view of a particular world, in which confusion does not exist. They also present (i) a microcosm of the entire ritual structure of Buddhist initiation (ii) a microcosm of the physical, social and conceptual world, which human beings generally accept as real. We used such a Meditation (Nydahl, 2000a) in evaluating the other processes of creating for our 2D Diamond Map of Design and the model of the Generic Process of Creating (A-K. Pahl et al., in press). The reader will need to refer to our original paper, since the table in which this is summarized is too large to reprint here. However, we summarize the process of using Meditation, to change one's present situation of perceiving problems, into a situation of perceiving solutions, drawing on Beyer's explanations (1973, see p. 67 and 103).

In Figure 1, we show the two directions of action, which are both required and automatic in Meditation. These are: (i) action in the pre-given e.g. external, physical or problem-space world, and (ii) reflection on, or from, the ideal world which appears as a 'solution-space' (ideal 'divine' world). Starting from a pre-given reality, it is considered that one realizes one's limitations and constructs (or is given) a formal map or model of a liberated reality, to help oneself transcend them. The

other direction of action starts from the ideal world, which reflects only the best qualities of the former. In this sequence, it is important to note that reflection is nevertheless not a passive consequence of mental action. Indeed, reflection must also be actively sought out. In other words, it is also action of the mind. This double-ended action preempts the concept of 'co-evolution', which will be discussed in 'Backgrounds of Engineering Design' below.

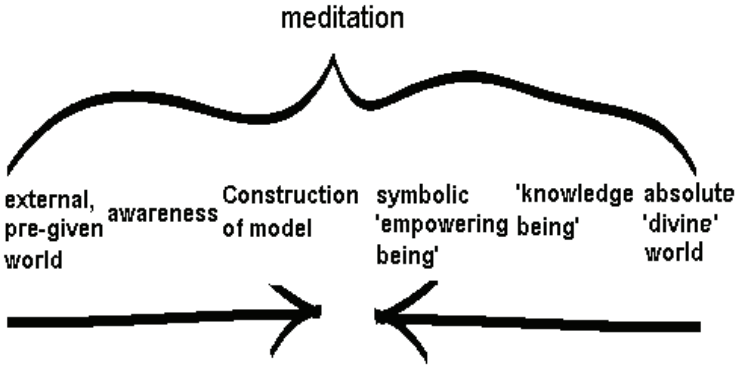

Figure 1. The ritual and experience of meditation. There are two directions of action, which constitute the ritual and experience of meditation. One is from the pre-given world and the other is from an ideal 'divine' world.

When Buddhist Meditation is applied as magic or religion instead of science, the reflective action of the practitioner is said to be instead carried out by a being called from the divine world. This being changes from something absolute and indescribable (discussed further below) into something, which can be identified as knowledge as he comes closer to the practitioner (Beyer, 1973). The act of reflection upon a divine object or being (as itself, as being within oneself, as a projection of one's own mind, or seen in others), is considered empowering. Reflection on the divine thus works in the same way that receiving answers to questions asked of one's peers and friends are empowering. It enables one to gain positive feedback in the world of one's experience, and improve one's understanding of the way things really are.

Geometric Structure

The Three Jewels

Buddhism identifies three irreducible elements, which define the first most important structure of mind, on the human side of an 'indescribable absolute' (we invent this term to capture the reported experience of achieving the goal in Buddhism, which approximates experiencing Beyer's 1973 absolute 'divine' world, and the godhead as described in all world religions). Grouped together under the term The Three Jewels, they are called Buddha (interpreted as 'awakened one', and often standing for the historical Buddha Shakyamuni), Dharma (interpreted by Nydahl, 1996, in the Vajrayana sense as 'how things are' but generally standing for the 'law' or teachings of the historical Buddha) and Sangha (interpreted as 'community of practitioners'). Vajrayana Buddhism adds a fourth element – the Lama (interpreted as 'highest principle' and standing for one's own teacher), who unites The Three Jewels, and thereby presents the indescribable absolute nature of mind.

From our broad research during these last five years, we have seen that these irreducible elements recognized in Buddhism are also elements, which are common to every society and organization (ancient and modern) on earth. We did not formally document evidence to back up this proposal, however trust it will ring true with the reader if we explain our observations for this paper now.

We can, for instance, recognize the elements of Buddha in the founder of a village or inventor of a product. He may no longer be alive, but he was the one who started it all off. He's the one of whom people make posters, venerate and strive to imitate, like a movie star. He gave the rules or Dharma, to help people work or advised on the operating instructions for an object's proper functioning. These may be written or unwritten, verbal or implicit. Either way, they are always common patterns and shareable knowledge. Rules can be further co-created by his community, as the latter get used to the way things flow. The third element – the Sangha, villagers or Users of inventions are also indispensable. In small societies and large production companies, individuals would achieve little without colleagues to share the load and help overcome difficulties on the way. They iron out the quirks in each other's understanding and practise of the operating instructions for their product or life, and strengthen each other's resolve to continue using the rules to achieve their agreed ultimate goal. A community will continue

to exist as long as all members strive for the same ideal or goal. Similarly, those who strive for the variations of the same goal, quite naturally create communities to rely upon, while working for the same guy. The fourth element, the Lama, is obvious in the fact that founders die or reach retirement, yet a need for leadership remains. Consequently, a new Mayor or CEO is elected. He's the one who knows the newest trade routes and market conditions, and who has experience in all aspects of the business. Usually, he has worked his way to the top of the ladder from the bottom. He knows what it takes to play by the rules or break them, while he also consistently builds towards the original founder's vision for the villagers or stakeholders in the business.

In Buddhism, these three elements, which can be seen as people and objects in the pre-given Western world, also stand for inner qualities or functions which one (i.e. one's mind) can develop. All three are inherent and coincident in the absolute ideal state of being and in the 'nature of mind' (this term is distinguished from mere 'mind' in Buddhism and can be defined only by experience, not by words). For this paper, we suggest these elements are 'meta-qualities' of mind (to be discussed further in 'Mandalas for Engineering Design', below).

We note however that, while talking or writing about qualities and functions sounds quite abstract, The Three Jewels start to make real sense imagined as people and objects in actual Meditation. They are then placed in a very specific geometry. In the case of a modern Vajrayana Meditation on The Three Jewels, for instance: (i) the Buddha is called to mind as the historical Shakyamuni, sitting in front and a little to the left of oneself (ii) the Dharma is visualized as books or a library directly in front but a little away from oneself, (iii) the Sangha is visualized as a compassionate being, in front and a little to the right. In addition, (iv) the Lama is added as a teacher in golden, kingly robes, as close as comfortable and directly in front of oneself (Nydahl, 2000b). If all these elements are visualized as sitting in the plane of the practitioner's point of view, the Lama might obscure the library behind him. Figure 2 illustrates the Geometry of a Mahayana Meditation on The Three Jewels of Buddhism, seen from the point, and in the plane of view, of the practitioner. The central element is a Vajra-yana addition. The formal Meditation follows after the correct preparation (outlined above), by acknowledging these figures from left to right in turn, and confirming their prime relevance to one's life. In Vajrayana practise, one starts with the Lama and completes the cycle with the Sangha. In Mahayana prac-

tise, one starts with the Buddha and does not include the Lama. Either way, one does as many repetitions as one likes.

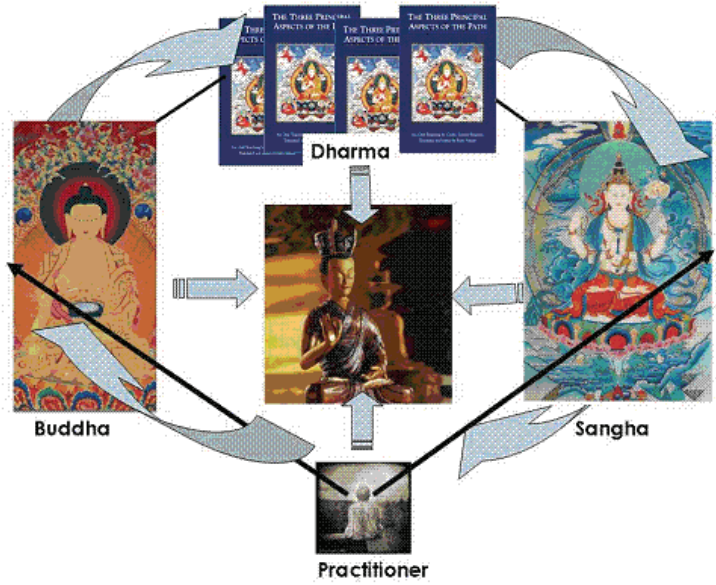

Figure 2. The Geometry of a Mahayana meditation on The Three Jewels of Buddhism, seen from the point, and in the plane of view, of the practitioner.

What this geometry of movement of attention actually does is create a crude Mandala with four objects in it. The Three Jewels occupy the entire visual field of the practitioner. Figure 2 shows the geometry of a Mahayana meditation on 'the three jewels' of Buddhism, seen from the point, and in the plane of view of the practitioner. The central element is a Vajrayana addition. The straight black arrows and lines signify the limits of the practitioner's field of vision, looking at the elements as if they were physical objects situated at an imagined horizon at each side, and towards a vanishing point, in the distant foreground. In the Mahayana version, a square is created by joining The Three Jewels with the practitioner as if they really were sitting together in physical space. The blue circular arrows represent the cycle of attention around all the elements in the field of view.

The same square and circular geometry are also created in the case of Vajrayana practise, which extends The Three Jewels by introducing the

Lama. We have included him as the fourth, unnamed, element in the centre of Figure 2. The only difference between the two versions of the practice lies in whether the practitioner or the Lama unifies the activity and function of the other three meta-qualities of mind in themselves. If the Lama unifies the other elements, the geometry of the practice is preserved by completing the square with him, and seating the practitioner invisibly outside the square. We will discuss this geometry further in Figure 4 below.

Suffice to say here that, like all other Meditations in the Buddhist toolkit, the Meditation on The Three Jewels forms a basic and implicit non-verbal or symbolic language. This language can be understood by all who practise seeing the same conceptual space. It can even be understood by those who do not practise Meditation but intuit that such an idealised pattern (of the pre-given world) makes common sense.

We ask readers to note that this method in particular (and Buddhism in general) is designed so as to promote links between the manifestation of the three different meta-qualities in external society as well as inside one's own mind. In other words, Buddhist practise is intrinsically inclusive of a group, both in the internal structure of the formal Meditations, whereby one imagines a community to exist, and in an external physical team which accretes around their common goal or teacher. Each team member vows to support others to develop to their highest potential, as if they were interchangeable with oneself, and this naturally leads individuals to heightened awareness of emergent patterns in teams.

The Three Pillars

In a previous literature review of multiple discplines, we summarized the work and terminology of Csikzentmihalyi (1990, 1997), Koestler (1964) and Boden (1994a, 2005) among others, to define 'Three Contexts of Creating' (A-K. Pahl et al., in press). These contexts are generic to the complete cycle of creation from idea conception to public recognition, regardless of the product type.

The Contexts of Creating are (i) 'The Person' who activates creation, (ii) 'The Field' of stakeholders in which the creation is accepted and widely applied and (iii) 'The Domain' of knowledge which holds a map of all creations for the benefit of The Field, that they might reproduce, use, or further develop existing results. Note that all three are coincident with each other and with the product co-evolving with them.

It is hopefully obvious to readers that these three contexts distilled from Western scientific research are virtually identical with The Three Jewels of Buddhism, as described above. This coincidence is helpful both for Engineering Design and for explaining Buddhism. In both cases, we can say that The Three Jewels represent the perfected outcomes of certain styles of behaviour, where by conceptual liberation and/or innovation takes place.

Naturally, a style of behaviour is enhanced and easier for others to see, it if takes place in an appropriate environment. The styles of behaviour do therefore have appropriate environments, which allow The Three Jewels to evolve to perfection. They are called The Three Pillars.

The first of the Pillars presumes that some people like to deal with structure, methods or formal tools. The second Pillar identifies that others like to use these tools in an informal way to make a difference in their community (and do not necessarily desire a full understanding of their structure). The third Pillar focuses on acquiring the kind of knowledge, which applies to understanding both the underlying structure and its application or reflection. All three styles of behaviour support each other and Buddhism suggests that an individual is capable (and indeed required) to carry out all of them, to achieve the ideal final result. The more one does so, the more likely one is to reach a comprehensive understanding of the reality one co-evolves with others, and the way things really are (Nydahl, 1996).

To repeat what we have already said in regard to the Meditation and The Three Jewels, this description of The Three Pillars is also not supposed to remain a mere pretty concept. It is also supposed to become a practical 'view' or 'worldview' (these terms are loosely used, to cover both the Buddhist meaning, and also the general English sense) and phenomenological starting point for one's experiments and experience of reality. In Table 2 we contrast the Three Contexts of Creating, The Three Pillars and The Three Jewels with the terms we earlier introduced as Designer, User and Researcher (and which are discussed further in 'Mandalas for Engineering Design'). Each column states the main behavioural style and environment in which Meditators and Engineering Designers act.

Table 2: Comparison of terms used to describe The Three Jewels and The Three Pillars of Buddhism with the Three Contexts of Creating and the Diamond Model for Design.

The Three Contexts of Creating	The Diamond Model of Design	The Three Pillars of Buddhism		The Three Jewels
Previous paper (Pahl et al., 2007)	This paper (Pahl & Newnes, 2007)	Modern interpretation (Nydahl, 1996)	Modern Interpretation (Seegers, 2007b)	Classic translation
Field	User	Holding the View (while applying the methods in real life)	Action or Behaviour	*Sangha*
Domain	Designer	Meditation (methods)	Contemplation or Meditation	*Dharma*
Person	Researcher	Knowledge	Hearing or Learning	*Buddha*

The Mandala of the five Buddha families

Buddhist Mandalas are Meditation practises, which originated over 1500 years ago in India and were brought to Tibet in the mid-7th century. The Sanskrit term 'Mandala', which predates Buddhism, is best translated as 'circle'. This is also the best-known visual or geometric feature (in Figure 2, called 'the cycle of attention'). The Tibetan word 'kyil khor', which means 'centre circle', also captures the point at the centre of the Mandala circle, from whence the divine being is said to emanate from the absolute indescribable reality (in Figure 1, this is the extreme right hand side of the diagram). There are many different kinds of emanation – in Vajrayana Buddhism each kind is considered a different 'Buddha Aspect'. Aspects with similar functions, activities and qualities are considered to belong to one 'Family'.

A Mandala is, of course, not merely the home of a Buddha Aspect. It is also considered a map or reflection of both the practitioner's individual conceptual world (or indeed of the true nature of his mind) and of the pre-given world (this will be discussed further in the section on 'Mandalas for Engineering Design'). The instructions for the representation of these Buddha Aspects, in the creation of all (the hundreds of different) Mandala forms are therefore very specific. There is not much room for spontaneous individual expression (see for instance, Leidy & Thurmann, 1998; McArthur, 2002, p. 175). Indeed, the Mandala itself was never intended to be freely created but to provide the rules whereby the practitioner could more freely create his own life. Use of

the Mandala is intended to transform both the individually perceived and socially pre-given conceptual worlds in which the practitioner feels he exists, from being an experience of confusion, problems and suffering into one of wisdom and bliss (among other things).

Of the many available teachings on Mandalas we will abstract only those elements, which are relevant to the simple purpose of being helpful to Engineering Design. Thus, of the many available Mandalas, we will concentrate for this paper only on the Mandala of the Five Buddha Families. For more extensive information, the reader should please look at texts such as those by R. Beer (2003, pp. 234-236) and Snellgrove (2004, pp. 191-213).

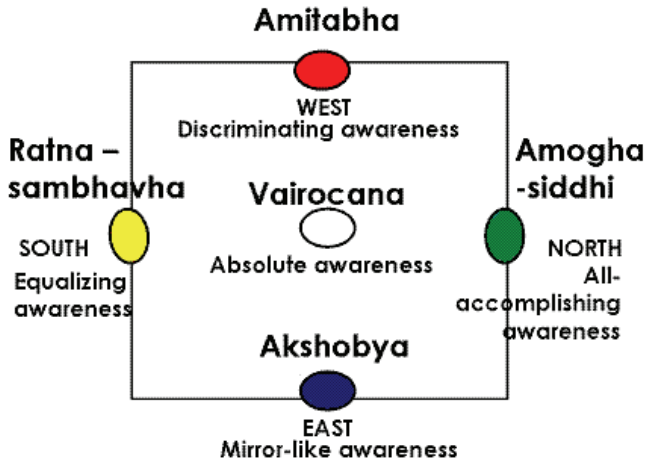

Figure 3. The Mandala of the Five Buddha Families stylized for this paper.

Figure 3 presents a template of this Mandala, stylized for this paper. For the more beautiful original version, we ask the reader to please look at traditional Buddhist thangkas (scroll paintings), in Art Galleries, Museums or a Buddhist centre in his country. Each compass direction of the square is assigned (or considered to inherently possess) some aspect of a 'completely functioning mind' (this term is from Vajrayana Buddhism and used comparably with Stafford Beer's Viable System description, to be explained below). Please note that the compass directions given in the diagram are those of traditional Buddhism, and included for that sake only. They are not relevant to our argument for Engineering Design. However it is important that the complete, inte-

grated function of mind is assigned the central position.For the same reason that The Three Jewels are represented as objects rather than behaviours, each function of mind in the Mandala of the Five Buddha Families also is depicted not in abstract words, but as the physical form of a Buddha (or Buddha Aspect). But this should not be construed as concretising the concepts! The Mandala of the Five Buddha Families is nevertheless intended to represent how the pre-given world looks when it is liberated from a fixation on concrete objects into displaying qualities of energy and light. Notably, such a transformation from material to energy is also the ideal final result of the evolution trends of entire classes of engineered products (Altshuller, 1984).

In Buddhist teaching, one constructs the Mandala from the starting point of a pre-given world based on the five senses and the five emotions. That means the Buddhas are called into being 'from space' (which may be conceptual or physical). They are intended to help the practitioner transform all fixed, pre-given mental conceptions of the world into knowledge of the absolute reality. Thereby (or as a prior step) they help transform the emotional tendencies associated with perceptual or mental fixation. Traditionally, the emotions associated with different kinds of mental fixation are: anger, pride, desire, jealousy and ignorance.

To be specific; Akshobya (in the East) functions in a way that overcomes the anger of separation from a divine world. He himself is said to have reached this realisation and now bestows and represents a mirror-like quality of awareness of one's own 'Buddha nature' on the practitioner (the term Buddha nature is traditional to Buddhism, and used to represent a composite of the concretely recognisable Buddha as well as the more abstract nature of mind). Moving clockwise round the circle we find Ratnasambhava, who is said to have overcome pride in his own accomplishments. He thus bestows and represents a many-faceted, jewel-like or equalizing awareness that all beings have Buddha nature. Opposite Akshobya sits Amitabha, the transformer of general passion or desire into a discriminating awareness focussed only on the highest bliss. Then there is Amoghasiddhi (in the north), who has overcome the jealousy accompanying unrequited passion and now represents the awareness of all-encompassing and thus all-accomplishing bliss. And finally, in the centre, sits Vairocana, who is considered to have overcome the ignorance of separation from Buddha nature in self, other beings, and in all elements of internal and external space and thus

represents the wisdom and 'awareness of the absolute, indescribable reality itself' (Scherer, 2005, 171-173 & 204-205; Vessantara, 1993).

Although, as we suggested in 'Preparing for Meditation', reflection can be considered a function of mind (one's inner conceptual space), it is interesting to note that reflection is also inherent in the qualities of a pre-given or 'physical' space.

In this respect, we point out that the geometry of the Mandala is highly symmetric. There would be four major planes of (mirror) reflection and lines of (8-fold) rotation, were different functions of mind not assigned to the cardinal directions. The fact that there are, however, directional differences, means that the only plane of geometric reflection which truly exists, lies between an external 2D Mandala and the practitioner's inner world of percepts and constructs. Mathematically, the practitioner adds a third dimension to the whole, by his very existence and contemplation of the object, so that it fills his entire field of view (whether he knows it or not). Although Mandalas can be placed (or created) horizontally on tables as well as hung vertically on walls, for ease of explanation, we have shown the relationship of practitioner and Mandala in

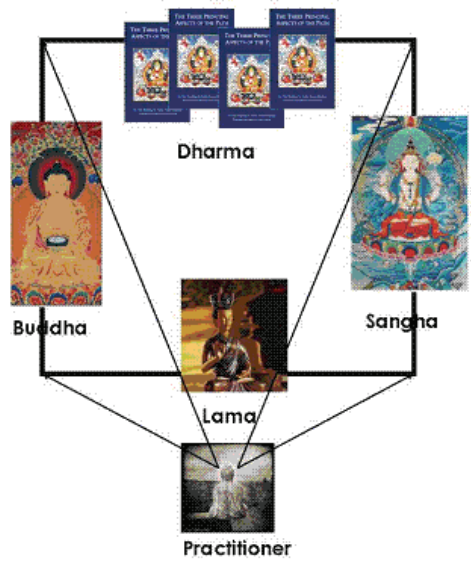

Figure 4. View of the Meditation of Figure 2 as if it were a framed Artwork hung vertically on a wall.

Figure 4, as if the former were sitting, looking at a framed painting of the latter on a wall. To show that this is a general principle inherent in the geometry of all Meditation and not limited to the Mandala of the Five Buddha Families, we use the elements of the Meditation of Figure 2, to furnish the illustration. Keeping in mind this view, a Mandala can be considered as a 3D space including the practitioner, even when it is drawn in 2D. We suggest that all formal Meditation elements are automatically projected into (or perceived as existing) in a virtual external space, whether the practitioner is conscious of it, or not. The second point will be discussed a little further in the section on 'Contradiction', below.

Backgrounds of Engineering Design

Co-evolution

Modern engineering design and coincident innovation is notoriously 'wicked' or 'under-defined' (in the sense originally coined by Rittel & Weber, 1984). This means there are often no rigorous specifications of the starting point, just as there is no scientifically measurable finishing point. Both situations depend on a complex combination of the desires and limitations of the stakeholders, be they ethics, values, social or technical requirements. In order to progress from concept to marketable realisation, all of these factors and actors must 'co-evolve'.

The term co-evolution was originally developed in respect to engineering design by Gero (1990), Qian and Gero (1993, 1996), Suwa, Gero, and Purcell (2000), Dorst and Cross (2001) and Gero and Kannengiesser (2004), and is emerging as a useful concept in that community. It describes the phenomenon whereby, as product design (a solution-space) evolves, Designers understand their restrictions and requirements (problem-space) better. Work in the solution-space informs the problem-space and vice versa. Knowing that this is the case, it becomes possible to consciously work in both directions. That means one continually reframes or reformulates one's perception of, and relationship to, the problem while at the same time allowing a solution to emerge from the space between both.

This kind of shared interaction of people with their environment and each other has been known to philosophers interested in phenomenologically acquired knowledge for some time. We presume, for instance, that Alfred Schutz in the 1930's would have equated co-

evolution with a 'communicative common environment (which) … is filled with objects and events apperceived … and experienced simultaneously (by both parties), although … the situation has two subjective foci: Each of the persons … lives through his own experience, of which the other is (only) a part. Yet he not only experiences himself in (a) situation, he experiences the experiencing of the situation by the other' (Schutz, 1992, as cited in Wagner, 1974).

Maturana and Varela (1992) also note that in the acquisition of knowledge, there must be dual, mutually informing processes taking place. In Vajrayana Buddhism, their point would be spelt out a little more explicitly, such that 'the knower, the known and the act of knowing are mutually specified' (Nydahl, 2004, 14 & 18). In the terms of interest to this paper, this means the Designer, the designed (object), and the act of designing are linked, at the same time as the User, the object used and the act of using it are specified. That, at least, is what we are looking for.

In this paper, we consider the concept of co-evolution from the point of view of Designers and Users (or other stakeholders) who come to a discussion with apparently opposing concepts of what should be achieved. Our model therefore deals not only with technical requirements, but at the very least, with a combination of technical and social requirements, which can often seem to form a real conflict or a contradiction in terms. Thus as we shall see, Users can fulfil some of the functions which Designers must otherwise inadequately carry out themselves, and vice versa.

Contradiction

Calling something a 'contradiction' is not normal engineering terminology. It was the Russian Genrich Altshuller who renamed what others perceived to be problems as 'contradictions' (see Altshuller, 1984), to take the intellectual sting out of the situation. A similar approach is taken in modern English-speaking countries, where it is now also politically correct to talk of 'challenges' rather than problems. Altshuller's 'theory of inventive problem-solving' (known in the West by its Russian acronym, TRIZ), which was originally developed in the 1950's, uses contradiction as the basis of its primary and the best-known tool – the 'Contradiction Matrix'. Due to the strength of this tool, TRIZ has been used by many American Fortune 500 companies. It is touted as the quickest methodology for generating patentable ideas both on its own

and combined with other well-known systems such as Quality Function Deployment (a method of 'total quality control' developed in Japan in the 1960's) and '6 Sigma' (a process improvement and failure reduction method which originated at Motorola Company in the early 1980s).

The Contradiction Matrix provides a shortcut to problem-solving, as long as the problem is formulated in a simple way. It has to be simple enough for Designers to see it in a 'play-off' between only two targets or variables that must be attained simultaneously, and which can be stated as two single words. This means, for instance, one would say 'I want to improve strength' and 'I don't want to increase weight', in which case one has 'a strength-weight contradiction'.

Please note that the concept of contradiction, in the way we use it (and no one knows whether Altshuller intended it to be used this way) differs from the concept of 'dialectic' known to Marxists and philosophers. The latter proceeds by arguing each salient point in turn, in a zigzag fashion, while we see contradiction as arguing two points at the same time. In that sense, we define contradiction as 'a line between two end-points, which represent dual targets to be reached, and whose length does not include the resolution' (A-K. Pahl & Bogatyreva, 2003). The resolution of the contradiction is achieved by thinking in another dimension. This is mapped as two arrows of thought converging on a

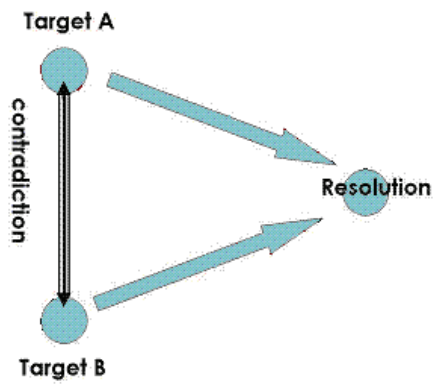

Figure 5. A way to present contradiction.
Contradiction can be represented as a line relating two targets, which does not include a point resolving the contradiction.
(From A-K Pahl & Bogatyreva, 2003; A-K Pahl et al., in press)

single point, whereupon the resulting triangle forms the solution-space, in Figure 5. The figure describes how contradiction can be represented as a line relating two targets, which does not include a point resolving the contradiction. (from A-K. Pahl & Bogatyreva, 2003 and A-K. Pahl et al., in press).

Our map of an internal conceptual space obeys the same rules as a mapping of external physical space. This is because we suspect people think of their conceptual resolution as if were a physical object, situated in the distant future, or unreachable, like an object on a distant horizon. Thus we also map it in the same way that parallel railway tracks mapped in a pre-given world triangulate on the horizon.

However we need to point out that there are many directions in which one can look, and many places at which one can start mapping one's conceptual space. Certainly, looking at a point the physical horizon first in front and then behind oneself would produce a diamond-shaped map. Conceptually, the same is true. Thus a Designer can stand in the middle of a 2D 'Diamond Map of Design', looking both forwards to the expected solution, and backwards to the unknown problem origin. This situation, the 'Diamond Map of Design', evolves by establishing a line of contradiction, and defining points at which the resolution and problem-source exist. This is illustrated in Figure 6 (from A-K. Pahl, 2006a).

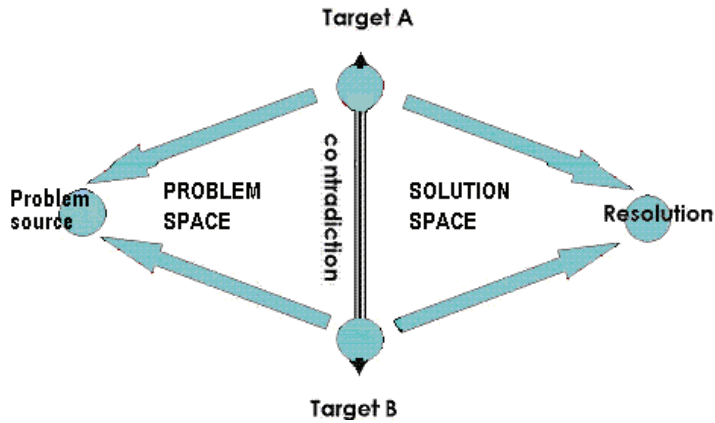

Figure 6. The 'Diamond Map of Design'.
The 'Diamond Map of Design' evolves by establishing a line of contradiction and defining points at which the resolution and the problem-source exist.

We also wish to point out to the reader that a diamond-shaped map of conceptual spaces is not only a construct of our making. The diamond geometry of conceptual space more or less coincides with the research of others. In particular, most empirical research studies in creativity now confirm what psychologists have intuited since the time of Wallas (1926) – any process of creating something new is defined by a sequence of roughly the same kinds of (between three and seven) discrete acts, periods or steps. These steps can be summarized in even fewer stages. The two most important are a period of 'divergent' thinking (term from Guildford, 1950) or apparently uncensored idea generation and multiplication, followed by a period of 'convergent' thinking (term again from Guildford, 1950), which we also identify as editing, criticism and evaluation. These stages have also been well-known to engineers for some time, even though they were largely disregarded in practise (due to the simplicity of the original literature) and rarely drawn on paper. As Figure 6 intimates and Figure 7 confirms, mapping the thought process of divergent and convergent thinking in its simplest combination on paper produces a diamond. Figure 7 gives an overview of the 'Diamond of Creating' and 'Diamond of Problem-solving' (which are the same). Note that the arrows of thought on the left hand side of the

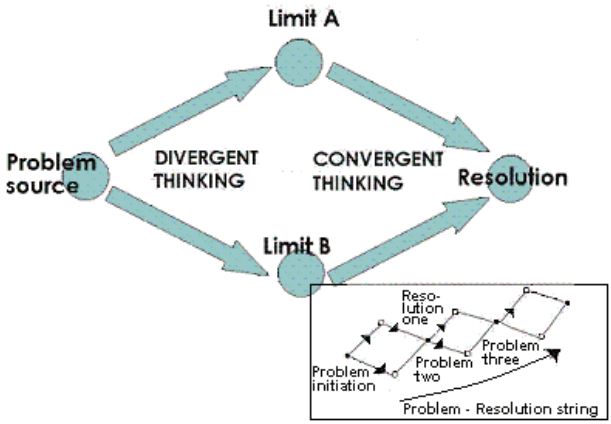

Figure 7. The 'Diamond of Creating' and ' Diamond of Problem-Solving'.
Note that the arrows of thought on the left hand side of the diagram (in the problem space) move in the opposite direction to those in the 'Diamond Map of Design.'

diagram (in the problem-space) move in the opposite direction to those in the 'Diamond Map of Design'.

The fact that a diverging and converging conceptual space is already familiar to Designers indicates that the diamond is not only an obvious choice, but a useful one. In spite of this, we ask the reader to please note that depending on where one stands (perceives and starts creating one's object or world), the arrows of conceptual thought move in different directions.

In previous literature and practice (and as is illustrated in Figure 7), people spoke of both creating and problem-solving, as if Designers moved only in one direction, from left to right in the manner of reading text in the West. This is presumably because creation of an object with a known template proceeds neatly from a starting point to a finishing point. Likewise, Designers may think they know exactly what their problem is, and believe they move from the source of this problem to a solution, in the same way that they would create their product, if no problem existed.

In that case we point out (and engineers also know this from their daily work) that the first resolution can immediately become the second problem, and so on. In fact, there need be no end to the cycle of problem-solving, just as there is no end to the cycle of creating potential solutions (even for potentially non-existent problems).

In short, what we call the 'Diamond of Creating' is identical with the 'Diamond of Problem-solving' and both are a problem-resolution string.

This kind of thinking is not very innovative. It does not liberate Designers' previous concepts from their old constraints; it merely replaces them with the same ones in different guises or contexts. In Buddhist terms, this kind of thinking typifies samsara (Sanskrit. approximately meaning 'cycle or process of illusion' and 'bondage of ordinary life').

Innovation, on the other hand, is distinguished from pure problem-solving and also from the simple single act of creation by the ability to look in both directions simultaneously.

This kind of thinking allows the Designer to start constructing his world from either the problem-space or the solution-space, or preferably, both together. This paradox is crucial to innovation, to introduce new ideas not just for the sake of having ideas, but for the sake of being

in the appropriate context (A-K. Pahl, 2006a, A-K. Pahl et al., in press). It is obvious that one cannot solve a problem using the same kind of thinking that created it in the first place. That means, by definition, new ideas are sourced outside the original problem-space.

Comparing and matching the elements in a problem-space and those in solution-space is easiest if the elements are temporarily highly abstracted. Altshuller's (1984) formulation of technical contradiction in two terms is the simplest way to do this. Having formulated his contradiction, the Designer then stands at the centre of our Diamond Map of Design.

Just as importantly however, in innovation (as opposed to creation or problem-solving) the Designer need not find his own solution. As every TRIZ practitioners and Google users know, it is possible to create more quickly and arguably better by 'stealing' (this term from Vincent, 2002, meaning 'adapting') someone else's existing solution, or a close match. This match can be carried out on the level of the individual working with intellectual knowledge databases. Or it can be carried out by the Designer discussing possible solution scenarios with others. In any case, the two directions of evolution co-exist, such that the worlds, views and maps of conceptual spaces for other stakeholders can be superposed and interactive with those of the Designer. We will discuss this in more detail later.

Lastly, we propose that the process of innovative design (via resolving contradiction) is not a single act of looping forward and backwards, but an iterative or recursive process. This is intimated by its etymology – the term 'innovation' comes from the Latin novare, meaning 'to make new' and Latin inne, meaning 'within itself'. In the same way, it is also intimated in the ritual of Meditation (discussed with Figure 1). It is intimated in the process of establishing analogy between two previously unconnected objects, events or worlds, in ever-finer precision of measured similarities and differences via a repetition of three simple mathematical steps (A-K. Pahl, 2001; A-K. Pahl et al., in press). It is mentioned by S. Beer (1984, p. 25) in terms of his Viable System Model, as will be further discussed below.

Action, Reflection and Research

Engineers would generally say that their practise consists almost purely of action. Design, on the other hand, includes some cognitive reflection

on previous actions (A-K. Pahl et al., in press). Where and when reflection occurs is the key to success. Engineering Designers, especially in very large companies, often carry out both kinds of behaviours, from the early stages to the end stages of product design. They not only act but also reflect on their actions, and thirdly even also often attempt to observe, record and interpret their activities and reflections (traditionally in diagrams and more recently through computerized 'creativity-support tools') both during and post design. Such behaviour is ad hoc – implicit in community practise and not consciously acknowledged or executed as a meta-design or research activity. This situation exists, because they rarely have a chance to interact directly with stakeholders outside their team, who might fulfil some of the functions of reflection and research. Thus they are subject to the 'character of practical knowledge … (for) the knowledge of the man who acts and thinks within the world of his daily life is not homogeneous: it is (i) incoherent (ii) only partially clear (iii) not at all free from contradictions' (Schutz, 1972, as cited in Wagner, 1974).

Of course, reflection on product design is best supplied by those who are or will be the users of the product, and no longer by its creators. The User can, and usually does, present the Designer with a different view of requirements based on social considerations that may appear initially to contradict current technical capabilities. Yet this contradiction from the market of Users always drives engineers to find another resolution and add more dimensions to the final system (or product or process).

Despite the fact that human beings can and ideally should carry out multiple functions, in this paper, we still assume an important distinction exists between the technical functions of Designers and social activities of Users. This is because we know from real life Engineering Design that both parties are not really in a position to speak for each other.

A facilitator or Researcher must behave in yet a third way, that of trying to generate 'knowledge'. He is in a difficult position, where he cannot speak purely for either Designers or Users, he cannot align himself completely with one party or the other. Instead, he must try to generate a better understanding of the important relationships between action and reflection, on behalf of others who are fully engaged in either process, while perhaps semi-detached from both. Of course this does not mean that the Researcher is separate from the process and experience,

for one can nevertheless also not be a mere 'objective observer' as Western scientists would traditionally have liked. As is well known in phenomenology (Psathas, 1973, pp. 129-156) and popularly cited from quantum physics, one cannot be separate from the world one observes. In the Researcher's situation, one alternates and ultimately integrates his judgement between the conflicting parties and avoids promulgating a view of 'us and them'. One negotiates between a solution-space and problem-space, and considers internal emotional considerations together with external system requirements, for the product or issue being discussed.

We hope the reader has noticed the authors are Researchers who speak not only for ourselves, but also hope to speak for, 'copresent', contemporary academic researchers (to use the terminology of Wagner, 1974), whom we know. We speak for all those people, who have multi-disciplinary backgrounds that cause them to cognitively stand between two groups of people (such as Designers and Users) or two or more scientific domains, trying to find coincidences and differences that will inform both sides. To be exact, we believe a Researcher can and should take the position both of the Designer (who creates a physical product and an associated conceptual system of rules) and of the User (who buys a product and intuitively enters the associated conceptual system). By making it linguistically clear that there are distinctions in function between them, we can better understand how each of the participants in a system composed of opposing viewpoints can best function. Furthermore, due to this unique vantage point, the responsibility of building a model or structure of the dynamic process where action and reflection inform each other (and are potentially unified) falls to the Researcher, rather than either of the other types of individuals or functions.

It must be said that there will, in an ideal, fully functioning system, be additional roles to play – the Manager, for one. However although we can (and will later) show that his role has a central position in the Mandala for Design, considering his full impact and relationship to our three primary roles is beyond the scope of this paper.

The 'Generic Process of Creating'

The authors of this paper recently carried out a comparative study of the stages of creativity and innovation which are well-accepted and arguably dominating in hundreds of processes in many fields, including

psychological literature, engineering design, knitting fashion, sociological action research, Organizational development (of commercial enterprises rather than biological systems), theories of colour and perspective in renaissance art and architecture, baroque and early classical music, the classic dramatic structures of literature and modern screenwriting, commercial creativity tools and innovation tools, and the practise of Buddhist Meditation (please see Pahl et al., in press, for a literature list).

The 'Generic Process of Creating' in a Table

Laying all processes whereby various things are created side by side, and carefully translating the keyword terms for behaviours from different domains, a set of common, standard or underlying stages and principles of behaviour becomes obvious, as outlined in Table 3 (and further discussed in the section 'Mandalas for Engineering Design'). A single 'generic process of creating' is presented in the extreme left column, which includes all the steps of the processes in all domains, but at the same time abstracts their essence and simplifies their language. The column entitled 'Commonalities in humanities literature' abstracts another table from A-K. Pahl et al. (in press), which summarizes the steps of creating that were identified by psychologists since 1926. The terminology we chose for the generic process is linked with the geometry we developed for the evolution and representation of the conceptual spaces of design. That means we attribute the complexity of the problem-source to lie nested inside a (non-dimensional) point at some 'infinite horizon'. Likewise, a complete solution (the specifics of which have not yet been defined) is nested inside a point at the other horizon. In between these endpoints lie two fields of expanded awareness or conceptual space. The first field encompasses the ideas evolving around the problem, and the second field entails the ideas, which are worked into a solution.

The fact that such a generic pattern does exist cannot be merely a vague coincidence, or a device of wishful thinking. While it is true that minute difference in process and potentially major differences in the problem- and solution-spaces of domains do exist and are fundamentally important for including personal experience and context (and can be explored under the auspices of a formal hermeneutics), the express aim of identifying an underlying framework is that it should provide a structure upon which all succeeding differences can exist and make sense.

We therefore return to a question we alluded to earlier: Why, when inventions are obviously invented without requiring conscious awareness of the process by which they happen, do we need to make explicate a structure for innovation in design?

We can answer this question with a brief diversion into the Theory of Music. Music had no formal notation system in the Western world, prior to the Middle Ages. It was taught and remembered and passed on orally, aurally and through practise. There had apparently been some knowledge of fundamental principles, which linked sounds irrespective of the instrument used to produce them – in other words, there was an intimation of a previous theory of music, in the time of the Roman Empire. But this was lost at its fall. The (re-)development of symbolic musical notation towards the very end of the Dark Ages occurred to facilitate and preserve Gregorian chanting in English monasteries. The point relevant to our argument about a system for innovation is that the development of musical notation did not affect any implicit understanding or cultural feeling for the ideal spatial relationship of tones. Music continued to be sung and played and passed on around the world, as it had been for millennia. Having notation did also not change the frequency of tones or their factual relationship to each other. Nor did it change the fact that each composer could vary the temporal relationship of constituent tones, in order to make sonatas distinct from symphonies for instance or to allow jazz music to develop from classical. The development of a common notation did, however, have an enormous impact on how music was shared and taught. Understanding – and developing a notation for- the principles, which connected the sounds (as a Theory of Music) made it possible to pass music on to people who had never heard a particular kind of music. Then, given the right environment for practise and the provision of appropriate tools, musical notation enabled practitioners to recreate the original composition, through an imagined aural transmission, rather than the oral transmission.

It is for this reason that we propose the pattern of creating, which we have identified and call generic, is necessary for Design. We hope that the existence and passing on of this pattern should not be subject to debate for emotive reasons we discussed as hindrances to this research in the past (in 'On the difficulties entailed in reporting').

The Generic Model of Creating – A Diamond Map of Co-evolution

The generic pattern of creating is, happily, not merely a matrix or taxonomy, but as we have already seen can be geometrically represented as a diamond of cognitive or conceptual divergence and convergence (in Figures 5, 6 and 7, above).

In our previous paper (A-K. Pahl et al., in press), we gave a rather complex explanation of how the Designer can simultaneously view his conceptual space from different starting points and fulfil all functions of action, reflection and understanding of his system. Thus we started to define the mechanism of co-evolution.

We will not repeat that explanation nor reproduce that map here. For this paper, we can explain the mechanism of co-evolution more exactly by considering how Designers interact with Users.

Suffice to say that we assume Designers have a tacit or explicit Diamond Map of Creating for their conceptual space of Engineering Design and Users also have a separate Diamond Map of Creating for their conceptual space of product use. In order to find a coincidence of their expectations and experiences, they – or a Researcher acting on their behalf – need to superpose their respective maps of the world.

The simplest way to do this is to assume that the divergent thinking of the Designers is met by the convergent thinking of the Users. Figure 8 shows a simple 'Diamond Map of Co-evolution'. The divergent thinking of one team is met by the divergent thinking of the other in a pre-given space of knowledge transfer. In other words, the Users act to provide reflection to the Designers and the latter need not do it themselves. This is the situation akin to that described to considering Buddhism as magic (Figure 1). It is also the ideal situation of innovation for, if one has understood the problem-space systematically, correctly and completely, the pattern of the problem-space and the solution-space are easier to match and knowledge can be transferred. When this process is unconscious, it can seem as if the solution comes to meet the seeker by divine inspiration (A-K. Pahl, 2006b). Note that the arrows signifying thought in this diagram are different to those in Figure 6 and Figure 7. We will explore this form further in 'Mandalas for Engineering Design'.

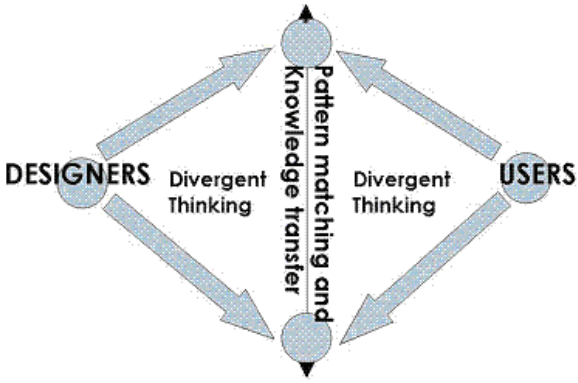

Figure 8. A simple 'Diamond Map of Co-evolution'. The divergent thinking of one team is met by the divergent thinking of the other in a pre-given space of knowledge transfer.

The last important point to extract for this paper from our previous one, is that the seven steps of the Generic Process of Creating (see Table 3) are divided into the three stages of (i) divergent thinking, (ii) convergent thinking and (iii) pattern matching, knowledge transfer and/or transformation, as illustrated in Figure 9. This figure describes the 'Diamond Map of Co-evolution', with divergent thinking at one end of the diamond, convergent thinking at the other and knowledge transfer in the middle. Please note in this diagram the thought arrows defining the map are given for Designers only. The fifth step of innovation, which takes place immediately right of the plane of pattern matching and knowledge transfer (also the plane of reflection), requires Designers (and Users) to specify a complete system description. It is this step, on which we concentrate for the remainder of this paper.

Table 3: The 'Generic process of creating' on the left, juxtaposed against other processes of creating in the remainder of the table (from Pahl et al., in press)

GENERIC PROCESS OF CREATING		*Commonalities in humanities literature*	*Engineering DESIGN PROCESS*	*CREATIVITY METHODS, MODELS, TOOLS and TECHNIQUES*			
				Mindmapping	CYNEFIN MODEL for COMPLEXITY	Narrative/ Literature	Meditation
Pahl (2005 a, b)			Pahl & Beitz (1984)	Buzan and Buzan (1993	Kurz and Snowden (2002)	McKee (1997)	Nydahl (2000a)
Problem as point	1	Problem or situation definition	Identify essential problem, need or task	Identify goal (implicit)	Define known domain - cause and effect of situation are repeatable and predictable	Inciting incident	Define current situation –which inherently creates the motivation and reason for moving toward another goal
Problem as field	2		Establish function structures	First burst of associative ideas around the goal (brainstorming)	Establish parameters of Knowable domain – cause and effect may mismatch in time and space	Establish context	Establish specifications for the ideal final goal
		Incubation	Create specifications for solution				
Idea generation	3	Idea generation	Search for working principles	First reconstruction and revision	Explore complex domain - cause and effect are coherent only in hindsight	Define conflicts	Set up conceptual template of a potential solution
			Combine principles into concept variants	Incubation		Search for resolution	
Idea evaluation	4	Idea evaluation	Concept preliminary layouts	Second reconstruction and revision (analysis and decision – making)		Critical choices which are most likely to lead the hero to success	Establish detailed structure of solution template in iterations addressing material, information and communication systems
			Test embodiment with respect to solution principles		Explore chaotic domain – cause & effect relations are completely incomprehensible		
Insight, integration and pattern matching	5	Incubation	Form variants of assemblies	The final stage of matching solution with goal	Return to complex domain		Overlay (melt) solution template on (or into) current situation
					Establish second known situation	Climax	
Solution as field	6	Solution generation including problem situation recapitulation	Optimize design				Evaluate best fit of solution in context of current situation for activation
			Definitive layout			Reversal	
Solution as point (Ideal final result)	7		Finalize production documents			Resolution	Dedicate a general application or template for all other systems and societies

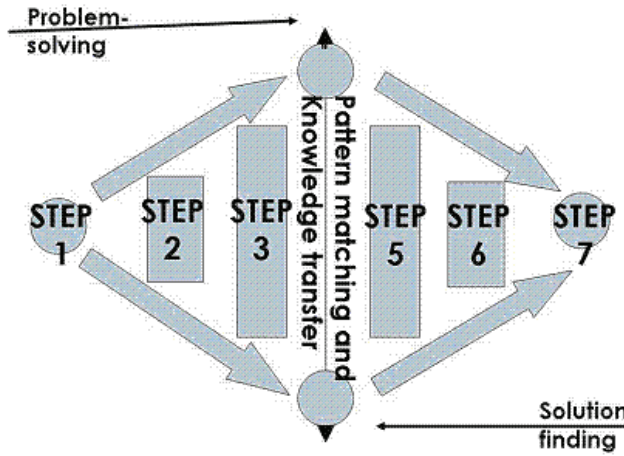

Figure 9. The full 'Diamond Map of Co-evolution'. Divergent thinking is at one end of the diamond, convergent thinking at the other, and knowledge transfer in the middle.

Insights from Managerial Cybernetics

The Viable System Model

In this section, we will introduce some parallels of our research with that of Stafford Beer, who was acknowledged as 'the father of managerial cybernetics' by Norbert Wiener ('the father of cybernetics') (1948) himself.

Over the course of 30 years, Beer developed a rigorous model for Organizational behaviour based on an assumption that the biological structure of the human and his social behaviour were intrinsically linked. Starting with observations as a psychologist in the army, and then during several decades in management of the steel industry he dedicated his time to diagnosing Organizational behaviour and understanding long-term growth. To pass on his insights, he started with a mathematical (set-theoretical) model of the brain as the template for organizational growth, but quickly realized that peers preferred to understand his concepts with more concrete information. Thus he combined the maths with what he considered everyone knew about their

bodies, in particular, about the central nervous system and general brain structure. In other words, he considered that the organization of the living and the mechanisms of perception were linked (cf. issue discussed in 'The need for Maps and Methods'). What is more, he believed that 'the organization of the living' referred not only to the individual, but also to society. He assumed that whatever patterns existed in the nervous system of the human would determine their behaviour and patterns of working in the physical and/or pre-given world.

The most important point for this paper is that Beer (1984, 1985) realized that a well-functioning and independent or 'viable' social system invariably included five distinct (necessary and sufficient) types of behaviours and sub-systems. In a trilogy of three books developing this idea, he proposed their integration in a 'Viable System Model' or VSM. In these books, Beer describes how functional decentralization and inherent cohesion of any system is possible once it is built on solid foundations. His model offers a way of providing autonomy in the design of adaptable and flexible organizations. Organizations built on his principles are apparently better able to balance both external and internal perspectives, and long- and short-term thinking, than others who do not use them (Leonard, 1997).

Beer never actually provided an explicit list of the five behaviours in any of his case studies or in any theoretical chapters of 'The Brain of the Firm' (1972) or 'The Heart of Enterprise' (1979). As he explained many years later, in response to others trying to create such a list, his rationale for leaving it out was that, 'the five sub-systems work recursively and cannot be isolated from each other, so attempts in the literature to identify them separately with managerial names are ill-conceived' (Beer, 2000).

However we propose that he was being over-cautious. The fact that a system includes interdependently arising and recursive behaviours should not stop us from identifying what these behaviours actually are. Thus we now provide an interpretation of the stages, qualities and functions, which the VSM sub-systems exhibit. This list is distilled from many different parts of his work, and of course, as Beer (2000) also said, does not imply a definitive order of manifestation:

(1) structural physical elements which provide the elements to be controlled and the initial direction in which movement takes place (e.g. the body or environment);

(2) the information systems, which coordinate relationships between elements in (1);

(3) the autonomic command centre, for operation and distribution of the internal functions of (1) and (2);

(4) the centre for planning and foresight and integration of (1) and (2) and (3) with the outside world;

(5) the overall command or control centre, which balances all other functions and demands (and is the so-called 'heart' or brain of the firm).

A more succinct summary of the VSM, whose stages are nevertheless comparable to ours, has been proposed by Leonard (1997), who worked with Beer for 25 years:

- Implementation (System1)
- Coordination (System2)
- Control (System3)
- Intelligence (System4)
- Policy (System5)

The sub-systems in the VSM are also comparable to the Mandala of the Five Buddha Families and the grouping of the Buddhist 'skandhas' (meaning 'heaps' of aggregated sense consciousness), as shown in Table 4 (using Leonard's, 1997, terms for the sub-systems). In other words, these three systems make similar conclusions about the way in which human perception and behaviour is organized. This is not completely surprising, given that Beer used models of the physiological functions of the brain and nervous system to underpin his VSM. We propose it stands to reason that if humans are built the same general way, then they must also have an inbuilt tendency to build structures and relationships in a particular order – or at least to include many of the same steps in creating, no matter what or in which field they create. Thus it is also not an unexpected coincidence that the five sub-systems of the VSM are evident in the first five steps of the generic process for creating, which was partly shown in Table 3 (A-K. Pahl et al., in press).

Table 4 Comparison of Mandala of the Five Buddha Families and Buddhist skandhas with the Viable System Model of Stafford Beer (2000).

Organizational System describing perception and experience	Predominant function of Sub-systems of an ideal whole				
	Sub-system 1	Sub-system 2	Sub-system 3	Sub-system 4	Sub-system 5
Mandala of The Five Buddha Families	East - Identification	South - Equality in Diversity	West - Discriminatio n	North - Overall accomplishment	Centre - Ultimate reality
The Five Skandhas of Buddhist philosophy	Form, structure, body, sense objects	Perceptual stimulus, feeling, sensation	Cognition, recognition mental processing of sensory stimuli	Mental habits, thoughts, ideas, relationships, associations, volitions	Conscious awareness of self, others and cosmos
Viable System Model of Stafford Beer	Implementation, initial direction	Coordination or information	Internal control	Integrated & externalized intelligence	Intention, Policy, overall command

Interestingly, Beer once laid out his four subsystems in a square 2D geometry, which can be compared to a Mandala (Beer, 1972, p. 143) – this is recreated in Figure 10. This diagram illustrates the coupling, which he suggests takes place in human organization and Organizations, both between the elements of the individual nervous system, and between the elements of societies or companies. In particular, a coupling exists between sub-systems one and three, which represent his 'external sensory' and the 'internal motor' worlds respectively. We paraphrase his 'external sensory' as the material world, which can be perceived with the five senses – this is a subset of our pre-given one. The 'internal motor' world is the set of neural and muscular connections which enable action and communication to take place. Another coupling exists between sub-systems two and four, which represent his 'internal sensory' and 'external motor' worlds, respectively. In our terms, the 'internal sensory' includes the five senses which facilitate perception (e.g. sight) as well as the nervous connections and mechanisms by which that sense is activated (e.g. the lens, pupil and iris). The 'external motor' world is the one in which action and communication takes place – again as a subset of our pre-given one. Each of the systems needs to 'switch' their mode of behaviour in order to integrate incoming information from their coupled system. He also points out that system four is 'the biggest switch', since it brings in information from outside the system altogether, as well as dealing with that from

the other three interior sub-systems. Sub-system 5, at the centre, refers to the overall control or command centre of the central nervous system.

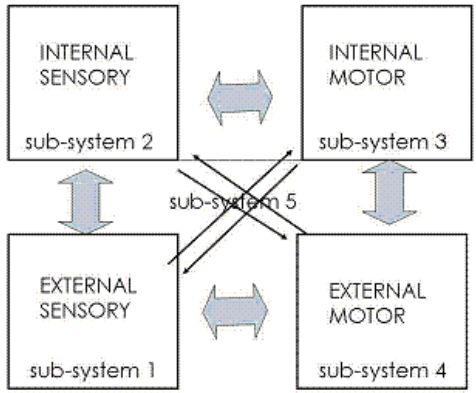

Figure 10. The Sub-systems of Stafford Beer's Viable System model (after Beer, 1972).

We note that Beer says nothing, which is categorically about perception itself, only about its environment. However, in both cases, Beer (1972, p. 182) implies that the pre-given world mirrors the perceived world. He implies that perception depends on the way in which movement and experiences are wired into the brain, and vice versa. In effect, Beer thus assumed as given from the outset of his work what other researchers have always generally questioned at the outset of their own. But of course, this was possible because Beer was interested in behaviours of groups in a pre-given world, and could only start his observation by proposing a generalized hypothesis of individual function. Maturana on the other hand, was not influenced by this consideration, and was interested purely in observing the specifics of individuals. Beer and Maturana were, in any case, also not the only ones to make observations like these. The phenomenologist Merleau-Ponty (1964a, 1964b, 1965) was convinced the experience of the outer world and the organization of the inner world are linked – his work is continued in the current philosophy movement focussed on 'Interactive Mind'. While we do not expand on the connections in this paper, we hope the reader will bear in mind that the perception and organization of the living may indeed be linked, as we describe 'Mandalas for Engineering Design' in the next section.

In Beer's VSM, just as in the Buddhist Mandala, each of the sub-systems one to four supports the function of the others in a recursive, co-evolving relationship, and is subservient only to sub-system five and the whole. This means that while sub-systems one to four are 'open' (in the mathematical sense), the fifth sub-system of a complete system enables the whole to 'close in on itself' (Beer, 1984).

This is mathematically relatively easy to say.

In practise however, Beer reported that Organizations find closure and hence viability difficult to achieve. He noted that teams were often flustered when asked to define the components of the crucial fifth sub-system in their Organization, even though they had easily decided upon the components of sub-systems one to four. In his experience, everyone gave a different answer, when nominating what sub-system five was or should be made of (Beer, 1984). In other words they could not agree on what ought to have been the central question, or 'heart' of their Organization.

Reflecting on why this should be difficult, Beer realized (particularly during his work with President Allende in Chile) that people projected their expectations regarding their own particular sub-system (and pre-given world) onto the whole. Since the Organization grew from different directions, there was no coincidence in the view of how growth of the whole was expected to take place (this is, of course, the exact situation a product Designer and User face when trying to integrate their worldviews). At that point of insight, many years after first establishing his model, he realized that it was the duty of the fifth sub-system to set, and affirm if necessary, some original intention as to what particular kind of Organizational growth all sub-systems should undergo (Beer, ibid). This point will be further discussed in 'Mandalas for Engineering Design' and the discussion on 'Purpose', where we integrate Beer's insights with our Diamond Model.

Mandalas for Engineering Design

A Five Element System

Iterated meditation on a Mandala, as Leidy and Thurmann (1999, in appendices) explain, should lead the practitioner to ever more refinement. In particular, one is expected to transform the five gross modes of sense-related behaviour prevalent in the pre-given world to three

more subtle modes of perception and behaviour (which we called 'meta-qualities' in the section on The Three Jewels). Now we will explore the exact steps how this transformation from 'real to ideal' happens and why it is relevant for Engineering Design.

As a complement to the ideal world represented by the five Buddha families, we introduce another Buddhist Mandala, which traditionally represents the pre-given world. In this, five figures are represented as worldly 'Kings' who are not completely liberated from fixation. They do, however, still hold the key to mystical knowledge and outwardly seem to act in a manner similar to the Buddhas (see for e.g. McArthur, 2002, p. 71). Buddhists suggest the reason for this similarity is that someone who strives to reach the pinnacle of achievement and also contribute to the best of all his fellows, will reduce chaos in his actions, and streamline, refine and evolve his preferred style of behaviour to achieve his goal. Ultimately he will exemplify a behavioural pattern which psychologists call 'archetypal' and Buddhists call 'achieving highest worldly dharma'. Without Meditation, this is the closest a person can get to true dharma. The so-called Mandala of the Five Kings is said to mirror the Mandala of the Five Buddha Families.

In Vajrayana Buddhism, the two kinds of world (that of the Kings and that of the Buddhas) relate to each other not just by reflection, but by being integrated in the perception of someone sitting in the middle of both worlds. The one who sees both worlds and integrates them, thereby overcoming all duality and discrepancies, is the historical (and primordial) Buddha.

How can this be possible?

This is possible because, as we pointed out in 'On the difficulties entailed in reporting'; and 'The need for Maps and Methods', both worlds (the pre-given world of the Kings and the ideal world of the Buddhas) are actually based on a concept or mental construct. We can exist in a mentally constructed world only with a mental body and not with a physical one. Thus, as Long & Burnama (2005) point out from ancient Mahayana texts, '… the mental body of the (Buddha-to-be) … proceeded to the (divine world), even as his (physical) body remained seated on the bank of the … River'.

The practical use of this statement will become more evident in Figure 11a, where we show how a Buddha might separate his view, while seated in the centre of the two Mandalas. This figure is based on the

view of the practitioner we introduced in Figure 4. We, the external observer (outside the plane of the page on which the diagram of the event is drawn) looking at a theoretical Buddha, would see him seated in the centre of one non-conceptual and two conceptual worlds. The only non-conceptual world is the one in which he is seated, meditating. Of the conceptual worlds, one is a pre-given divine world, to which he travels to with his mental body, and whereupon he becomes its central figure (the world of the Five Buddha Families). The other is a pre-given human world, in which he ordinarily acts with his physical body (when he is not sitting on the bank of a River) and where he has also reached the highest attainment and become the central figure (the world of the Five Kings).

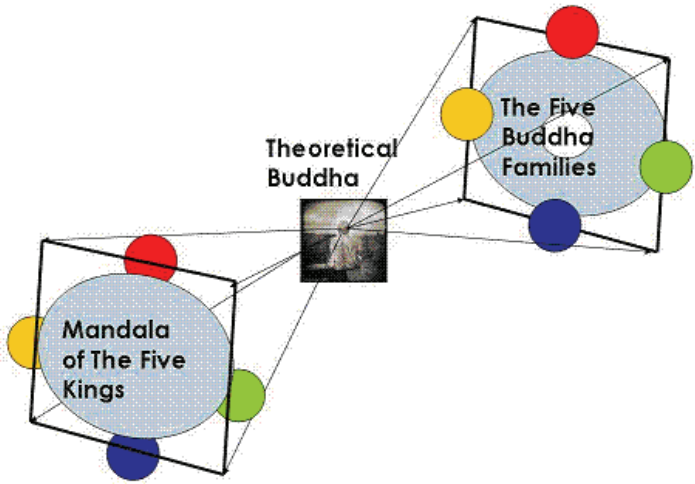

Figure 11a. A theoretical Buddha at the centre of two conceptual worlds.

Importantly however, we can show the very same situation integrated into a single geometry. As is described in Figure 11b, the theoretical Buddha of this paper may also make both his worlds coincident and co-evolving. This integrates (and inverts) the geometry of the preceding figure. This diagram is technically speaking an octagon, but we loosely call it a diamond. It illustrates how the action and reflection of Figures 6 and 8 (and the practice and ritual of meditation described in Figure 1), would look in 3D. At this point, the theoretical Buddha of this paper can appear to us (the external observer), to be coincidentally King, practitioner and Buddha. The three positions of true centre and

the two central end points are completely equivalent although they are expressed in different contexts. The Buddha acts in (and indeed creates or co-evolves) all these worlds simultaneously. What is more, as the theoretical Buddha makes all his worlds coincident, to our external eye, this not only integrates but inverts the geometry of the preceding part of this figure.

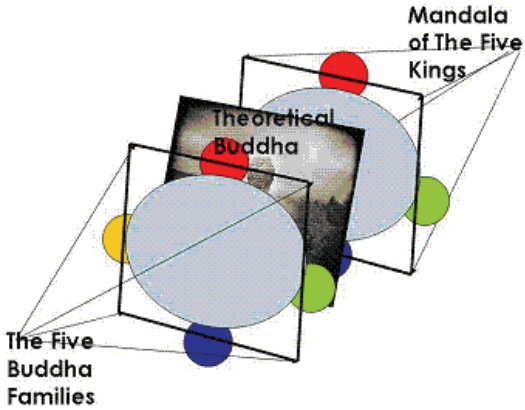

Figure 11b. The theoretical Buddha of this paper.

In Figure 12a and 12b, we show our first attempt to make the situation of the Buddha in the previous diagrams useful for Engineers and immediately find we cannot. The reason why we cannot do so is as follows: An ordinary person in a pre-given world based on Aristotelian logic constructing his or her worldview in isolation from other possible worlds. Let us say he projects or perceives the important elements of his world around him in the geometry introduced in Figure 4, i.e. a half-diamond. Now let us say there are two such people, each with their own geometric projection, and we, the external observers wish to join the two half-diamonds up in a single diamond, as shown in Figure 12a. We cannot do it because there is a mismatch in the position of the elements of the respective worldviews. It is possible, if we do not look too closely, that we might propose the worlds mirror each other. But they do not. The Mandalas on either side of the central plane are simply opposites. Figure 12a shows how the worldview of the Designer and User may be considered by two teams to oppose each other. Even though both have independently evolved similar Mandalas of thought and behavior, they do not naturally match over the central mirror plane.

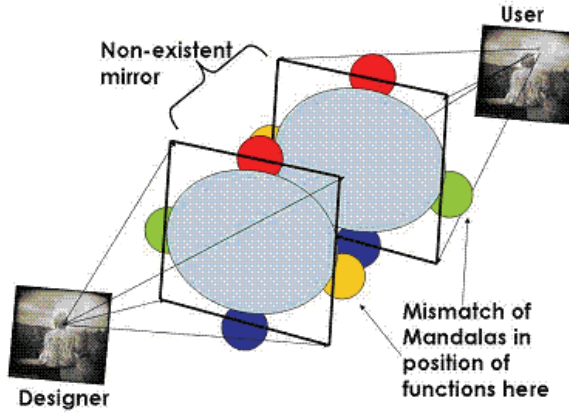

Figure 12a. The worldviews of the Designer and User considered as opposing.

Of course, that is precisely what occurs when we look in a mirror in the Western world. The image that greets us on the other side does not actually part its hair on the same side as we do. This mismatch is unavoidable because, as Plato pointed out in his book Timaeus (quoted and extended in Plitcha, 1998, p. 108), two mirrors must be placed at right angles to each other, giving four-fold quadrant symmetry (assuming the mirror extends behind the intersection we see), with infinite space in each direction, in order to get the correct image reflected back from the central join.

Actually, as Plitcha (1998) tested it, such a four-fold mirror '…shows me as if I were standing in front of myself and thus in reverse. In addition there are two normal reflections, one on the left and one on the right'. He goes on to ask '… do the four people – (myself) and the three reflections - also exist when I take away the mirror? …. (because if that is true then this) mirror makes it possible to see a hidden phenomenon, such as a mental picture, an idea.'

Plitcha thus proposes that a 'space of concepts' can be said to have or require a quadruple structure because it can only be seen completely by arranging two plane mirrors in this way. His argument links with Giordano Bruno's mathematics that ' … infinite space with (the mirrored planes measuring D^2 x D^2 giving a resultant) 4D geometry differs from finite space, which is measured in 3 simple axial dimensions' (Plitcha, 1998, p. 105).

It will be obvious to the reader that Plitcha's exercise establishes a Mandala of five elements, which includes the perceiver of a world within the central space of its mirrored geometry, as well as outside it. We thus confirm from a mathematical point of view that a five-element system is appropriate to model a complete conceptual space in the plane of the perceiver, just as is proposed in the Buddhist point of view. Furthermore, the existence of the perceiver both inside and outside that five-element system confirms the extension of that basic plane Mandala to create at least a sixth element and half the Diamond Model, which is the object of this paper.

We must also note in passing that having said two ordinary people cannot fail to mismatch the meeting point of their two worlds, our theoretical Buddha cannot geometrically fail to match his. This is in the first instance because the Buddha is just one being and not two separate individuals or teams with opposing concepts, motivations and views. Thus, when he starts moving into any world from his own central point (which is also the central space of Beer's fifth subsystem), he comes and goes from each of his perceived worlds in the same way.

To that end, he focuses not so much on the diamond structure itself – nor even on the individual elements which define that structure in a pre-given world. Rather, he focuses on the dynamic cycling of mind which links the elements and thus activate the diamond structure (as already alluded to in Figure 2) or indeed produce a Mandala coincident with the diamond in the first place.

In 2D, the cycling of mind is approximated by a wheel. In 3D however, this same motion is actually double helical and vortexial spin along a time axis. Thus the theoretical Buddha's mind cycles out from a single point in the centre where he sits between the worlds and comes back into a point at the centre. Next of course, it is important to note that the centre can exist in more than one place – at the very least in a Mandala at each end of Figure 11a and 11b. This movement produces ever more elaborate shapes. Further elaboration of the geometry and its implications for Research and Design is beyond the scope of this paper, but will be treated in a forthcoming project.

To be fair, we could actually disregard the situation of mismatched worlds for the sake of simplicity and force the elements of the Designer's world and the elements of the User's world to coincide like those of a theoretical Buddha, on either side of a central mirror plane.

We do this in Figure 12b, here we make a prototype of the Diamond Model, which is the penultimate step before building the model that is the focus of this paper. We force a coincidence of the worldview of the Designer and User upon each other. If we had no other option, we would thereby achieve a relative simplicity in the protocol of discussion between the two opposing teams (see 'Structuring Designer-User conversations with the 3D Diamond model') and a kind of prototype model. Thus we have loosely called this option a Mandala for Engineering Design. But it is not quite our Diamond Model yet.

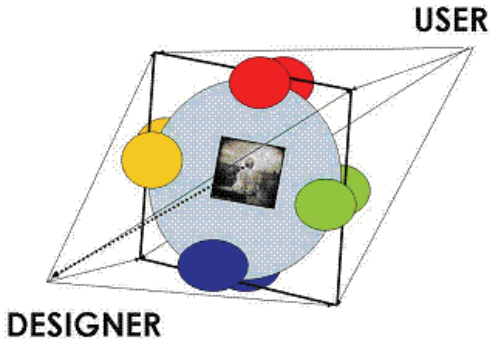

Figure 12b. A prototype of the Diamond Model.

Luckily, forcing the world to fit is not necessary. There is a way to resolve all discrepancies and dualism as if by magic, so that everything fits perfectly. This is possible because there is a second way for the Buddha to create a perfectly integrated world, utilizing the structure we can reognize as external observers. This involves the Mandala of the Five Buddha Families morphing into (or from) The Three Pillars of Buddhism, at another level of creation, as we will elaborate in the next section.

A Five Element System has Three Meta-qualities

In Buddhist terms, formal Meditation is a first step toward moving from a problem-space towards a solution. However, considering the elements of a formal Meditation to exist outside oneself involves only uni-directional movement of thought. As we have mentioned in Figure 1, and as explained by Leidy and Thurmann (1999, see the section above), the true experience of meditation is bi-directional. Not only does a practitioner move from his pre-given world, but the reflection of his action or the ideal reality should come in to meet him.

What we wish to consider now therefore, is the other side of the equation, especially in regards to innovation. In other words, how does one move from a solution-space to meet a problem-space?

To help answer this question, we looked at the elaboration of steps a Buddha takes to manifest in the pre-given world. Buddhist teachings explain that the last task an aspiring Buddha must undertake to prove his accomplishment is not merely to complete his own understanding of the absolute indescribable world, but to return from his realization of how things are, into the physical world, to teach others. In our terms, he must emanate from what we can consider the solution-space of Engineering Design.

The process of emanating a perfect form and perfect knowledge from space is described as unfolding yet hierarchical (in early Pali sources such as Mahavagga of the Vinaya, Mv 1, 5 and Majjhima-Nikaya 26 and also by Mkhas-grub-rje quoted in Long & Burnama, 2005) as follows:

Having completely realized himself as existing in the absolute indescribable reality, the new Buddha-to-be emanates two additional variations of himself. This corresponds exactly to the view of oneself as three people, which is created in the four-fold mirror of Plato and Plitcha (explained in 'A Five Element System'). On his right, we paraphrase that one emanation is responsible for giving (or enabling) methods or tools to achieve perfect reflection. The other emanation, on his left, is responsible for the power (or intensity of application) of the methods. Altogether, the trio is said to represent The Three Jewels – respectively, Buddha, Dharma, and Sangha.

Early Pali sources then say that, in order to penetrate and become inseparable from the physical world, the two emanated forms of the Buddha-to-be each split themselves into two more forms. The emanation of Dharma emanates two variations of himself – these being Akshobya (the Buddha of mirror-like awareness) and Ratnasambhava (the Buddha of equalizing awareness), whom we introduced in the section on 'The Mandala of the Five Buddha Families'. The emanation of Sangha also emanates two further variations of himself – these appearing as Amitabha (the Buddha of discriminating awareness) and Amoghasiddhi (the Buddha of all-accomplishing awareness).

In other words, the three preferred modes of behaviour (and associated meta-qualities) we discussed in 'The Three Jewels' always become five modes of behaviour at a more detailed level. The converse is also true:

the three meta-qualities and behavioural styles should arise from fully integrating perceptions from the five senses, emotions and physical experiences in one's pre-given reality.

This division of conceptual space into three and five categories can be shown as a neat hierarchy in Figure 13a, as the unfolding of space (The Three Jewels, The Three Pillars and The Mandala of the Five Buddha Families integrated and rephrased for this paper) from an absolute in-describable reality (which we first indicated without details on the right hand side of Figure 1).

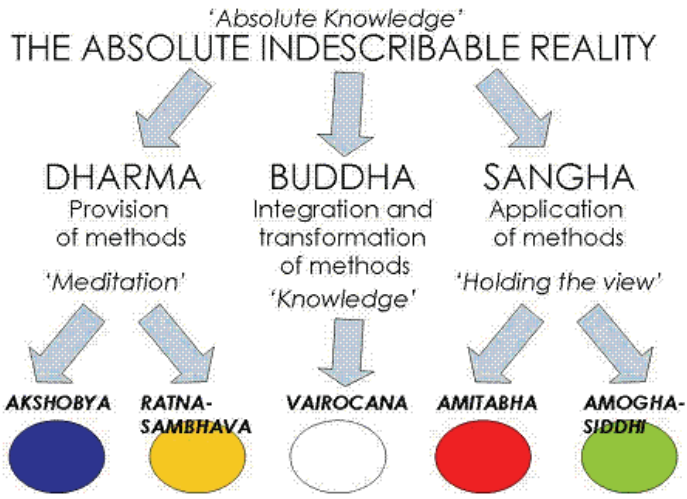

Figure 13a. Unfolding of space – Three Jewels, Three Pillars and Five Buddha Families.

The Buddhist division of conceptual space can also be rephrased for use in Engineering Design, as shown in Figure 13b. This renders the above explanation useful for this paper. We thus propose to consider the primordial Buddha of the Pali explanation as existing somewhat impersonally at the highest level, as 'The Complete Informing System'. At the next level down, his function can be carried out by a person who facilitates exchange of conversation and integration of information between the two opposing teams. In a static Organization, this role could be filled by a top-level Manager. In this paper and in the Mandala of Engineering Design and the Diamond Model as we use it now, the role of the Facilitator is carried out by the Researcher. As everyone knows, the Researcher does not have absolute knowledge at the outset of a

project. His knowledge evolves as the details and the conversations between parties evolve. He is, however, in the position of making questions simple for the participants in a discussion.

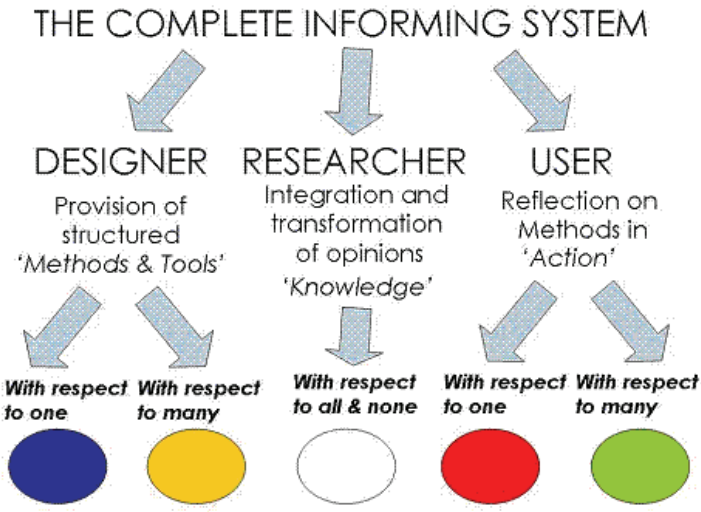

Figure 13b. The Complete Informing System - Buddhist division of conceptual space for use in Engineering Design.

In Buddhist teachings, the function of knowledge is present at every level of unfolding of space, as the central element or mirror plane. Both in Buddhism and in the Diamond Model for Engineering Designfor , if all functions perfectly, the system informs itself and the central role becomes invisible. Thus the holder of the knowledge both acts and does not act in two conceptual and one non-conceptual world. His only role in facilitation is to appear to others as if he understands both sides of the story of Design and Use.

The function of providing structures, methods or tools is exemplified in the spokesperson for Designers, who acts on the level of the meta-qualities. The spokesperson for Users also acts on the level of the meta-qualities, where he provides reflection and feedback on the use of said structures, methods or tools in real life.

The functions of mirroring- , equalizing -, discriminating - and accomplishing total awareness of one's reality are achieved by different teams acting as different sub-systems of the Complete Informing System. In

order to achieve the best result, it is easiest if we (and the Buddha-to-be) do not think of the sub-systems as being four completely different behaviours. It is possible, quite succinctly, to apply just two different modes of thinking about action and its reflection in the pre-given world, albeit in two different ways. In Figure 13b we describe the Complete Informing System' – The Buddhist division of conceptual space as rephrased for use in Engineering Design. The two ways are: in respect to one (the individual), and in respect to others (many interdependent 'universa'). In other words, the ideal Researcher should not necessarily look in a plain mirror to reflect on his own actions, but left and right at his spokespersons (or in a multi-dimensional mirror), to see the actions and reflections of others. In these two ways, he covers all possible problem- and solution-spaces.

This finally brings us to the Diamond Model for Designer-User interaction, which is the point of this paper as, we return to a point we promised to clarify at the end of the section on 'A Five Element System'.

There is, in fact, a magical resolution of the mismatches of the two five-element Mandalas, which are experienced and projected by Designers and Users respectively. The key is in the hierarchy just presented and in Beer's insight on the purpose of a Viable System. Assuming of course that Designers and Users wish to see themselves as part of a single informing and co-evolving system, then the answer to achieving it is to (tautologously) propose a template for its existence first. This does not need to be completely visible or spelt out, but it must certainly take at least a rudimentary form.

This should be followed by assigning two spokespeople, who are integral to achieving the central purpose. The one provides the methods in the first place; the other provides feedback on the application of the methods. Both can be called into being simultaneously. These two spokespeople are then responsible for a delegating their work in a further two people in a third step.

We tried visualizing how the functions of the Designer, User and Researcher relate during emanation and found the easiest option is to place them in a straight line, with the Researcher in the centre. Then the Designer and User form end-points of a line. From the end-points, we then visualize the placement of the two sub-systems for each primary function back into the central plane. The spokesperson for application of the methods is responsible for only two functions in a com-

plete Mandala system which has five second-level functions. Likewise, the provider of methods is responsible for delegating only two functions in the complete Mandala system. Each delegation forms half of a full, stable Mandala square around the Researcher. The important point in unification of the opposing teams is precisely that – the Mandala of each side is not complete on its own. They complete each other. The ideal and expected natural order of set-up of functions in a Complete Informing System is shown in Figure 14a, with arrows indicating direction of emanation and set-up. Together, the spokespeople and their sub-functions (teams) form the rough outline of a diamond. This figure shows the ideal order of set-up for achieving a Complete Informing System. The higher level purpose and view of the Designer and User form end-points. The two sub-functions of each end-point add together, to create an integrated and stable whole.

Lastly, we integrate and paraphrase the terminology of The Three Jewels, The Three Pillars, and the Mandala of the Five Buddha Families, as already shown in Figure 13 with the VSM of S. Beer (1984, 1985), and arrows of Figure 14a, to produce the Diamond Model for Designer-User interaction in Figure 14b. This figure describes the final Diamond Model for the Complete Informing System of Designer-User Interaction.

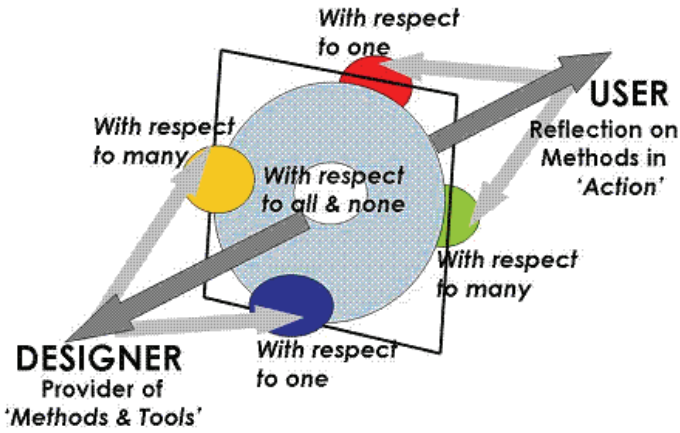

Figure 14a. The ideal order of set-up for achieving a complete Informing System.

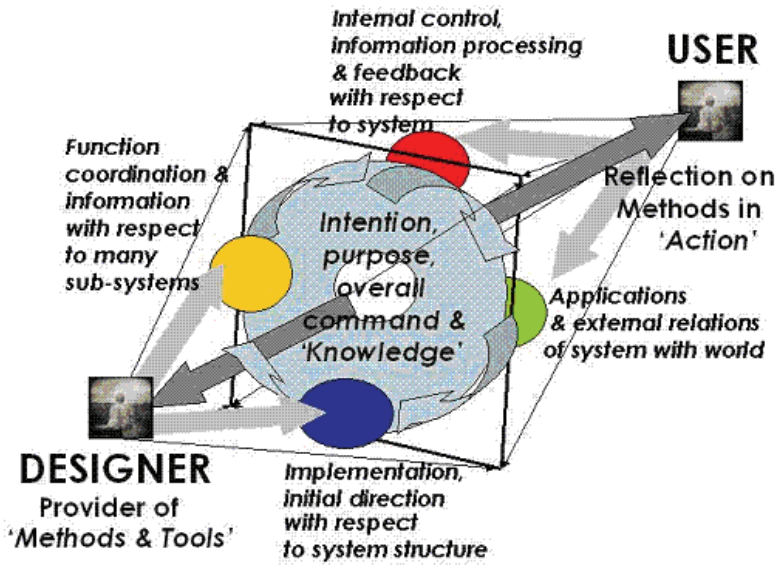

Figure 14b. The final Diamond Model for the complete informing system of Designer-User interaction.

Structuring Designer-User Conversations with the 3D Diamond Model

Why?

The ideal representation of the process of discussion and resolution of contradictory requirements in design is probably a spinning, double-helical vortexial model. This would show that the process is fluid, flexible and integrated and might help Designers understand how the 'flow' of the creative process should feel (to use the terminology of Csikzentmihalyi, 1997).

Such a model would not, however, provide any structure whereby teams of Designers and Users could interact and consider all angles or directions of their potentially conflicting technical and social issues. And since we know from S. Beer's (1984, 1985) VSM that having a clear structure is basic and integral not only to building a world in the first place, but also to establishing viability of an organism or Organiza-

tion, we propose to take Beer's lead, using a solid geometry – the diamond described in the previous section, for modelling conversation.

Beer (1994) used an icosahedron to marshal and enhance the dynamics of (Organizational, personal or product) design and thought processes in a process he called 'Team Syntegrity' (from a playful combination of 'synergy', meaning the condition in which the properties of the whole are greater than those of the sum of its individual parts; and 'tensegrity', which was a word coined by Buckminster Fuller around 1975, to mean 'tensile integrity' – the structural strength provided by tension). Beer (1994) chose this topology both by trial and error while running workshops on the technique, and was also influenced by theoretical considerations. As we saw earlier in this paper, Beer was predisposed to seeing five-fold geometry as being the most useful for representation of the way in which individuals formed teams in their pre-given world.

In his model, groups of five triangular faces form twenty pentagonal clusters. Thirty people are needed to represent the edges of the structure, as well as the innovative design solutions at the vertices or nodes. The latter represent combinations of two or more ways of perceiving a given problem (Itsy, 2006; Leonard, 1999; and Schwaninger, 1997). For an extract from Schwaninger's summary of the protocol, see Appendix A. For an interpretation of Leonard's work as applied to our Diamond Model, please see Appendix B. Suffice here to say that, having defined what is important via less structured processes (including a 'Problem Jostle' leading to 'Statements of Importance'), five people discuss one topic, and thereafter thirty discuss twelve topics. Each participant is a member of two conversations, which are different to those of all other participants, to provide 'compressive strength' to the structure (Leonard, 1997) and there are at least three iterations of the procedure, which ensure that there is over 90% of information shared throughout the whole group.

What is notable about the Team Syntegrity model, in comparison with our Diamond Model, is that the topics to be discussed are not pre-empted. Strangely, Beer never applied his insights from his VSM to the protocol for discussion in Team Syntegrity, although he did suggest that the latter could be used as a periodic activity in the former. In that case, he expected it to balance attention between the inside and outside of the system, and thus between the functions of sub-systems three and four (Leonard, 1997). In short, while he saw the need for combining the views of opposing teams, he did not attempt to ensure that any par-

ticular types of issues would be covered. He left all decisions regarding the kinds of issues that were to be raised around a central theme, to emerge from the team.

By all accounts, Beer's model works well and is not so difficult for a Facilitator or Researcher to learn and apply in an Organization, with a little practise (it is licensed to business consultants and widely used in Europe today). However, it also requires companies to set thirty key decision-makers free from their everyday duties (one for each icosahedral edge or strut), for five full days – which is the time it usually takes to come to a final conclusion using this model, and this is a significant investment, which not everyone can make (Leonard, 1997). As a result, Beer and some of his colleagues (Cullen & Leonard, 2000; Leonard 1996) experimented with extracting 'short-forms' of polyhedra from the icosahedral model, which could achieve the same structure with fewer people, retaining the same twelve-fold depth and complexity of topic discussion. He felt the 12-fold nature of icosahedral vertices needed to be retained for the process of dialogue, in order to reduce the risk that topics and points of view would collapse onto each other too early, before there had been enough divergence of ideas.

Although they subsequently decided against implementing any of them, it is of note for our paper, that the first of the short forms, which allows the Team Syntegrity protocol to be run with only twenty-four people, is a distorted cube-octahedron (Truss, Cullen, & Leonard, 2000). Successive compactions of the icosahedral geometry lead yet closer to our own favoured geometry, making use of the dual quality of a cube-octahedron that allows it to flex in peculiar directions and fold in on itself (called the 'vector-flexor' property by Buckminster-Fuller). The ultimate compaction produces a topic space, which approximates a flattened cube-octahedron approximating the 3D Diamond Model, where twelve people can fulfil all the previous roles and depth of discussion, which were expected in the larger form (Truss et al., 2000).

It would seem there is merit in considering our Diamond Model as an addition to Beer's original geometry for the following reasons:

The first is that, over and above the need to have shortened versions of Team Syntegrity on the basis of saving time, we can fill a gap for a model of conversation and activity between not just one team but two distinct teams, who must come to a common ground.

The second is that we can definitively state that the ideal system can be described in merely five sub-systems from a science of mind, which has some 2500 years of experiment to its credit. Applying the structure of the Mandala of the Five Buddha Families to team discussions enables the different starting points of participants to be honoured and does not force anyone to view their 'Organizational Mandala' from the same direction as other participants, from the outset of discussion (or indeed at any other time). At the same time, providing a coincident and co-evolving structure for conversation from two end-points contributes to the faster emergence of a common purpose.

How?

Beer's model was worked out over many years and it is, as Allen Leonard (1997) writes, 'beyond its experimental stages in some sense but not in others'. The existing protocol and 'key questions to be asked' during the process (also appended to this paper) are known to produce results, but there are many avenues for further research.

Our model seems to fit with (and is potentially integrable with) what has been done by Beer and associates referred to previously in this section, although we have not yet confirmed a formal protocol for its use. Our Diamond Model is still very much in experimental stages. However, based on what already works, we have drawn on Beer's (1994) Team Syntegrity protocol to help structure our questions and movements in the physical space of the conference room where discussion takes place. Our suggested protocol keeps the crucial 3-fold and 5-fold geometry (which Beer also thought important for reasons of his own), which has been discussed at length in the previous section.

In this respect, we have proposed the following protocol to start experimenting with using the Diamond Model of Designer-User interaction:

1. The process can be carried out with as few as 10 people – two teams of five, plus a facilitator or Researcher.

2. The process is launched by proposing a core issue for the discussion (this can be done according to Beer's 'Problem Jostle'). This proposition will naturally be incomplete – its form can only evolve during discussion and its final iteration will be agreed upon at the conclusion of the exercise. Thus, since this statement is only a starting point, little

time should be given to agreement between participants at this stage. The purpose should be written succinctly enough to fit on a post-it note (or similar) and kept by the Researcher for reference, in the central position in the room.

3. The time limit for discussions should also be set at the beginning. It can vary with each cycle of discussion – and coincidently with each new core issue addressed. It should however, be kept strictly by the Researcher. Based on our experience with facilitating similar conversations with other creativity tools, we believe it is possible to spend as little as five minutes on one topic. Thus the total for one cycle of the entire discussion process can be as little as twenty minutes and produce a meaningful result. Of course, this depends on the complexity of the initial issue of the meeting.

4. Then one participant from each team should volunteer to function as spokesperson or coordinator for his team. He will initially sit at the apex of the Diamond for his team. The Designer (the creator of structure, tools and methods) forms one apex of the Diamond Model, while the User (who applied the structure, tools and methods), forms a complementary one. These should be physically as far apart as possible in the room.

5. The remaining participants should place themselves on the edges of a Mandala square (just as in Beer's protocol), where the four outer Buddhas of the Mandala of the Five Buddha Families sit. They may choose the position of their natural inclination, or go against it. If the former option is chosen, time needs to be set aside for participants to determine which mode of behaviour suits them best. One person from each team then pairs with one person from the opposing team, so there should be four pairs (or groups) of participants. Two notebooks should be given to each group –one for Designers and one for the Users. When participants move discussion, their original notebook should be left on the table, for the next participant (or team) to continue adding their discussion results on that topic in the same book.

6. The topics of discussion for teams are determined by Figure 14a and 14b. They are as follows: generation of Structure and Methods in respect to one (implementation of initial direction); generation of Structure and Methods in respect to many (function coordination and information between sub-systems); Application of Structure and Methods internally or in respect to one (information processing, sub-system control and feedback); Application of Structure and Methods externally or in respect to many (applications and external relations). These discussions should be about all the practical issues concerning the topic. They should cover all possible technical and social contradictions. All stories and ideas about the issue should be recorded but not evaluated (that happens later). We trust the roles are simple to understand and any topic can be comprehensively covered, assuming that a team can allow enough time for discussion.

7. After the allotted time, participants are moved round to the next discussion. Two cycles of movement need to take place. In the first instance, the Design team should stay put, and the Users should move clockwise round the Mandala, taking part in a discussion at each new edge, till they return to their starting positions. This means there will be four iterations of the conversations at each point. In the second cycle of conversation, Designers should move anticlockwise round the Mandala, also taking part in a discussion at each edge, till they return to their starting positions. The sum total of conversations in both cycles is eight. It is inevitable and desirable that there will be cross-fertilization of concerns and issues to be discussed.

8. The spokespeople at the apices of the Diamond can choose to take part in whichever discussion they like. In each case, their function is to 'keep the overview' and remind each discussion group of their primary vision, when they seem to get bogged down in practical details (i.e. they should either create methods and tools, or apply them).

9. The Researcher likewise, need not stay with either Designers or Users, nor move in any order. He can move to any discussion he likes. His role during the discussion time is

to ask probing questions and keep time. He may not give his opinion on any topic at this time.

10. When the agreed time is up, each team should collect all notebooks belonging to them and convene at the apex of their Mandala, to produce a short series of statements that covers but summarizes all their current concerns.

11. Each team presents their summary in turn to the Researcher. The Researcher should consider the information presented from both teams, integrate it and propose a new, improved core issue. Teams should take part in establishing the common elements of the issue.

12. The new core issue is written on a new post-it note and sets the starting point for the next cycle of the discussion process. This begins at step 2, above, and remains identical to the previous iteration of the process.

13. When three cycles of the discussion have been completed, the evolution of the core issue should be quite robust, and lead to establishing a 'common purpose' for both teams.

Although it is obvious that three iterations of the process will cover a substantial amount of ground with the Diamond Model, we do not know if that is enough, nor what is ideal. We have not yet carried out a formal test.

What We Expect

The Role of the Researcher

There are three issues we currently face in our research in Aerospace design. The first is, as cosmologists and mathematicians have also discovered, it is not possible to solve existing problems by using the same methodology that created them in the first place (Penrose, 1990). The second is that the reasons for needing to change a given protocol that appears to be working are also not obvious, till viewed retrospectively from the new one. Lastly, there is great difficulty in capturing the outcomes of inadequately or inappropriately structured discussions.

The presence of a central focal point, such as a Researcher, in a discussion between teams of Designers and Users can help integrate new information in a more seamless way than would otherwise be possible.

The Researcher can help facilitate implementation of good ground rules for individuals and for the whole system. Even better, our field tests confirm that the role of a Researcher is vital to maintaining the question protocol only at early stages of application. At later stages of application, when the questions are known, teams can facilitate themselves and the role of the Researcher can be left open with no ill effects.

Readers will surely have noticed that in making the model three dimensional, we also move beyond a five-element system, to a seven-element system. The extra levels hidden in the original Mandala are only noticeable when the Designer and User are asked to give their own view of the whole and the Researcher brings the two extreme views together. In some sense, the ultimate function of the Researcher is typified in the seventh, solution-finding step of the generic process of creating (Table 3). However, in actual practise, this is not an end-point of the process of discussion or design. Instead, is a place of self-reference and reflection or recursion.

Relating to self – Purpose

The central point is to some extent a hidden or quasi-secret level in the system, in that this particular model of an informing system can evolve and even achieve closure (and viability) without itself understanding its purpose. However, the system is much more robust, if the purpose is known. To make this innermost level explicate requires all participants to move beyond concerns about their sub-systems or indeed the material structures and functions of the system as a whole, to identifying its fundamental character.

This character may be considered 'the mind' of the evolving system (to play on Beer's concept of a 'Heart of Enterprise', although the term is also related to Buddhist goals). Its 'essential character' (Latin. natura) or point (Greek. kharakter or kharax for 'engraved mark' or 'pointed stake') gives a system both a reason for moving, and a direction in which to move.

When the seventh function is carried out, after considering all actions and reflection, a Researcher must make a choice about whether or how data is put together. Any act of making a choice forces awareness on the system, since one must return from the outer reaches of one's quest for new information, to compare it with the original purpose. Naturally, the centre links all points and participants in the system – not least, according to Giodarno Bruno, because the point represents infinity, and

thus its centre is everywhere. Beer likewise points out that ' … incidentally, if we put (the Self) as a viable system in the centre of the (sphere) generated by the set of recursive chains, then we have a model of selfhood that both expands to embrace the universe and also shrinks to a vanishing grain of sand – a model familiar in oriental philosophy' (Beer, 1984, p. 25). Thus we consider that when the Researcher acts on behalf of all and none, he is simultaneously 'self-referent' (we consider this geometrically as standing at the centre and acting on behalf of the central point of the system) and 'other-referent' ('referring to the central point of all other sub-systems at any stage of evolution'). As we are describing the system, there is no pure observer. In our case, he is built into the system as a function rather than a person, as a meta-quality of mind. If the Researcher is doing his job correctly, he exchanges a simple meaning of existence of him 'self' (to use the term from Beer), for a greater meaning. In other words, the purpose of the self is inseparable from the purpose of all co-evolving sub-systems or meta-qualities.

As we suggest in the section 'How?', the conscious intention of the Designer, User and Researcher evolves as information is gathered and structure manifests, to resemble a 'core intention' which is itself perhaps unknown at the start of proceedings. Yet a transformative and self-referent behaviour of conceptual space is the key to success in creativity and innovation (Boden, 1994a, 2005; Csikzentmihalyi, 1997). When there is a functional coincidence of the world in which Designers act, the world which provides reflection and world in which both are joined, the separate activities become 'ultimately creative', as Boden (2005) suggested should be the case. This is especially true when the process whereby coincidence is achieved is iterative (and implicitly recursive) behaviour that 'constructs the situation within which the (situation) itself is constructed' (Boden, 2005).

As already mentioned, Beer's VSM model requires the fifth sub-system to be the place where the core value and purpose for Organizational growth is set and retained. It does so, by making choices that align the design and use of any organization of sub-systems with the central intention or purpose. We add that the meta-activity of knowledge, which is implicit in the heart of Beer's model and also in the heart of Buddhism, is in our model a seventh function of 'knowing the purpose of (our) existence'. At this point, it is not possible that an entity other than the informing system itself can be falsely attributed with the power of divining its purpose. It is not duly affected by incoming information

from outside itself. Thus it is accurate to say that when information from two worlds of Design and Use are integrated at the (seventh) central point, then the system also knows itself.

Relating to others and the world

Self-reference and other-reference are made possible by both reflection and recursion.

As we have mentioned earlier, reflection requires plane geometries (or maps of static situations in which symmetries exist that look like plane geometries) to act as mirrors. And similarly, when people use the phrase, 'I'll reflect on that (mental) point', we can imagine they mean, 'I'll make a mental picture to consider the relationship of aspects in that situation as if it were geometric and symmetric'.

We have also said that the centre of the informing system is the place of self-reference. Yet the central point cannot really be reflected upon in a way that makes spatial, mathematical sense, since it does not exist in the normal space of a pre-given world. Indeed, for self-reference to be possible recursion is the only option. Recursion is a special kind of non-linear (fluid) process of repetition, which occurs often and (or) over longer time periods, and allows or causes elements to be repeated at different scales. It does not refer to the repetition of elements themselves but to the process, which makes it happen.

In the 3D Diamond Model discussed in this paper, recursion is implicit in the central point, which forms the reference for the entire map. Recursion takes place at this point (or, more accurately, through it), as long as the Researcher keeps asking questions. For each recursion (of the mapping) a smaller diamond now exists within the core of the larger one. Moreover, the point can holographically reproduce the characteristics of the larger one, like any small mirror can reflect a large amount of the world, if it is held close to the eye.

The holographic nature of this particular model is characteristic of resolving contradiction, and the hallmark of creative processes, where the nascent solution is periodically injected into the process of idea generation (A-K. Pahl et al., in press). In other words, if our model is structured correctly, it will be a template for innovation. Thus the system can produce nothing but itself and yet appear, to outside observers, to produce variations of itself. And that kind of dissemination is what we are all aiming for.

Conclusion

As the Dalai Lama has affirmed many times, '… if elements of Buddhist doctrine … are compellingly refuted by new empirical (scientific) evidence or cogent reasoning, then those Buddhist tenets must be abandoned … (or) revised accordingly' (Wallace, 1999, p. 158). In this paper however, we have proposed the opposite – that some elements of Western scientific doctrine would be well served by incorporating scientific principles from Buddhism. The ancient methods provide important means of structuring the psychological and social elements known to contribute to ideal human functioning. Coincidentally, the structure provides a reference map for viewing personal behaviours, Organizational behaviour and innovative design. In particular, the conceptual structures of the Four Basic Thoughts, The Three Jewels, The Three Pillars and the Mandala of the Five Buddha Families correlate well with general Western Research about the above topics. But in addition, the Buddhist methods propose a way of structuring this information, which has been lacking in the West.

Our trial integration of these Buddhist maps and methods with Western ones seems particularly compatible with the elements of Beer's (1984, 1985) Viable System Model, and with a protocol similar to his Team Syntegrity (1994) model. Combining these insights has allowed an extension of our recent 'Generic Model of Creating' (A-K. Pahl et al., in press), in such a way that teams of Designers and Users can complement each other in discussions about innovative engineering, especially at the stage of considering the complete system description.

The most comprehensive representation of the process of innovation approximates a diamond. In 2D, this is a 'Diamond map' and in 3D it is a 'Diamond Model of Designer-User interaction'. In practise, the Diamond Model of Designer-User interaction forms a Complete Informing System with as few as 10 participants, who co-evolve their purpose in three cycles of discussion. We believe that this kind of co-evolving discussion which integrates both the Designer-based problem-space and User-based solution-space leads to faster product development.

In order for maximum benefit to be gained from discussion, a common purpose for the system is best defined at the outset of design and modified as conversations evolve. Conceptually, the common central purpose can be represented in many ways. Certainly, it is situated at the very centre of the Diamond, a space of self-reference, reflection and

indeed recursion. In terms of conversations between Designers and Users, it signifies the integration of all contradictory thoughts and actions between the end-members of the different teams.

It is the mechanism of recursion, which occurs during questioning of the common purpose and answering this question that allows flux to exist in the system. The important thing is that movement happens even while the principles that relate the elements (participants and topics) to each other stay the same.

Originally, a Researcher takes on the function of guiding the two teams to the integration of their opposing views and realisation of their purpose. He must be someone who can draw together the threads of (1) making structures, rules, methods and tools, and (2) applying the structures and tools in different ways. Later, this role becomes somewhat redundant and can be left open, since the system eventually informs itself. At this time, the participants in the system would be expected to self-liberate themselves from fixations. In other words, they would see the solution immediately on encountering any situation, without the necessity of ever experiencing it as a problem-space. Thus, at the instant in time when the system of Designers and Users informs itself, we can say that the system not only integrates all information and knowledge. It also transforms what it knows of the problem-space into the solution-space, in all situations and levels.

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Appendix A: A Comparison of the Syntegration Process of Beer with the Generic Model for Creating

Syntegration Process

GENERIC MODEL	Fractal Subsets of action	S*yntegration* process (simplified after Schwaninger, 1997)
Problem definition as a field		**1. Opening:** Syntegration encompasses a general topic that focuses all mutual efforts. The opening question is also general eg: Which form should x take in future?
Divergent thinking		**2. Generation of the agenda (Problem Jostle) :** Each participant makes contributing 'Statements of Importance' that seem important to him. These are discussed and successively synthesised into 'Aggregated Statements of Importance'. Then they are prioritised and the agenda for the actual work on the general topic or problem is generated (by Hexadic Reduction). This is finally worded into exactly 12 topics or 'Consolidated Statements of Importance'
Evaluation		
Convergent Thinking	**Problem definition as a point**	**3. Assignment to groups (Topic Auction) :** Each participant decides on the (2?) topics to which he or she would prefer to contribute. Based on these preferences, they are assigned to teams which ideally consist of 5 players and 5 critics each, with the help of an optimization algorithm (or randomly)
Solution definition as a field	**3 or more Re-iterations of:** Problem as field Divergent thinking Evaluation Convergent Thinking	**4. Working on the topic (Outcome Resolve):** The individual teams discuss their respective topic. Teams meet several times, while players move between groups so that the problem setting is continually, subtly reformulated and processed in alternating compositions and the different but interconnected aspects can be more clearly seen. This leads to a highly integrated self-organizing process
Solution definition as a point	**Solution definition as a point**	**5. Conclusion:** final coordination if necessary in Triplets (corresponding to the triangular faces of the icosahedron), and presentation of the results in plenary.

Appendix B: Questions from the Team Syntegration Process

Questions from the Team Syntegration Process described by Leonard (1999) were modified so as to be now used with the Diamond Model proposed in this paper.

Two main questions can start it all off:

- What pattern of events could we expect to see, if x were implemented in our department/team?
- What pattern of events could we expect to see, if x were implemented elsewhere or not at all?

For discussion during cycles through the Diamond Model, teams might consider more specific questions, such as:

- What do you think you need right now
- What do you need it for
- How much do you know about it
- What tool/system/way of doing things would it replace
- If it would not replace anything, then how would it affect the current system
- Who else would use it/be involved in future
- Would they need it for the same reasons/use it the same way
- What other services etc. could/would merge with the programme
- What do you think would be the impact on the team it.

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