USE OF SYNECTICS AS AN IDEA SEEDING TECHNIQUE TO ENHANCE DESIGN CREATIVITY

Julian O. Blosiu
Jet Propulsion Laboratory/California Institute of Technology
4800 Oak Grove Drive
Pasadena, California, 91108, USA
Tel: (818) 354-1686; Fax: (818) 393-4539
e-mail: Julian.O.Blosiu@jpl.nasa.gov

ABSTRACT

An approach to generate creative design that employs the practice of synectics is presented. The integrated use of the Theory of Inventive Problem Solving (TIPS) technique, along with physical, chemical and biological phenomena and effects knowledge data base provided by IM-TechOptimizer™ software, and the Robust Engineering Design methodology is the core of this proposed new creative design. The creative design approach starts with the clarification of the term "requirements" vis-à-vis "design decision." Creative design concept generation and design decisions are addressed at system, sub-system, assembly, and part level. This concept is based on the hypothesis that many new design options can be quickly generated. It is believed that design decision is strongly enhanced by this new approach when many design options are present. The Creativity Domain Process is defined as the means for the generation of new ideas and concepts. Functional modeling analysis using the triad of subject, action, and object is considered as a desired analytical tool to identify the right problem to be solved. The identification of contradictions as problems and their categorization as managerial, engineering, and physical indicates the category of design concept solution to be generated. The TIPS offered contradiction metrics and standard solutions engage the mental analogy and metaphoric thinking as part of the synectics idea generation process. The inclusion of the ideal function concept is described as a creativity measurement. The closer the new concept performs related to the ideal performance, the higher the grade of the new creative design. The ranking of the newly generated concepts relative to the ideal performance is presented as a structured approach of selecting creative design concepts or as a technology road map layout. Finally, the parametric design and evaluation of functional performance is viewed as the robust engineering design implementation and optimization of the selected best design concept.

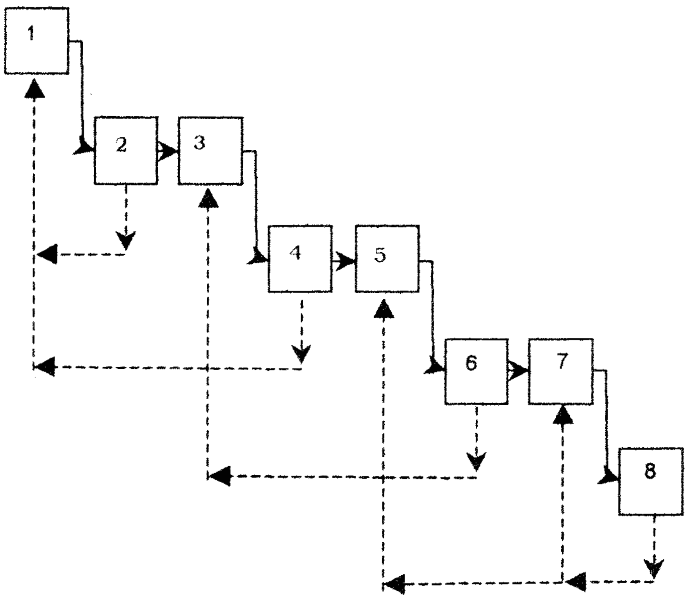
INTRODUCTION

DO WHAT NO ONE HAS DONE BEFORE in a **FASTER, BETTER, CHEAPER** environment, and **DO NOT FAIL** is a major component of the current high technology industry-wide imperative. To successfully accomplish the future technology challenges, a major paradigm change from the old way of implementing projects to a new way is required. To enable the new approach, a comprehensive training and re-training program in creative design has to be established. "How you start a day is the way you spend the rest of it" is an old saying. How you start with the System Requirements and System Design Decisions is the way you will succeed with the accomplishment of a given project or task. Creative design concept generation and design decisions need to be addressed and percolated not only at the system level but also at the sub-system, assembly, and part level.

A successful new break-through technology project relies on how many inventive and creative design options are available at the different levels of design. New creative design is the result of a non-linear process, where existing knowledge is mixed with new information and imagination. The approach suggested here is to enhance design creativity by exercising analogies and metaphors embedded in the practice of synectics, where the idea seeding is stimulated via the availability of a diversified knowledge and information data base.

CREATIVE DESIGN AT MULTIPLE LEVELS.

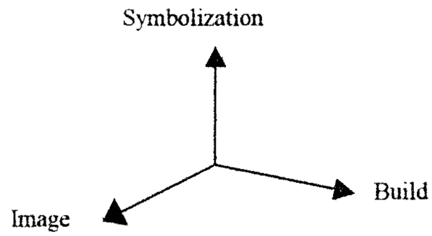
The use of the most possible inventive and innovative means to enhance design creativity is the cradle of birth for all new breakthrough technologies. The design decision and design selection criteria rely on how accurately the initial functional requirements could be implemented, as well as, on the availability of resources, technology readiness, and risk management. The diagram on the next page describes the relationship between the initial system functional and performance requirements and the cascading nature and repetitive cycle of the lower level requirements and associated design concept generations and design decisions encountered during the project development life cycle. At the beginning of the first phase of project implementation, the original system functional and performance requirements are specified. In response to these requirements, several architectural design system concepts could be considered for implementation that would allow the implementation of the desired system functional requirements and performance. Only after a thorough analysis and evaluation of each design system option, a decision of best architectural design system implementation is performed. The architectural design system selected to implement the initial system functional and performance requirements only now will identify the functional and performance requirements of the second tier of requirements at the sub-system levels. Based on this second tier of requirements, the next step is to generate several sub-system design concepts. Again, analysis and evaluation of each sub-system design concept will require a design decision and selection of the most appropriate sub-system design concept. In turn, the sub-system design concept selected is now dictating, in fact, the third tier of functional and performance requirements for the assemblies included in the sub-system. For the next phase as you can now predict, the assembly functional and performance requirements are triggering the design concepts generation for the assembly, followed by the appropriate design decision and best concept selection. And finally, based on the assembly design that has been selected, the fourth tier of parts functional and performance requirements is established. Parts design and parts selection and decision making is now completing the project waterfall development cycle. The above description clearly illustrates that design concept generation and design decision is the driving force of requirements generation, and definitely not the other way around [1]. Design decisions are performed in the context of the availability of many creative design concepts. As observed from the cascading project design implementation, design decisions are based on the availability of design options at different levels of project design, including; architectural design system, sub-system design, assembly design, and part design. Creative design concepts are generated during the process where requirements and designs are percolated at all the above project design life cycle levels. In order to accomplish what no one has done before, training and processes have to be established, where multitudes of creative design ideas and design options can be easily generated at system, subsystem, assembly, and part design levels.



1=System Functional Requirements
2=Architectural Design System
3=Sub-system Functional Requirements
4=Sub-system Design
5=Assembly Requirements
6=Assembly Design
7=Part Requirements
8=Part Design

COMPLETE REQUIREMENTS ARE IN FACT A FALLACY

Requirement generation is the act of symbolization of an embryonic **image** concept of a product that enables the original creator to communicate with his/her peer members [2]. The image **symbolization** can be expressed in more than one form such as written descriptions, diagrams, figures, or drawings. After the concept symbolization is generated, a concrete product design and product **build** follows. As described in reference [2] and as diagramed in the next column, the concept of triads will be used for other description in this paper. The requirements generation described by this triad reflects a vertical or top down requirement generation process. Requirement documents are usually part of a contractual agreement that is used by a customer to convey functional and performance requirements to a builder in order to design and implement a final product [3]. Time and time again, project schedule slips are often blamed on late requirements, incomplete requirements, design modifications and/or late improvements. Tiger teams, which are teams created by multidisciplinary experts, are frequently used to rescue troubled projects. Unplanned and unscheduled activities related to late requirement modification result in additional implementation cost, and schedule slips that often lead to project overruns, low product quality, and poor reliability.



To claim the existence of a complete requirement specification prior to any design is, in fact, a fallacy [4]. Lower level requirements are derived from the measurable attributes of the immediate higher level design. Total system requirements are complete only when the product and its total utilization history is available, including details of all techniques used to produce the engineering product. Nevertheless, "requirements phase" is still included in Project Implementation Plans and projects are held accountable for requirements phase completion prior to proceeding to any design implementation.

INITIATIVE 1: Do what you say; say what you do.

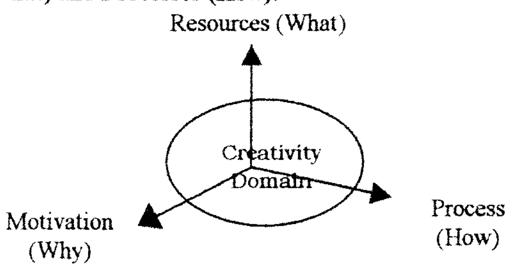
In the old paradigm, practice has demonstrated that mandated top down requirements do not convey a smooth project development. Only after repetitive iterations and complete involvement of all key stakeholders, various design options of the original image concept are generated. To select the best design option, a final design decision is in order. In fact, all of the unplanned, unscheduled and uncosted repetitive design cycles, where often a late multidisciplinary tiger team is called upon to rescue a troubled project, represent the real and natural process undertaken by all projects during the project development life cycle.

In the new paradigm, the next natural step is to include in the Project Implementation Plan, from the beginning, all of iterative design cycles and design decisions, detailing all of the related and projected schedules, milestones, and costs, along with the planned and continuous participation of all encompassed multidisciplinary teams. Most important, it is suggested that the Project Implementation Plan to include schedules with milestones for the special process of creative design generation specifying appropriate training and methodology practices. The project design teams will include representatives of the owner as a customer, the contractor as a builder, and the associate as an advisor/observer [2.] The outcome of this approach will strongly enhance the project cost and time performance that in turn will also positively affect the quality of the final product. The above described approach is also in perfect agreement with the ISO-9000 principle where the concept is; TO SAY WHAT YOU DO; and TO DO WHAT YOU SAY. The strength of this design decision approach is brought to light by the utilization of the lateral thinking process [1,5] performed by all involved stakeholders.

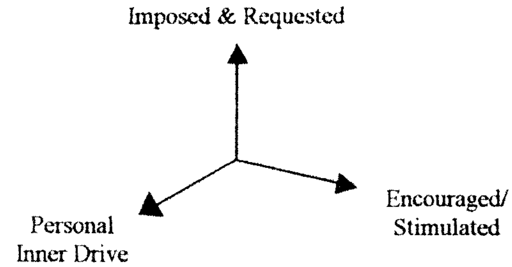
INITIATIVE 2: Innovation and Design Concept Generation

As mentioned earlier, the new creative design generation and design decision paradigm is suggested to undergo an iterative process for design option generation and selection. This implies that one needs to establish a methodology that enables a process that when followed can produce many new creative ideas and innovative design concepts at all project development life cycles. This new creative and innovative design concept generation environment should be included under the term called **Creativity Domain** [6].

It is known that information becomes knowledge only after all attributes of a given information related to the **WHY**, **WHAT**, **HOW** pertaining to a subject information has been identified. Other attributes related to **who**, **when**, and **where** could also be considered [18]. The Creativity Domain is performed in the context and as a function of **Motivations (Why)**, **Resources (What)** and **Processes (How)**.

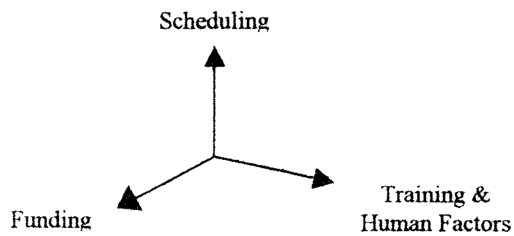


A. Motivation (Why):
Psychological inertia is a major obstacle to creative design concept generation. Not everybody feels at ease to publicly express a new "wacky" but potentially innovative idea. When the new idea has not been demonstrated as feasible yet, the potential for failure is large. Most of us are threatened by peer criticism, and non-acceptance is viewed as failure, particularly in the presence of non-constructive criticism. The motivation to create new thoughts, ideas, and concepts needs to be nourished in an environment of teamwork, thrust, and empowerment. To dare to generate many new innovative ideas for product and process concepts, motivation is the cradle for the creative thinking environment. Managers and engineers should pay special attention to education and training in order to foster a psychological environment that stimulates rather than obstructs creative idea generation [11]. The Creativity Domain **Motivation** (the Psychology) is composed by environments such as: **Personal Inner Drive**; **Imposed & Requested**; **Encouraged & Stimulated.** The implications and descriptions of each of the above three psychological inertia acting as barriers or stimulants are in support of the **"Why's"**, and are related to creativity motivation. All living organisms on earth are striving for survival solutions every day of their life. Human beings are not different; all individuals have built-in **personal inner drive** to improve life conditions and the world around them. People manage to perform better when there is a need to respond to **imposed and requested** demands for change. The saying, "necessity is the mother of all invention," is well known.



Nevertheless, best results are obtained when **encouragement**, **stimulation**, and praise are cultivated and nurtured. Self-esteem and the feeling of accomplishment are the real self-motivators.

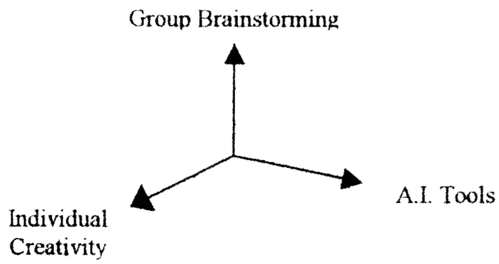
B. Resources (What):
Funding, **Scheduling**, and **Training & Human Factors** are the three elements of the Creative Domain **Resources.**



It is impossible to implement a real creative environment without continuous and adequate **funding**. The presence of funding indicates how serious the endeavor to establish a new creative concept paradigm is. Determining what is needed to systematically generate many new design concepts and to be part of a design decision process is a task in itself. Planning and **scheduling** of activities that allow room for design concepts and the associated design decisions is a major component of any project planning effort. Scheduling of time and milestones to be allocated for accomplishing activities is the next item to consider. For creative design, it is suggested that project planning establish a quality metrics that can be used as success criteria for self-assessment. Personnel **training** on concurrent engineering for all contributing teams of Customers, Builders and Associates [2,3] ensures the success of the creative design and design decision-making. Specialized design training is a critical element of the **human factors** activity of team building.

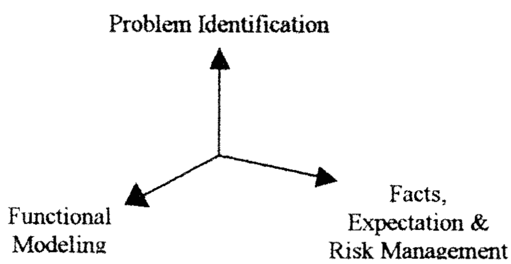
C. Processes (How):
The Creativity Domain **Process** identifies the suggested methodologies and steps to be taken that would lead to many new, inventive, and creative design concepts. Past experience has demonstrated that invention and innovation is attributed mainly to **Individual Creativity**. In the context of teamwork, **Group Brainstorming** processes formally and in-formally conducted activities are recognized lately as very efficient idea generation techniques. More recently, more and more organizations are now embarked on a new approach where the theory and applications of **Artificial Intelligence Tools** are employed (i.e. Theory of

Inventive Problem Solving (TIPS or TRIZ) and Invention Machine TechOptimizer™ software) [12,13]. All of the three above idea seeding technique processes are based on elements such as: **Data** (related to problem identification and evaluation); **Knowledge Base** (in the form of chemical, physical and biological effects and phenomena); and **Concept Generation** (using analogy and metaphors as part of the process of synectics).



C.1. Data

The process for gathering the factual data on which new concepts are generated is the key to identifying the right solution for the right problem. The process includes; **Functional Modeling, Problem Identification**, and **Facts, Expectations, and Risk Management.** New concepts generation and development are driven by functional needs that provide solutions to the problem that created those needs.

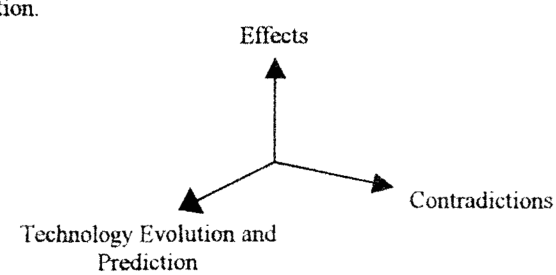


Without a comprehensive functional analysis, simulation and modeling of a given product or process, a thorough system performance is not possible. At this very early state of **functional modeling**, preliminary designs are actually performed. Functional modeling, simulation and analysis identify the weak functional performances and the undesired effects of the preliminary designs. Through functional modeling, simulation and analysis, design problems are identified. Identifying the right problem is not only essential but also crucial. Perfect solutions can be generated, but the solution could address the wrong problem. And every so often, this actually happens. That is why **problem identification** and analysis [21] is one of the first essential steps in the creative design process that ensures the development of a successful new idea for an innovative concept. Problems as contradictions are established at three distinct levels: administrative contradiction (cost, performance, and risk); engineering contradiction (improvement of one feature performance, is associated with worsening the performance of an another feature); and physical contradiction (the same object needs to posses opposite characteristics) [15]. **Facts, expectations, and risk management** are the elements of the domain where the ideal performance is balanced against the factual or actual performance of a chosen design approach. The inclusion of the ideal function concept is considered as a measurement of creativity [13]. The better the new creative design performs relative to the stated ideal performance, the higher the design creativity will rank, and the lower is the risk undertaken. The availability of many creative design concepts allows a ranking of the newly generated concepts relative to the ideal performance that leads to a structured approach in the decision and selection among the competing creative design concepts.

C.2. Knowledge Base. As previously mentioned, knowledge is quantification of information. IM-TechOptimizer™ contains three main knowledge base modules: 1) **Contradictions**, 2) **Technology Evolution and Prediction**, 3) **Effects**. This knowledge base is augmented by thousands of examples of practical applications, most of which are filed patents. It is suggested that the functional modeling analysis be performed using the concept of **Subject, Action**, and **Object** where the subject, action, and object are evaluated as the potential sources of problem manifestation.

The identification of the **contradictions** as problems and categorization of these problems as managerial, engineering and physical indicate the category of design concept solution. The 39 standard feature contradiction matrix and 40 standard principles solving contradictions are viewed as standard solutions offered by TIPS and by the IM-TechOptimizer™ software. These AI concept generation tools can be used to engage the mental analogy and the use of metaphors in the process of generating more than one relevant and creative design concepts.

Technology evolution trends, as identified by TIPS and collected by IM-TechOptimizer™, should be considered as essential components to be included in the process of creative concept generation. Technology evolution is related to the improvement and modification of the subject, action, and object elements [13] of a given engineering design component. The 72 suggested interaction improvements among the three components, as suggested by TechOptimizer™ software tool, can also be exploited as avenues of idea seeding techniques in the quest for creative design concept generation.



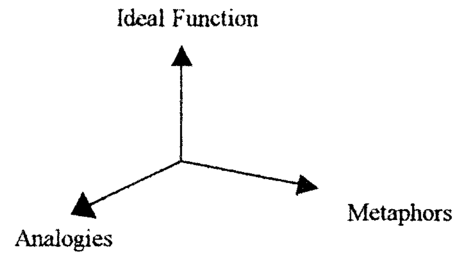
Availability, accessibility, and use of diverse knowledge bases allow for the lateral thinking and out-of-the-box approach to creative idea generation that brings out the best performance in the creative design process. Chemical, physical and biological **effects** and practical application of these effects, as described by IM-TechOptimizer™, constitute knowledge base to be selected to suggest the most appropriate idea in the performance of a desired function [17]. Single person creativity relies only on the individual's personal knowledge and experience, and for that reason, creativity is limited to the resources of that individual. Group brainstorming techniques are superior due to the availability and the sharing of knowledge and experiences of the group. The concept of synectics is enhanced by the availability of the current IM- TechOptimizer™ knowledge base that contains over five thousand effects and practical applications. As a plus, one of the main advantages of AI-provided knowledge base is that the environment under which the information is provided is completely free of criticism, ridicule, and/or inferiority complex.

C.3. Creative Concept Generation

An inventor finds an original and creative design solution. Often, the new design idea is attributed to chance, sudden enlightenment, and luck. A close analysis indicates that, having a given problem, any new concept is generated through several steps compiled as a process. If and when the process is more or less formalized, it is observed that in fact three main steps were considered in the process: the **Ideal Function** or **Situation** concept; the mental engagement of **Metaphors** [7,8,20]; and the use of the parallel mental path of **Analogies** [9,10,,21].

It is desirable that any new required function is to be performed in an ideal way. Previously, we shortly described the ideality concept. For a more detailed description, a truly ideal functional performance requires no resources, there is no time needed for implementation, and in the performance of the function there are no negative side effects [13]. That is why the inclusion of the ideal functional performance as a first step to concept generation is viewed essential. Furthermore, the inclusion of the **ideal function** concept establishes the criteria of creativity measurement. The ideality paradigm is a wishful thinking. Never-the-less, the closer the new design concept performance is to the desired ideal performance, the higher the new design's creativity ranking is considered. Design decisions makers include in their evaluation criteria elements such as proximity to ideal performance, and implicitly include sub-elements such as resources, scheduling, reliability, quality and risk management. In the presence of multitudes of creative concepts, technological design concept creativity ranking and related implementation decision could also serve as a process to establish a technology implementation road map [16].

Imagination and creativity are stimulated by the mental utilization of **metaphors** and **analogies**. Supplies of ideas in the universe are inexhaustible [19]. All these sources of ideas are there, and just need to be harvested. The source of inspiration is best provided when similar situations or characteristics can be related to a new problem that needs to be solved. Solving a problem is like going to war. This statement in itself is a metaphor. Metaphors help us generalize the abstraction level of the source of inspiration for creative design. It inspires us to use the poet in us in finding analogies. How do we "win", or what does it take to solve a problem? Who is the "enemy" that has to be defeated? Let us consider the desire to establish an outpost on the Mars planet. But living on Mars is like living in a desert in Antarctica (if there is such a place here on earth.) Now we need to understand the available in-situ Mars resources and environments that need to be concurred and exploited. Before we send humans to colonize Mars, one considered approach is to send an army of large ant-like mini rovers to scout the Mars surface and environment. These rovers are equipped with sensors for terrain mapping, soil analysis, gas analysis, and life signature detection. These biomorphic ant-like sensors will include devices such as: electronic noses, computer visions, electronic tongues, dexterous arms and legs, and computer memories. New creative designs based on breakthrough technologies will be called upon to implement such functions electro-mechanically. The availability of a diversified knowledge base of physical, chemical, and biological effects and phenomenon augmented by application examples will again exercise metaphors and analogies to perform new designs for implementation of the above revolutionary biomorphic functions.

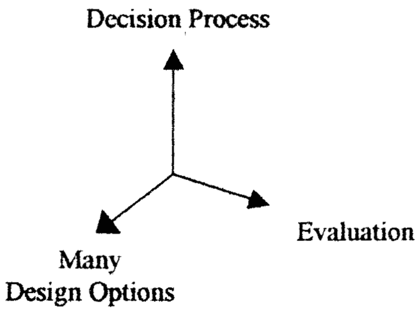


The integration of ideal functional performance with knowledge base and the use of metaphors and analogy open the door to the concept of synectics. Webster's dictionary describes synectics as the " *the theory or system of problem-stating and problem-solutions based on creative thinking that involves free use of metaphor and analogy in informal interchange within a carefully selected small group of individuals of diverse personality and area of specialization.* " The IM-TechOptimizesr™ knowledge base with its abundant and diversified number of number of physical, chemical, and biological effects and phenomena, as well as the large number of practical application of these effects, is a desired source of innovative design concept generation through the mental stimulation of analogy. By using an AI knowledge base, and by inclusion of metaphors and analogies in the context of synectics, provides the brainstorming group plenty of practice in the use of spontaneous activities of the brain and nervous system.

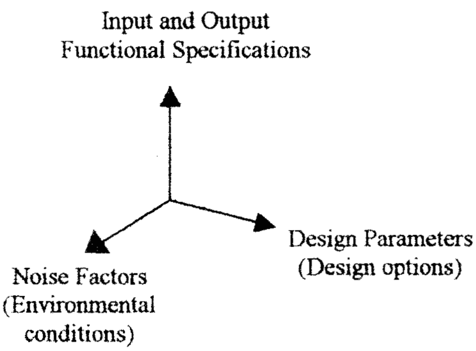
The "wackier" the new idea is, the better the concept of metaphors and analogy was engaged. All known forms of analogies are strongly encouraged to be exercised: wordly; unwordly; bodily; and symbolic [20]. The availability of phenomenon and effects at your fingertips, from completely different scientific fields of application, facilitates the opportunity for wacky design idea generation.

INITIATIVE 3: Parametric Design (Move paper concept to design simulation and robust design)

New generated inventive design concepts are now ready to be considered for implementation and evaluation. Simulation, Theoretical Modeling, Physical Modeling, and Parametric Design implementation and build are suggested as next steps for rapid concept design implementation and evaluation. Currently available CAD, CAE, and CAM tools are powerful techniques that are able to reduce design implementation time in support of design decision. Special training of such tools is to be included in the creative design training agenda. For best design implementation option selection parametric design or robust design is here suggested [14]. A product is described as robust when the output performance is insensitive to the cause of variation (noise factors), without eliminating the cause of variation. The parametric approach included in the robust design methodology allows the trial implementation and performance evaluation of **many design options**, the establishment of design **evaluation** criteria, and of an improved design **decision process**.



Many design options: Experimental design (Robust Engineering Design) is the methodology where a minimum but sufficient number of experiments are conducted when many parameters and assigned values are evaluated for the best and/or worst performance. The concept of "orthogonal array" and "signal to noise ratio" are the two major tools used. A sensitivity analysis of each design parameter is the main outcome of this design approach. As in any parametric design, the main components are; **inputs and outputs functional specifications** and performance, **design parameters** (parameters that can be controlled by designer to generate **design options**), and **noise factors** (parameters that can not be controlled, such as **environmental conditions**) [22].



Evaluation Criteria: Design decision is best performed when a pre-established evaluation and selection criterion is in place. Resources, schedules, and performances versus risk management are the most important tradeoffs for consideration.

Decision Process: Builders of engineering products are generating several design options. Decision process is the identification and selection of the most viable design options undertaken. The final design decision is the responsibility of the customer. The parametric approach to design provides the measurable performance based on which an adequate decision can be made. The "six thinking hats" [5] concept is a powerful tool to be included at all levels of the design decision process.

CONCLUSION

The creative design training program should include methodologies, techniques, knowledge base, and tools that lead to faster, better, and cheaper implementation of revolutionary technologies and programs. This new creative design training suggests the integrated use of Theory of Inventive Problem Solving concept, Artificial Intelligence knowledge base tools, Synectics that includes Metaphors and Analogies, and Parametric Robust Engineering Design methodologies.

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