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ON THE ROBUST DECISIONS MAKING IN PROJECTS

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Abstract. *This paper addresses a procedure for robust decision making in high reliability engineering projects. It uses more than one Multi Criteria Decision Method and the Kendall rank correlation to evaluate the decisions' reliability. Many risk data are considered: human errors (Jelinsky-Moranda-Mils), mis-documentation (sampling), adequacy of resources for the development (information entropy), lack of specification, proper solution's space exploration (S curves), overall project success chance (joint statistics), obsolescence risks, among others. In designing an item with hundreds of thousand failure modes, parallel solutions shall be employed, in order to assure at least a solution, and the decision frame shall point the priorities correctly. Techniques like TRIZ and Pugh Matrix assure that enough feasible solutions are considered in the early design phase. High reliability complex systems are deceiving, in a 170,000 failure modes one, even a 5 standard deviation failure margin in each mode, means a 4.7% overall failure chance. The method will be illustrated with horizontal axis wind turbines, the Maglev vertical axis wind turbine, the Magenn airborne wind turbine, and the airborne driven ground generation system "air strip".*

Keywords: *TRIZ, Pugh Matrix, Multi Criteria Decision Method, risk.*

1. INTRODUCTION

Projects, and specially innovative ones, may fail by many reasons, and at least 9 failure reasons are more common than the technical issues. If a company decides to develop a product without a market, losses are inevitable, even if it's technically perfect and incorporates the most of the recently discovered technologies. Many chances are always available, and even to select some among them, a Multi Criteria Decision Method, MCDM, shall be used. If the first opportunity or idea is developed immediately, the success will be pure luck. The Fuzzy Front End methods, explores lots of ideas to each opportunity, generates concepts: ideas detailed just enough to allow comparisons, join them by synergy in draft projects, and then set up development priorities with MCDM. In all intermediate phases worst options are discarded. Any development activity is useful in more than a fashion. For instance, a polymer with fillers may have either augmented or diminished gas transport, and depending on the case, used as a gas blocking material or selective membrane. But whatever are the resources and team abilities in a firm, efficiency means using them in the best way possible, if it's possible to know what's this best way. To make any really credible comparison, costs, risks, time to market, adequacy of all kinds of usable resources, specifications adequacy, competitors reactions, consumer desire, cash flow and other items, generally over 40, shall be considered. To rank options, a method and support models are needed. This papers explores these support models.

2. METHOD BASIC TOOLS

Maxwell was the 1st to see that information has an entropy content, with his famous devil. According to (Frey,2000) Shannon was the 1st to propose entropy as a measure to information content in communication, writing it, H_o, as:

$$H_o = - \Sigma\, p(x) \log_2 p(x) \tag{1}$$

where p(x) is the probability of the state x. Once any search scheme has a desirable and an undesirable state, the above equation may be rewritten in terms of desired states only as:

$$H_o = - \Sigma\, p(x) \log_2 p(x) - \Sigma\, (1-p(x)) \log_2(1-p(x)) \tag{2}$$

Taking a single degree of freedom, DOF, in equation 2, and setting its derivative to zero, one finds that p = 1/2 leads to a peak entropy contribution of a DOF equals to one. The number of dimensionless groups is the total of variables less the number of fundamental physical quantities (Buckingham Pi theorem). The total of dimensionless groups, less the total of equations, plus the entropy of the equations and its variables uncertainty (any distribution has a tabled entropy) is the entropy reference, H_r, to the fully coupled system. Suh related the success probability, p_s, with the information content by:

$$2^{-Hr} = \text{(common range)/(system range)} = \text{(process tolerance)/(acceptable zone)} = p_s \tag{3}$$

where the system range, SR, represents how well a design fits functional requirements, the design range, DR, is the zone the designer suggests to the item, and the common range is the overlap of SR and DR. Process tolerances and acceptable zones are self explaining. In machining, if tolerances are smaller than the process variations, roughly the ratio of both gives the chance of a good part. The failure chance is 1-p_s. Regarding data, there's a chance p_d that it's correctly filed, and an entropy H_d to each filed item equal $p_d\log_2(p_d)+(1-p_d)\log_2(1-p_d)$. If a document is exact, $p_d = 1$ and $H_d=0$. But this isn't true to all data, that may be even not filed. This way it's important to evaluate somehow the error chances in a documentation, see latter. A car seat may have height and distance adjusted in a entirely independent way, or may have a inclined plane and distances adjusted after the height. For 10 positions in each DOF in this case, uncoupled, there's no need to test the whole set of 100 pairs, a good fitting is found in less than 20 trials. The peak number of tests is less than 50 pairs in the 2nd case, decoupled. But in full coupled case all pairs are in the test set. For decoupled cases, the Frey procedure to evaluate real entropy is suggested. In a limited set of n options with a single correct option, the chance of a wrong option in the 1st trial is (n-1)/n, in the next it's (n-2)/(n-1). It's clear that for $m \leq n$ trials, the success chance is 1-(n-m)/n = m/n, which is one to m=n. In this case we had learning during the tests. In order not to find a right option in m trials, ones has to get wrong choices in all trials. Without learning, the chance of failure remains constant. Taking the chances of failure given by the entropy, ones get to m trials in any logarithmic base a:

$$(1-2^{-H_r})^m = (1-p_s) \Rightarrow m \log_a (1-2^{-H_r}) = \log_a (1-p_s) \tag{4}$$

that relates the total of trials and global success chance, p_s. So it's possible to relate the success chance and the total of trials once the problem has a solution and once the searching zone is the right one. If a guess like this ranks rightly a given set of items regarding the effort in solving them, it's useful to MCDM. A model is needed to get a searching zone. Any engineering system has a number of failure modes, and a dispersion of the variables related to these modes, and models for the failure chances in a mode. In the Gaussian case, a 4 standard deviation margin means a 1.5×10^{-6} failure chance. This is low, but means an 86% failure chance for a car with 100,000 failure modes, one less the product of success chances of all single failure DOF. Most people doesn't consider a design failure due to that in design stage, neither ancillary effects. A margin depends on the design concept. As a concept is explored by most companies and performance rises, the failure risk grows as margins are cut, and the burden is shifted to process area, so newcomers, with worse processes, have higher risks of a product with a worse performance. New creative concepts reduces the failure DOFs and raise margins. Besides parts properties changes, errors in used equations counts in each margin. Uncertainty in equations either implies in a bigger failure margin, or in enlarged search zones related by equation 3 with the standard one. This is clear in heat transfer correlations, but even less questioned equations, as for instance perfect gas law, gives values different from the Van der Val's or Virial equations. So modeling margins shall be used to get a preliminary chance that the solution is in a searching zone, that shall be multiplied the chance $(1-2^{-H_e+H_r})$, with H_e the entropy of the equations, and H_r the entropy used to reduce acceptable zone, to get the chance of a correct searching zone, supposing no documentation and no human errors. H_r allocation may be optimized. Another important issue, is that if ones gets a solution with inaccurate equations, this solution may not be a true one. The total of DOFs in a search is at least the Shannon entropy of the used equations, and some margin is suggested to compensate not modeled couplings, as for instance machining errors and corrosion. An extra DOF for each trade off is also suggested, as in general subsystems models are accurate, but iteration among subsystems are rarely well modeled.

Documentation and human errors are valuated with Jelinski-Moranda model, JMM, with/without Mill hypothesis, MH, (Pham, 2006). MH says that detection of artificial and real errors of a given kind, for instance equation sign or comment errors, have the same chance for each error kind. So the detection probability, p_{det-k}, of a type-k error is the number of artificial errors, n_{ak} found divided by their total number, N_{ak}, so the number n_{det-k} of real errors found is linked with total number of errors, N_{tot-k} by: $N_{tot-k} = n_{det-k}/p_{det-k}$. The JMM says that given a constant C, the probability of detecting an error p_{de}, the inspection time, t_i, and the number of errors, N_b, at the beginning of an inspection, and white noises v/w,w',w'', are related by:

$$p_{det-k} = 1-\exp(-C\,N_i\,t_i) + v = 1-\exp(-C\,(N_b-N_f)\,t_i)+v = \Delta N_{fi}\,N_b^{-1}+w = n_{ak}N_{ak}^{-1} + w' = (n_{ak}+\Delta N_{fi})(N_{ak}+N_b) + w'' \tag{5}$$

As N_i is the total of initial errors at very beginning, N_b, less the total of errors found in all inspection N_f, $N_i = N_b - N_f$, ΔN_{fi} is the number of errors found in the ith review. It's possible to get iteratively the values of C and N_b that minimizes the sum of the squares of the errors in p_{det-k} for all the errors types with the gradient method. This allows not only the control of documentation errors, but also calculations' or software ones. An item is error free with a chance given by the Chi-square goodness of fit test if the number of the errors found is N_b. If $N_f < N_b$, or the confidence is low, more reviews are needed, and gradient searches are repeated as more data is available. This is also valid for the lack of an information or an specification, and the finding of an existing solution (alike artificial errors) or a brand new one (alike real error). But peoples only knows if a solution is an existing one or not, after a search in the patent basis. Without direct p_{det-k} a $\Delta N_{fi} N_b^{-1}$ guess is used. If a company develops a solution that is an intellectual property of other company and doesn't get a license, there's also a failure. The global success chance is the product of all individual success ones. Remembering individual success and failure chances sums one. The use of exponential or S curves is also helpful. The total of solutions obtained in a debate obeys an S curve, a function $a+[b+c\,t+d\exp(-\tau^{-1}t)][1+e\exp(-\tau^{-1}t)]^{-1}$, a common exponential to c=e=0. As people may think an old idea is a new one, each round has a ratio R of its new ideas over the total of ideas. R obeys an S curve, starts with one, and has a null limit value as time goes to infinity. A non-linear regression gives the 4 left parameters. S curves, even with search of 6 parameters, gives a 2nd indication of searches convergence and may be even drawn in a chart to avoid too many calculations. The chance of false fit is smaller if S curves and JMM are used at the same time. If people write their hints each round, JMM chances of a person hint and binomial chances of common hints, with N_i^{-1} success chance improves risk evaluation. With only an item left a common hint implies in the same hint. Effort/duration methods like COCOMO (software), its System Engineering analog COSYSMO, and Function Points don't predict the success chance or correlate it to effort, but even so they may be used to confirm estimations. A minimum path set is a set of items that makes the system work if it's working. The product of the symbolic failure chances of all minimum path sets, with powers of any failure chance greater than one set to one, gives any system overall failure chance.

Many MCDM are available as: AHP, ANP, QFD, KT, ELECTRE, MACBETH, MAUT-TOPSIS and PROMETHEE. KT is the oldest one, it uses arbitrary weights to add quantitative evaluations of each solution. AHP and ANP (immune to linear combinations) are based in comparing pairwise many options in a matrix with elements $a_{ij} = n = a_{ji}^{-1}$ if solution i is better than the solution j, being n 3,5,7,9 depending on what is used, intuition 3, calculations, testing, exhaustive testing 9, a_{ii}=0 and a_{ij}=1 if solutions are equal. Scores are sums of a_{ij} in a line divided by the sum of all a_{ij}. AHP and ANP have intrinsic quality control variables and at least one of these should be used due to this feature. ANP uses a larger matrix to include advantages of a choice to an item supplier. It also computes powers of this matrix till it stabilizes to get the final scores, and classify the solutions with these scores. The same technique is used to options and to weights of each criteria. Many levels may be used to evaluate any item. ELECTRE is an outranking method, it states a solution as worse than another when two conditions are fulfilled. QFD uses market research or AHP weights to the criteria, a secondary DOF sum up the effects of solutions components to each criteria. QFD evaluates, for instance, how the wheels of a car or its seats contributes to comfort. So double summations gives the score of each solutions, the 1st in how an item contributes to a quality, another DOF states the effect of a quality in the overall performance index. Different MCDM rankings and scores may differ. A classification of n items generates (n-1)n/2 pairs with two consecutively classified elements. These pairs in two different classifications will not be equal. With a single inversion, only a pair in one classification will be different from a pair in the other. Summing up in both classifications the number of pair presents only in one, a pairs differential, D_{pairs}, is obtained. The *Kendall Rank Correlation*, KRC, decision factor τ is $[n(n-1)/2-D_{pairs}][n(n-1)/2]^{-1}$, τ has a normal distribution if $n > 10$, and the values error chances are tabled if $n<10$. The chance of taking a wrong rank is the chance of assuming both ranks equal, when they aren't. For k ranks and a choice, there are (k-1) τ values, the wrong choices chance comes from a Chi-square distribution of k-1 DOF of τ^2. The rank with biggest success chance is the best choice. These tools allows risks evaluation at any time, including any round of a iterative process, as the search for specifications.

Once it's possible to detail the tasks and the resources for doing them, it's viable to guess the mean effort and major development risks including decision, with the above techniques. But they don't help people in the task of finding new good solutions, neither gives clues of the chances of finding a better solution, after a good result was found. Many times, a good idea doesn't work alone, but works together with another one. For instance, in the past the cars used longitudinal engines, and due to this the transmission efficiency was lower than the efficiency of transverse engine mounting cars. Lots of changes in the position and size of the the engine and gearbox parts were needed to feed power properly to the differential in transversal mounting. In this simple case, a resource (best position) is explored or not. If everything is in the best position and the car items still have positional problems, the resource best position is exhausted. Either S curves, or computer optimization may give clues of this, but computer action depends on human data, and if this data isn't complete, it may predict a false depletion of possible positions. Something more is needed to find new solutions: TRIZ and/or Pugh Method (also knew as Pugh Matrix, Pugh decision matrix method, or decision matrix method, and hereafter PDM). As any systems has more specifications than at initial guess, often the best choice to a subset of specifications isn't the best to a complete set, and often even not feasible for the whole set. Placing the criteria in the rows of a table, and the possible solutions in the columns, and choosing as a reference solution not the best one, but one that has solutions that are better and worse than it in most criteria, and trying to combine or derive new solutions that eliminate a weakness of a existing one, people find a better solution set. When it becomes too difficult, it is time to make two things: increase the number of criteria and discard the worse solutions, no matter the order of these. Then the whole process is repeated. There's a point, that the use of quantitative design is better than the use of PDM. For instance, if the issue is a matter of what material to use and many options are sure available, with at least one that fits all requirements, calculations are more effective than creativity. The Game Theory and the Arrow's impossibility principle see the PDM as a very good method. Everything in it is documented. Tough, according to Arrow's Principle, there's no perfect decision method that always preserves transitivity (if a solution A is better than B and B is better than C, if a group chooses C as soon as B is not available any more there's no transitivity), and is immune to a dictator. It's possible to prove with Game Theory that a method is more reliable: the more steps it has, the more transparent it is, the bigger the number of people involved in the decision, the more regimented it is, the bigger the availability of the goods related to a decision, the smaller the value of the decision. For instance, if a supplier wants a favor, gifts to everybody is much more expansive than gifts to a single person. The Shappley value is smaller the more people is in a coalition (anyone is invited to a coalition if it brings to it an advantage, being people willing to pay for this advantage, this pay change with different orders of entrance, being the Shappley value the pay average for all possible entrance times). Anyone that wants to force a solution has lots of trouble with PDM, much more than with common methods. After all, a person that wants to sell a solution will show the good side of it, not its problems. Independence of criteria and solutions searches forces analysis in all criteria, and is a key issue to prevent bribery. Finding solutions is easier with TRIZ (from Theory of Inventive Problem Solving in Russian).

With a many years search in patent banks, Alshuller (1996) correlated in 1942 40 problem solving principles to 36 engineering parameters, that measures the quality of a design. He puts in a table the most useful principles to jointly fix a problem related to one of the parameters in conflict and improve the performance related to the other. This matrix, now with 40 parameters, is the contradiction matrix and may be found in the address www.triz40.com, either for printing, or a direct search. The 40 inventive principles may also be seen in this site as well as in (Altshuller, 1996, 1997), (Orloff, 2003), (Rantanen, 2002) or at http://www.ideationtriz.com/tutorials. Another way to find good solutions is the separation principle, that avoid forgetting that a property isn't needed in all positions, time, frequencies and so on. Thinking how a system would be if it would be much more: expensive or cheaper, bigger or smaller, and so on, also helps people to guess new ideas. Also by drafting a symbolic sketch, where different lines represent different iterations between a material item that receives the action (substance), another that makes the action and is also a target of changes (tool), and a field, it's possible to represent graphically any system (Substance Field Analysis or **SuF**). 76 actions with these plots, related to specific problems, are also a checklist of possible solutions, and also allows people to recognize a system that works quite similar in that graphs to the one to be improved. At last, the 9 laws of the systems evolution gives other paths to solve a problem and metrics that allows people to guess the solution quality. One is the ideality, a very strong generalization, with things that may bother, of Value Analysis tools. All this together with an usage protocol, that avoid misuse and precipitation, helps problems solving. Depending on the principles usage in existing systems, it's possible to evaluate the chances of finding a better solution in the internal research, or by any competitor. TRIZ patent literature helps as it shows not only how many utile principles were used, but how many times each principle was used to solve a given system problem, and how difficult is to find a better use of each. All of this may also be found in this paragraph already mentioned references. S curves and JMM/MH shows the evolution of the efficiency of any method.

3. WIND ENERGY, AND INGENUITY

Figure 1 shows some wind energy systems: the standard horizontal axis wind turbine, HAWT, the vertical axis wind turbines, VAWT, the *Magenn* airborne wind turbine, and the *Air Strip* (Orloff, 2003). HAWT were first built in truss structures in Yalta, Ukraine, 1931, and Vermont, USA, 1941. But windmills, and even pinwheel toys uses a similar idea. The difference is the high aerodynamic performance HAWTs' blades, in terms of useful lift and drag. HAWTs have low turning speed and high power, and so a high torque on its support column, they are either small or made of expensive composite material. Some VAWTs use the blade system as structural support, like wind driven roof ventilators, the blades may carry the most of the loads as in *Maglev*. *Magenn* is a balloon with an internal DOF of spinning, with metal and cloth blades, it rotates with the wind forces, and a another part linked to the ground with cables, doesn't spin, by this an electric generator works with wind energy. It also uses the Magnus effect to rise more cable, and get higher to get better winds. The Air Strip is also a balloon, but it's alike a ram-air parachute, it is able to change wind resistance, by opening its blades to reduce wind forces, or closing them to get more force. As a result it moves back and forth and moves a linear generator in the ground. The higher the device, the stronger the winds it gets. HAWTs have in general a bigger usage of resources of all kinds and are a poorer concept.VAWT is structurally more efficient, difficults another terrain usage, and may reach heights of even 400 m, and powers much higher than HAWT. The HAWT have blades of a very high level of aerodynamic development occupying a small fraction of the frontal area. The VAWT have a high fraction of frontal area occupied by blades, that doesn't have a high level of development. *Magenn* has similar blades and the effect of the balloon main body, but is much cheaper and gets stronger winds due to its relatively high altitudes. It's marketed in many sizes, and may be easily transported by truck to any farm, to be its main electricity source. Together with batteries, and eventually solar cells (most of daytime no wind cases are clear sky situations) they may run a farm independent of any external electricity supply. There are already commercial electricity systems operating the *Magenn* with meteorological support. *Air Strip*, may be bigger than *Magenn*, as airborne parts are the minimum ones, it's easy to transport, and its concept resembles a kite and a parachute, and isn't anchored to the rotating generators. It's ease to see that resources are well explored in in *Air Strip* basic concept, but lots of resources are unexplored regarding its construction, allowing many actions in future evolution. In the other hand, HAWT didn't explore extensively resources in its basic concept, but explored them intensively in its construction. It's also the most expensive option. Patents are territorial and with 20 years of validity only, items that don't fulfill these two conditions are free for usage and copy. But if a company starts doing something, it may shows to the owner of a foreign patent that the market is attractive, and this owner may be a competitor, probably with more technology and with less distribution channels. Reliability is an controversial issue. Though HAWT has 80 years of use and a high level of development of its components, it may collapse if the blade control fails, due to low structural margins. What would be a good choice to a newcomer company in the wind turbine market? What is best two cables an varying operating height, or four cables when there's log of turbulence and instability in the atmosphere? What to do with atmospheric discharges? What the advantages of each kind of pulley tackle?

Figure 1: Main wind turbine systems

4. THE HARD WORK

At the very beginning it's needed to search for wind turbines concepts in Internet and Patent Literature. The *wind turbine* key gave 29,159 patents in the *Freepatentsonline*, 7,675 patents in USPTO, all formerly applications, and 21,961 records in the ESPACENET. The numbers are very high, and ones needs to read the newest ones first, as newer papers cite the older. It also should be remembered that old solutions are in books or reviews. In the 1st site visited, there's no content already cataloged even the is solution knew. A Patent Search S curve was not done, as this work aims to illustrate the method, but it was done with balloons flight models, after 97 documents the chance of new information was bellow 0.37%, number of documents was used instead of time for simplicity. As the search goes on, it's each time more common to enter in a site without any new content, and after a long time, the trend is to only find only old information. Figure 2 shows data of an intermediate step in ideas and specifications search for STR lightning protection, 594 items were found in 8.5 hours, and then the task ended without detection of all specifications, as the low fitting reliability shows. For more items than the ones found, the fittings were more reliable. In general reliability of fitting after convergence is a good estimate of the chance of a complete set. Even spreadsheets may be used, as a *paste special* allows to glue only values and hand controlled iterative searches. Once a 1st list is obtained, a 2nd group may get a list with lacking items, artificial errors, and this 2nd run rises dramatically the list reliability. Rarely people makes large specifications lists before starting design detailing, and due to that more corrections are needed in latter phases. Search isn't the best tool as soon as the chance of finding new data is too low, an information given by the S curves parameters and the estimated reading / downloading. The search reports give data to begin a PDM. It's interesting that the reports have to include not only solution, but also problems, specifications and all other relevant data in an organized manner. It's also possible to guess total amounts of specifications or modeling equations for each solution type, with S/exponential curves related with searches and debate. If a search is really good, many different models to any system would be found. Most of specific models don't discuss items like corrosion, tolerances, construction trouble, processes and so on. But by guessing a process or material, specific models of such items may be also found. With this basic material, it's possible to evaluate at least comparatively the development effort of the alternatives. Table 1 gives entropy of some relevant items. The MGN/STR spark protection is lower due to use of tight strand scheme. The risk may be obtained at any time according to section 2 given the entropy, limit effort and dependency structure. It shall be remembered that if the entropy of the decisions a manager have to do is over a threshold this manager will not be able to handle the project any more.

Table 1 - Entropy H_o of relevant items of new models without human errors effect. (wind turbine producer/**newcomer**/**mesh**)

Item	H_o	Item	H_o	Item	H_o
Blades attack angle control	7/**14**	MGN flight dynamics	5/**9.3**	Water sealing (axial seal – supply/**model**)	3/**6.3**
MGN discharges protection	10/**11.7**	Wind speed profile	5/**5**	brakes	2/**2**
STR discharges protection	10/**11.7**	Wind turbulence	5/**5**	airplane safety (FAA MF beacon)	2/**2**
MGL discharges protection	10/**12.5**	Cabling properties and parameters	3/**3**	Electrical generator	2.1/**9.4**
SHAWT mechanical stability	20.3/**26.6**	Twin propeller mutual interaction **.6**	17.6/**17.6**	Pointing electrical motor	2.1/**9.4**
MGL mechanical stability	15.1/**17.4**	balloon bird impact events damages	11.2/**14.2**	Alignment control	6/**6**
MGN mechanical stability	10.1/**16.1**	Single wing Lift/Drag (normal-winglet)	7-10/**7-10**	Pivot current transfer (supplier/**model**)	5/**12.1**
STR mechanical stability	8.1/**14.2**	Moving /still blades interaction (turbine)	17.6/**17.6**	Pivot SHAWT discharges protection	15/**20.6**
STR flight dynamics	**5/11.7**	Standard gearbox (≠ noise tolerances)	4.2/7**.2**	HAWT harmful effects (sound/spray,sand...)	15/**37**

Now is time to start a PDM. Table 2 shows the initial matrix. PDM is faster and safer, if contradictions are listed and solved with TRIZ techniques in any solutions' search step, and even better if possible defects of all proposals are listed with the use of TRIZ-AFD (**A**nticipated **F**ailure **D**etection), that uses TRIZ techniques to find failure modes. As a rule, only 6 proper transformations in the **SuF** are related to any use failure. Right questions make things go in the right directions. For the HAWT, one of them are: is it possible to reduce by any means the net torque over the column? All questions at all time shall be focused to relevant problems, not details. Their objective is to direct the work toward better concepts, not sizing. It's not needed to find everything in a single PDM step, as new chances to find solutions will come. But it's important to assure a good understanding of the solutions and its problems before going ahead, and S curves help. In the item wind profile, for instance, people usually thinks on current profile, missing that environments may vary (crop cycles, new buildings). The next step is a raise in the total of criteria. People need to look the the ranking regarding the old criteria, and the chance of fixing any solution problem with a new criteria, in taking the options that will remain in the study. Tough normal PDM is by consensus, a MCDM is useful. It gives at least a clearer solutions' view. Affect changes to match new criteria, entropy risk calculations are utile. Pyramidal cabling and rotary parts assures *Magenn*'s stability, even if wind has high turbulence and rotational. For Air Strip, the pyramidal arrangement use isn't so easy. Lightning current probability is always needed to design protection to any wind generator, and this probability changes with the device type and size, its description has 10 site dependent parameters (rain a/ discharge chances). Once a spark hits a rod, the chance of a current I in kA is $[(1+I/31)^{2.6}]^{-1}$. http://www.ieeeexplore.com/xpl/references.jsp?reload=true&arnumber=6110208 gives 50 references. NASA CR-168229 is an extensive paper on this issue. Spark diameter is near 1 cm, its duration is short, but many successive discharge occurs. What are the damages if the discharge is above the protection limits? Protecting balloons isn't unusual, as it looks at 1st glance, balloons were successfully planned to gather lightning energy and better thunderstorms knowledge: US20100220424, US6,012,330, US911,260 (1908). Even tiny auxiliary balloons of conductive material, or with a conductive net, may protect the main one, leading current to the soil with cables. HAWT uses either cables, nets, or outer conductive layers to drain discharges from a blade to the column trough slipping rings, and a cable lead it to the soil. *Maglev* is metallic and pass discharges to a metallic runaway. Feasibility and risks involves for example: the chances of a too heavy protection balloon or a too big spark; the *Maglev* on site welding effort. For the delivered power either slipping systems or magnetic couplings, more reliable, may be used. Cabling set ups and entangling troubles risks are related in systems with many airborne generators. Tables 3 to 5 shows respectively AHP data regarding: the selection criteria for wind systems and ideal weight for each criteria, solutions' development effort for 98% success reliability and rankings of many MCDM with the *Kendall* parameters and the choice's reliability. *Kendall* correlation shall be used in any decision step. Table 6 lists the total of: equations, variables, fundamental physical quantities; and the entropy of few items, a count like this leads to entropy data of Table 1. Variables have statistical spread near nominal value, and so entropy. The crucial in a PDM-TRIZ-MCDM process is the use of enough requirements and solutions in the analysis. Requisites or solutions may be an idea or insight of anyone, but may also be found in the Internet. One is wind turbines infrasound emissions and their health troubles. Despite of the controversy on the risk and size of such troubles there's a risk of not getting a license to build a wind turbine near a community, and this will imply in longer power lines and increase in control delays. On the other hand, air traffic security may forbid airborne systems near airports. The possibility of infrasound troubles wasn't considered in any wind turbine study, according to www.spiegel.de/wissenschaft/medizin/wind-turbine-syndrome-krank-vor-angst-vor-infraschall-a-890407.html. How far from a home a turbine may be installed is an open issue, as well as daily limit doses of its infrasound noise. A remodeled discarded solution has always a return chance, as new ideas may solve their main troubles with all specification already brought to the analysis. But these solution have to prove its real adequacy to all requirements. JMM, S curves and statistical tools are used to see how complete an specification list is, to raise the total of requisites, or to see the effectivity of solutions' searches. PDM avoids direct comparing among non-reference options and akin disputes. Lots of literature data are needed to get information entropy, uncertainties, equations, and so on. Coaxial twin propeller models may be found in helicopters papers. Unluckily, it isn't possible to list all references, even all Table 1 ones, different issues have different levels of literature quality. The entropy of developing a far better composite material is much bigger than the one of the use of coaxial opposite turning blades. Fiber diameter(s), fiber direction distribution, fiber content, delamination, fatigue or endurance limits, resin working parameters, among others are extra composites DOFs. If a given composite is used, the entropy is low, but for a new and stronger material, there's lots of unknown things, entropy and work to do. There are slip rings and magnetic transfer items in the market, but developing a supplier has its entropy too. An 1% human error chance gives a 0.081 entropy rise per equation without an effective error control scheme. There's also a chance of studying wrong factors, for instance considering radar cross section for a balloon instead of using an of the shelf safety beacon and lights to enhance the chances of a light aircraft seeing it. If parallel alternatives are considered, the project failure risk is reduced. The effort rises only if an option is really done. Rain drainage, droplet shock, sea waves, and alike items shall be considered.

Table 2 - Initial Pugh Matrix and after first round suggestions. (+/> better, -/< worse ~equivalent)

	SHAWT	DHAWT	DHAWG	DHAWI	DHAWS	WHAWT	MGL	MGN	PMGN	STR	PSTR	CSTR
C1	-	-	-	-	-	-	-	-	REFERENCE	+	+	+
C2	-	-	-	-	-	-	-	-		+	+	+
C3	-	-	-	-	-	-	+	+		+	+	+
C4	+	-	-	-	-	-	-	+		+	~	~
C5	-	-	-	-	-	-	-	~		+	+	+
C6	-	-	-	-	-	-	-	-		+	+	+
C7	-	-	-	-	-	-	+	-		+	+	+
C8	-	-	-	-	-	-	+	-		+	+	+

C1:SHAWT<WHAWT<DHAWT~DHAWG~DHAWI<MGL<MGN<PMGN<STR<PSTR~CSTR
C2:SHAWT<WHAWT<DHAWT~DHAWG~DHAWI<MGL<MGN<PMGN<STR<STR~CSTR
C3:STR~PSTR~CSTR>MGL>MGN~PMGN>SHAWT~DHAWT~DHAWG~DHAWI~DHAWS~WHAWT
C4:SHAWT>MGL>MGN~STR>PMGN~PSTR~CSTR>DHAWT~DHAWG~DHAWI~DHAWS>WHAWT
C5:STR~PSTR~CSTR>PMGN~MGN(safety)>DHAWT~DHAWG~DHAWI~DHAWS>WHAWT~SHAWT>MGL
C6:STR~PSTR~CSTR>MGL>PMGN>DHAWT~DHAWG~DHAWI~DHAWS>WHAWT>MGN~SHAWT
C7:MGL>STR>PSTR>CSTR>MGN>PMGN>DHAWT~DHAWG~DHAWI~DHAWS~WHAWT (discharge)> SHAWT (colapse)
C8:MGL>STR>PSTR>CSTR>MGN>PMGN>DHAWT~DHAWG~DHAWI~DHAWS~WHAWT (discharge)> SHAWT (colapse)

SHAWT - Standard horizontal Axis Wind turbine	MGL- standard Maglev
DHAWT – 2 opposite spin direction hub/blades set HAWT	MGN- standard *Magenn*
DHAWG -DHAWT with independent generators/blade contols	PMGN - pivotated pyramidal cabling *Magenn* (many)
DHAWI - gearbox extra gear to spin inversion	STR- standard air strip
DHAWS - single generator, spinning stator and sliping contact	PSTR- pivotated pyramidal cabling air strip
WHAWT - HAWT + 2 vertical wings wind aligned to counter-torque	CSTR - many interconnected PSTR

C1 - energy recurrent cost	C5 - availability of installing sites
C2 - recurrent investment cost per kw for each unit	C6 - risk of hazardous accidents
C3 - availability (repair time over repair plus mean operating time)	C7 - mean time between failure
C4- development effort for 98 % success chance	C8 - mean time between overhaul

NEW PROPOSALS after 1st round

MHMGN -mini home MGN concept	AFBUD - Airplane form balloon in up and down movement
VASB - Vertical axis spinning balloon sending down compressed air	PAFBU - pivotated AFBUD
HASB - similar to VASB but with vertical axis	PHASB - pivotated HASB
VMGN - MGN with sail area control	MGNP/PMGNP - MGN/PMGN with parachute
MGNB/PMGNB - MGN/PMGN with emergency inflated balloon	SIMGL- semi inflatable *Magenn* concept
XEB- Any solution with extra balloon discharge protection	AHAWT- SHAWT with friction torque limiter

Table 3: Wind power selection criteria AHP (recurrent cost is maintenance cost per kW only)

	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	weight: $\Sigma_i a_{i,j} / \Sigma_{i,j} a_{i,j}$ - i:row
c_1-recurrent energy cost per kw	0	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	9/442
c_2-operation safety	3	0	1/3	3	3	3	3	1/3	3	1/3	57/442
c_3-investment cost per kw	3	3	0	3	3	3	3	1	3	3	75/442
c_4-2% risk development effort	3	1/3	1/3	0	3	3	3	1/3	3	1/3	49/442
c_5-time to market	3	1/3	1/3	1/3	0	1/3	1/3	1/3	1/3	1/3	17/442
c_6-MTBF (out of network if low)	3	1/3	1/3	1/3	3	0	1	1/3	3	1/3	35/442
c_7-availability	3	1/3	1/3	1/3	3	1	0	1/3	3	1/3	35/442
c_8-site availability	3	3	1	3	3	3	3	0	3	3	75/442
c_9-maintenance safety	3	1/3	1/3	1/3	3	1/3	1/3	1/3	0	1/3	25/442
c_{10}-equipment life	3	3	1/3	3	3	3	3	1/3	3	0	65/442

Table 4: AHP Wind power alternatives ranking regarding development effort for newcomers
(based on task unity time recurrent, equation 4 and 95% of success and non-recurrent costs and total of tasks repetitions).

	SHAWT	DHAWT	DHAWG	DHAWI	DHAWS	WHAWT	MGL	MGN	PMGN	STR	PSTR	CSTR	weight
SHAWT		1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	11/1644
DHAWT	5		1	1	5	5	5	1/5	1/5	1/5	1/5	1/5	115/1644
DHAWG	5	1		1	5	5	5	1/5	1/5	1/5	1/5	1/5	115/1644
DHAWI	5	1	1		5	5	5	1/5	1/5	1/5	1/5	1/5	115/1644
DHAWS	5	1/5	1/5	1/5		5	5	1/5	1/5	1/5	1/5	1/5	83/1644
WHAWT	5	1/5	1/5	1/5	1/5		1/5	1/5	1/5	1/5	1/5	1/5	35/1644
MGL	5	1/5	1/5	1/5	1/5	5		1/5	1/5	1/5	1/5	1/5	59/1644
MGN	5	5	5	5	5	5	5		1/5	1/5	1/5	1/5	179/1644
PMGN	5	5	5	5	5	5	5	1/5		1/5	1/5	1/5	179/1644
STR	5	5	5	5	5	5	5	5	5		5	5	275/1644
PSTR	5	5	5	5	5	5	5	5	5	1/5		5	251/1644
CSTR	5	5	5	5	5	5	5	5	5	1/5	1/5		227/1644

Table 5: MCDM alternatives rankings regarding investment cost per kW, and *Kendall* statistics.

	SHAWT	DHAWT	DHAWG	DHAWI	DHAWS	WHAWT	MGL	MGN	STR	PMGN	PSTR	CSTR
M1-AHP	12	6	7	8	9	11	10	5	3	4	2	1
M2-ANP	12	6	7	8	9	11	10	5	3	4	2	1
M3-QFD	12	8	7	6	10	11	9	5	2	4	3	1
M4-ELECTRE	12	6	7	8	9	11	10	5	2	3	4	1
M5-MAUT-TOPSIS	12	7	6	8	10	11	9	5	1	4	2	3

Kendall parameters	1	.727	.939	.727	.939	.727	.788	.818	.727	Choice 1=2 chance 0.432
	1-2	1-3	1-4	1-5	2-4	2-5	3-4	3-5	4-5	

Method	1	2	3	4	5
Chances	.432	.432	.327	.428	.311

Table 6: Some items equations, variables, fundamental physical quantities and entropy balances.

Item	Number of equations datasets informations	Eq. uncertainty entropy	variables	var. uncertainty entropy	Fund. Phys. quantities	Overal entropy
Pivot SHAWT discharges protection	53	1.2	76	0.4	4	20.6
Pivot current transfer model	41	1.8	56	0.3	5	12.1
MGN flight dynamics	47	0.1	60	0.3 (wind)	4	9.4
STR flight dynamics	199	2.3	212	0.4 (wires curv)	4	11.7

If the M5 is neglected, for instance due to uncertainty in utility models, M3 would be chosen with .642 of chance of being right. Without M5 there's complete agreement about the best solution. Notice that if the options are competitive, i.e quite similar with small advantages or disadvantages in each DOF, it's normal that distinct MCDMs give different rankings. Choosing any MCDM without any criteria, one may be taking a high risk unaware of it. Note that cost investment relationships depend on items like wind statistics, price components variation, power demand fluctuation statistics, utilization factor, and isn't a fixed value.

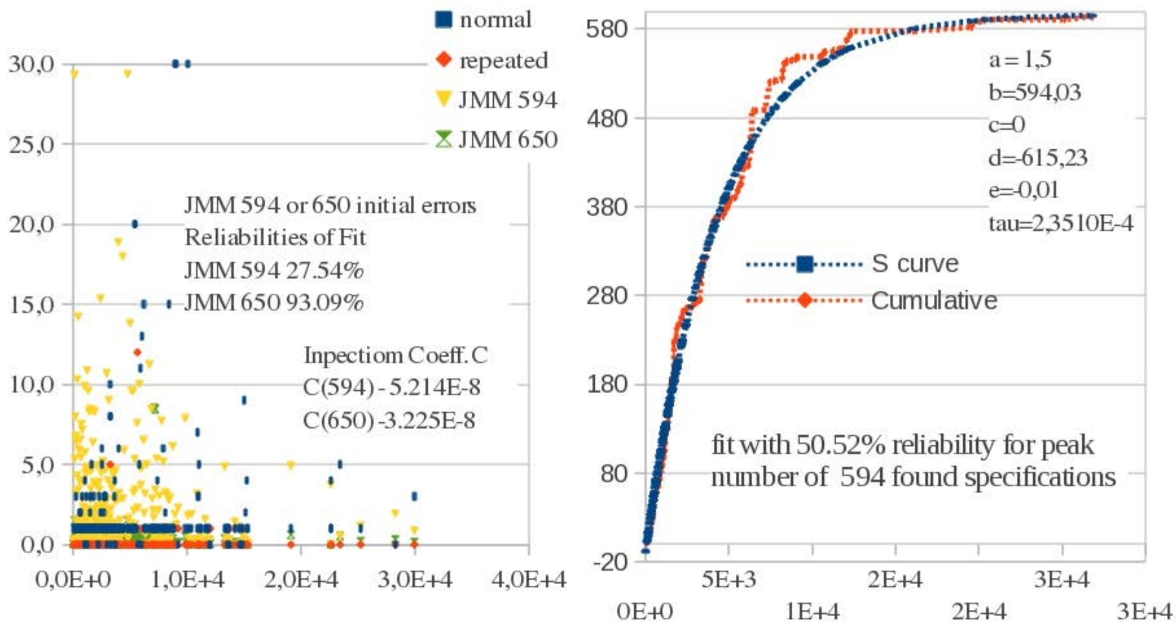
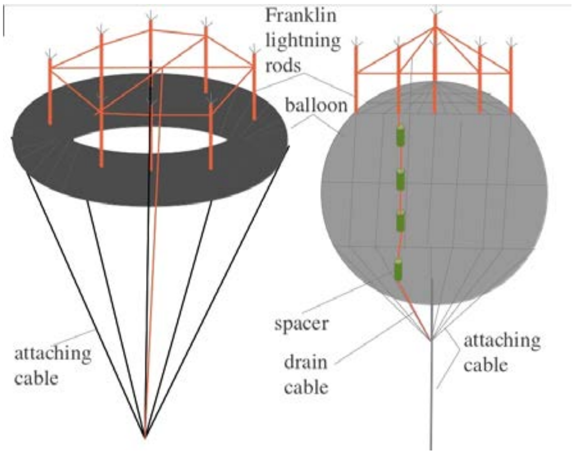


Figure 2: Evaluation of data set completeness with S curves and JMM for items related with lightning and “air strip”.

In S curve fitting for cumulative numbers of ideas, a start with opposite big values to b and d, is recommended, the initial difference is near initial number of guesses, and as the exponential multiplying the parameter d fades, the initial value of a for zero starting value of a and c shall be the number of items found or bigger, if peoples thinks more items will be found.

Figure 3 shows toroidal and spheric balloons lightning protection. They’re the basis for a work breakdown structure, WBS, shown in Figure 4. An option is to use a non conducting rope to bend conductors to improve protection. The balloon system can’t be heavy due to limited balloon’s lift. For preliminary estimates cone angle, or even with a little more work rolling ball schemes shall be used. It shall be seen that the strongest the spark, the smaller are the angles and the protection sphere diameter. If a secondary balloon fails, another one may be inflated, eventually already placed above the one in use and inside the holding cable net. For toroidal the use of such scheme is more difficult, by other side it is easier to assure protection to stronger sparks with the lines linking the rods. Metal cables accumulates charges to get an opposite electrical field, that neutralize external field in its interior, and this repels the lightning. All configurations takes advantages with the use of cables. In the ground many items may attract a spark. In the sky, the balloon is the sole target and more sparks will hit it. Electromagnetic equations or model testing shall be used to check the preliminary design. Due to weight tubes may replace rods, with more heat transfer area their limit current density is higher. Figure 5 shows a dependence scheme of the Figure 4 WBS, with the success probabilities, as all items in serial shall succeed to the overall success, and all items in parallel shall fail to overall fail, the tree reduction steps are shown, as well as the task set joint success chance. This series-parallel feature makes the use of different ways of doing a task the most effective failure control action. In structural modeling this may done, for instance, with Boundary Equation Method, Finite Element Method and analytical solutions. In author’s previous fuel cell work (Bambace et al. 2005, 2008a, 2008b), 7 routes for 8 μm inner diameter porous wall tubes were tested, to obtain tubes in 4 and get a single stable process. For more complex systems choices with error, the use of algebraic methods based on minimum path sets shall be used. Internal balloons in MGN may strongly reduce its fall risk, parachutes may also be used. Even simple systems have large numbers of specifications, a tire has near 130 and a squirrel electric motor near 240, as there are lots of solutions, PDMs have typically 10 to 50 rounds. The search for specifications may be done in parallel to it, but shall end before the PDM, with a tiny chance of forgetting any specification. Quadrelli et al. (2001) paper was used to get MGN flight entropy. Any paper numbers more equations than really available ones, once solutions and algebraic manipulations are also numbered. In parallel the derivation is for a single type of balloon, and there are for instance other alternatives available. The MGN the basic lightning protection is done by the two vertical stabilizers / rudders shown in Figure 1. They may be metallic or they may have a metallic edge, able to drain currents. If needed, conducting cable may link the rudders. Such cables may have sharp parts to act as extra rods. In the STR case, its top is a good place to lightning rods and conductive cables, for low attack angles an extra protection with longer rods or rods and rigid inflatable structure and cables shall be designed. Inflatable horizontal tubes may form a square with the upper zone of the STR, and vertical tubes may hold them. Other option is to use balloons. Altshuller (1988) made radio-telescopes lightning rods with low pressure glass gas tubes that ionizes due to the field before a lightning hits it. Only the tube rim is metallic or ceramic.. This option may increase safety in STR case. Rupke 2002 shows lightning aircraft damage, though internal safety is assured, the shell high currents at movable hitting local induces shell damages. Nets have worse damages. In the HAWT that isn’t whole metallic as an airplane, the problem is worst, as fiber system polymer is more sensitive to spark strike heating damage, and alike an airplane the hitting point changes as a blade moves. The Zeppelin had an outer shell and internal balloons, that are separated from the shell, an alternative safer against lightning and birds impacts, that’s not modeled in Mars mission. If the material of the shell is conductive it may help the rod scheme repelling the spark, but as even an airplane shell suffers damage, it won’t withstand strong sparks without appreciable damage. Eventually thermal sensors can detect the wrong lightning strike to alert maintenance teams of eventual problems in the airborne element. Is it viable to get a vacuum or low pressure zone inside a balloon with almost no weight penalty? We solved this with ARIZ 85. Think there's an outer sphere a inner one. If there's a high pressure in the outer one and this one has a foam, the external one push is transmitted to the inner one counteracting the forces from inner sphere lower pressure. Depending on the parameters an Altshuller lightning rod based on this is very light. But where a spark hits it? Making the right choice is much more important than making good mathematical models in product development.



-External rods may be inclined for better protection.

-the holding net with a spacer may be used for Faraday case purposes

-more than a single drain cable, with same area may be useful

-flat items have more heat transfer area than circular ones

-Kirshoff law may be use to dimension repelling cables with low current

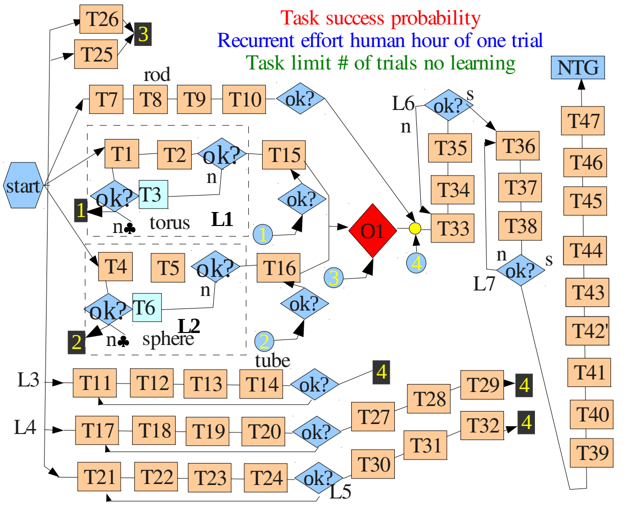
-mass above balloons have flight stability impact, to be studied

-this solution pair has a high number of design options, as at least number of rods, rods type, rods inclinations, number of large cables and its position, number of tine cables and its position, are design variables.

-solutions with different geometry shall be compared

$e = 0.5\ P\ X\ \sigma^{-1}$ to e shell thickness, P pressure, and X a characteristic dimension, R to sphere r (cross sectional radius) in torus case, and σ the allowable stress. The area and volume of a torus $4\pi 2Rr$ and $2\pi^2R^r2$, ratio 2/r and this ratio for a sphere 3/R, make the torus a good option due to smaller shell thickness. See that R and r cancels out in shell volume calculation.

Figure 3: Some concepts of lightning balloon protection.



T1/T4-1 0 1- set protection level, numbers of rods, cables, ropes, heights, angles
T2/T5 - .999 5 3 -model attitude, hitting point & rod height with rolling sphere
T7-.96 3 8 -model rod temperature against current and mass
T8-.99 5 6 -create rod test plan
T9-.99 7 10 -detail and check rod test plan
T10-.99 3 10-verify theoretical model with test after building prototype in 30 h
T11-.96 3 8 -model tube protection temperature against current and mass
T12-.99 5 6 -create tube lightning protection test plan
T13-.99 7 10 -detail and check tube lightning protection test plan
T14-.99 3 10-verify theoretical model with test after building prototype in 30 h
T15-.998001 .4 19-do a electromagnetic model to rod and test, 90 hs setup
T16-.998001 .4 19-do a electromagnetic model to tube and test, 90 hs setup
T17-.96 2 1887-model sphere flight dynamics/ attitude-wind speed- counterweight 1: 6 scale 60 hs setup
T18- .99 8 7-create sphere flight dynamic test plan
T19- .99 12 10-detail and check sphere flight dynamic test plan
T20- .99 4 10-verify theoretical model with test after building prototype in 70 h
T21- .96 2 1887-model torus flight dynamics: attitude-wind speed- counterweight 1: 6 scale 80 hs setup
T22- .99 8 7-create torus flight dynamic test plan
T23- .99 13 10-detail and check torus flight dynamic test plan
T24- .99 4 10-verify theoretical model with test after building prototype in 70 h
T25- .999 1 16-model effect of metal shell or net in sphere balloon
T26- .999 1 16-model effect of metal shell or net in torus balloon
T27- .99 8 7-idem T18 scale 1:1
T28- .99 12 10-idem T19 scale 1:1
T29- .99 4 10-idem T 20 scale 1:1 building prototype in 200 h
T30- .99 8 7-idem T21 scale 1:1
T31- .99 13 10-idem T22 scale 1:1
T32- .99 4 10-idem T 23 scale 1:1 building prototype in 230 h
T33- .99 15 7-test plan lightning hit 1:6 scale
T34- .99 12 10-detail T33 plan
T35- .99 20 10-T34 math model verification building prototype in 70 h
T36- .999 40 20-test plan lightning hit 1:1
T37- .9999 60 25-detail T36 plan
T38- .9999 120 250-T37 math model test building prototype in 290 h
T39- .9999 300 3-model of all margins
T40- .9999 220 3-model reliability
T41- .9999 6 3-choose the number of spares
T42- .9999 600 3- balloon detailed design
T43- .9999 1200 3-detail production plan
T44- .9999 1200 3-detail alternative production plan
T45- .9999 200 3- overall math model test
T46- .9999 1200 3-qualification test 180 h model/setup
T47- .999 100 3-production test ~720 h setup
O1- choose torus or sphere. L3/L4 .99 7
L1/L2/L5 To Be Defined
L6 .999
L7 .99999
NTG=Next Task Group

Figure 4: Lightning Protection using solid lightning rods only preliminary WBS top level.

Parachutes dynamics (Brent, 2006), and typical uncertainties of aerodynamic correlations construct a joint data counting to STR dynamics, that has a success chance of a single trial of 3.01E-4, or 9,966 trials for 95% success chances with a right search zone. Three parachutes main dimensions, cable number and control length, 2 air gap dimensions, 3 wing dimensions and its profile and number are 12 entirely free items that may be correlated in 9 dimensionless parameters, as these quantities will be use to control forces and torques, that involves dimension, mass and time in support equations. As a check, variables less equations shall always give the number free control parameters. Starting from previous parachutes experience, using qualified CFD models and gradient search algorithms test effort is greatly reduced. The difference between direct balance and proprietary models entropy values gives an information barrier to new producers. Regarding MGN and STR a crucial question is related to strong swirl wind. In pyramidal cabling this is less likely to be a problem, in single cables there's a chance of attitude control problems and instabilities, as there are problems to people in parachutes in similar situations. The risk depends on availability of support equipment as a wind profile radar, to detect that a swirl is coming and put the flight wind generators down to its protection. The history of swirl occurrences may exclude an site as a candidate to receive flight wind generators without pyramidal cabling. If many balloons are used to protect an equipment, they may be linked by cables to avoid entangling. If a balloon is used to protect an HAWT, it may be fixed to the rotating generator bay, with more than a single cable, and the bay may even have extensions. For DAWT one of the axis shall be prolonged to receive a cross mounted with ball bearings to hold balloons cable to pyramidal scheme.

In exploring Figure 4 developing options, ones guess preliminary efforts and risks with entropy methods and makes equations and items counting. Based in the literature and crude expectations of performance, an option is chosen as a working one, that is performance-risk-effort Pareto Optimal, i.e. to better something any other thing shall get worse. In Real Option, RO, information value is the peak change in an option value due to the confirmation of an information to any of its possible values. As things goes wrong analog information values may be drawn to risk and effort. Improve any other item knowledge or to go ahead with present option is a risky decision. Remain in the Pareto Optimal frontier is a good decision method in this case. WBS complementary data helps to see clearly at any instant the risks and effort to such options. If risk-effort Pareto Optimal curve, that changes with new information during development, is followed the effort is minimum. Figure 4 modeling options have common parts. By some degree of parallel modeling of any item, the reliability of the modeling grows. Subtasks in the base levels of the WBS may be common. The ratio benefits/costs takes in account the effort, that depends on the tasks in the lower levels, and results, that depends only of what is done as a global systems. To avoid values differences to scaling, all weights, tasks and projects ones, shall sum one. All possible combination of tasks and projects have a benefits/costs ratio, and the higher benefits/costs and benefits/risk ratios options shall be done. There's also no reason to quit a project with all tasks already in the select projects, as no cost reduction will be reached. With 12 alternatives, if they are fully independent even a failure probability of 20% would result in an overall failure chance of 4.1×10^{-9}, a very low risk. In fact models have common tasks, and for each item more than a model type may be done. Coleman formula and Moody Chart may be used in pipe flow, some problems allow the use of Finite Volume, Finite Elements and Boundary Integral methods, always there are independent models to the same item. By using of at least 2 independent teams to any model, and at least 2 models types for any item, reliability of common modeling may be set to very high values, mainly if JMM with Mils hypothesis is used. With imposed 5% search success chances, 0.5 to 1% of chances of wrong search zone, and 6 sigma margins in each failure DOF, plus 0.5% imposed limit for human error chance, risks are far bellow 20% per alternative. If 4 groups looks for specifications in parallel independently, the error chance is 6.25×10^{-4}, and this in series with equal modeling error chances gives 1.25×10^{-9} failure chance. If failure chances of human error were doubled, the two task failure chance would be 2×10^{-8}. Evaluating the hub torque on the column directly with the generator rotation and power, or sensors in its mounting in a SHAWT will make the control not sensible to the torques related to giving linear and angular momentum to the water that adheres the blades in a heavy rain. Alike best option problems are well spread in all items. People points of view are documented for future eliciting of any doubt or problem.

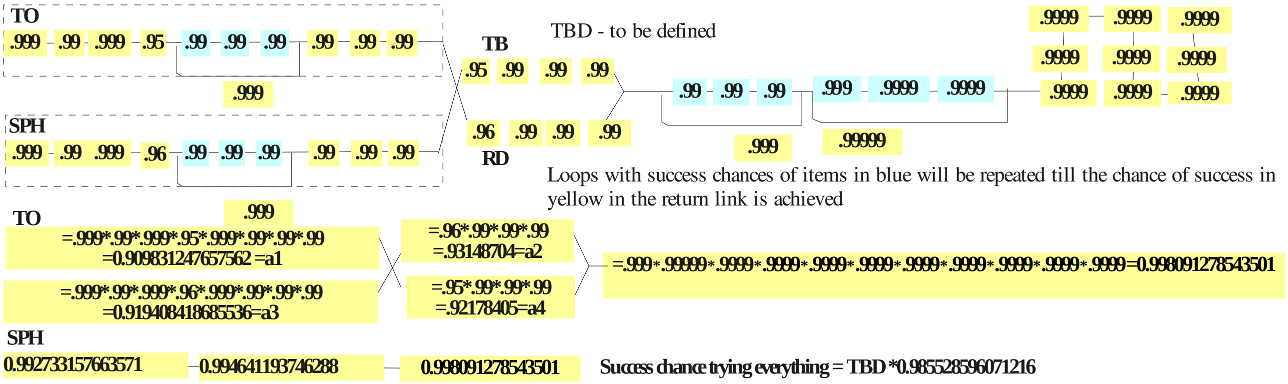


Figure 5: Tasks Dependences and Task Set Reliability of the WBS of Figure 4

It's not possible in any case to see all possible solutions or problems in a short time, and even with enough searching time a risk of missing a good solution will always be present. A good options tree and a detailed WBS of it is mandatory to good design estimates and less errors. Task breakdown is a point that deserves attention. If a task is a set of many ones, search repetitions may involve all the smaller tasks and not only the one with problems. If it's possible to do and test items separately, repetitions are done individually to each item and the efforts drops. But uncertainty in couplings may spoil these kind of strategy. Some degree of decoupling is possible with interface data sheets, IDS, and is also possible to calculate the risk of violating an IDS. With this, it's possible to simulate many possible WBS, to evaluate their probable effort, including the use of loops on many tasks, either by Monte Carlo or by the use of effort sensitiveness to specific changes and gradient searches. After WBS optimization the effort drops significantly in comparison with any first its guess. The main idea is to use reliability tools and Failure Mode Effect Analysis to organize the best way possible the design and developing activities aiming to enhance the future project success chances.

In the example of the car seating, the tooth space is more or less the people tolerance to a seating position not equal its ideal one. If a dividing any field by a manufacturing tolerance, that may or not be adequate to the solution of the problem, and taking the nearest bigger integer, a number of steps n_i for the i-th DOF may be obtained, and the number of sets with a member in each DOF is the product of all n_i. As pairs are tested and no solution is found, the risks that the current processes are inadequates increases. To avoid mis-centering, it is possible to use more points to each tolerance zone, but as the number of tests rises, a clear indication of process inadequacy comes. Somehow the development supervision shall changes to another option if the process inadequacy increases. With more trials than the average number o trials with binomial distribution, more trial than the product of all n_i, or to k DOFs, this number times 2^k, or any other verification standard, is advisable to improve activities in an spare option. Searching algorithms, as Newton-Raphson, strong reduces the number of trials. Though most people uses them in numerical calculations, they may be used in model physical tests. Fluctuation it test parameters are used to estimate slopes, and a physical change in parameters estimated and implemented. But it isn't advisable to count with a faster convergence of searching algorithms without previous experience with them in similar problems. Convergence problems may occurs, software errors may appear and so on. The more estimates are based in support tools and less base in pure guesses the bigger the success chance of any endeavor. In the protection balloons example, if a 10^{-6} chance is used for the chance of a spark stronger than a given value is taken, and a design able to withstand with no damage this spark is found, there's no need to explore effects of spark size in the system. If damage occurs as in HWAT blades, the effect of the sparks shall be explored, to get reliability, mean time between failures, and the chances of catastrophic failures. For instance if a spark damages the blade control, a torque above the limit one may act in the tower causing failure. So what are the chances of such a damage with an spark weaker than the protection limit, and stronger than this limit?

The direct logarithmic forecast of number of repetitions may be use as pessimist prediction in PERT, GERT or even Critical Chain, the binomial distribution associated with the logarithmic success chances to find the number of repetitions the task is concluded 50% of the tasks, and the single trial time used as optimistic prediction is such methods. In case of Critical Chain the pessimist prediction is used to calculate the buffers in the not critical paths and at project end.

Its interesting to notice that a process like the one suggested gives lots of ideas of how any family of solution may be improved, for instance discharging protecting balloons with pyramidal cabling, due to the help of extra bars, may be use to protect SHAWT or DHAWT generators, and raise their lifetime due to reduced blades discharge damage. A second blade control for preclude colapse in case o main one failure and many other ideas were found. Though there's a lot of extra initial work in this approach, in general there's an overall work reduction, as it reduces the number of unexpected development problems. In parallel better products are obtained. The techniques illustrated in this paper example was used with success in many real systems development or analysis that due to patent processes are in secrecy. These systems involve reaction wheels, atmospheric reentry, energy generation among others. It effectively rises the success chances of engineering and design activities. With the highest development effort to newcomers, SHAWT has a big entropy barrier against its fabrication by any newcomer. So the companies that already have it ready will have a strong market advantage till SHAWT replacement by any other system. This was the case with the television. Now besides cathodic tube models, there are plasma, LCD, LED and DLP TV systems. A plasma TV patent doesn't protect the company against a LED system. That's why scenario analysis and product comparisons as NEWPROD (Cooper 1992) are needed.

Methods like the one here described are a trial to make good predictions in preliminary design phases, in order to make better choices, and reduce the risk of resources shortage. Regarding figure 5, if there's enough time and resources, a wrong choice among the options would cause a delay, but if not a wrong choice would implies in project failure, in this case if the choice is associated with a success chance a_5, and with $x_i=1-a_i$, the system minimal paths include items (1,3), (2,4) and (1,5,4), (2,5,3), they have a simultaneous failure chance of: $(1-a_1a_3)(1-a_2a_4)+(a_1a_4x_2x_3+x_1x_4a_2a_3)x_5$, or 2.47% for x5 equal to 15%, that may be obtained with product of the failures chances of all paths and setting powers of any chance over one to one. The chances of failure with an ideal choice is 2.31%, that is related to the $(1-a_1a_3)(1-a_2a_4)$ term only. With this simple formula, the impact of the choice may be estimated. The bigger the choice impact, the better it shall be. The less reliable the options the more important are the options. A plot of choice error chance against global error chances helps to set the choices reliability to optimal points, avoiding unnecessary effort with irrelevant choices. In our experience, the main problem related to research and development is that most items are not evaluated before detailed activities start, generating lots of difficulties. A coarse estimate is better than the use o blind trials. According to Deutsch et al. 2006, there are 3 loops either in conflicts or in problems solving: an inner and very immediate loop, were people may even not thing acting through conditioning, a loop with superficial thinking, and an outer detailed analysis loop. This is related, for instance, with cost reduction in a plant (inner), better design of an existing option (middle) and brand new options with a very broad analysis of options. No design team has success without using the 3 ones, as even if a team has very good ideas, they have to be detailed to become products. Never using the external loop means obsolescence of the product portfolio. Most people avoid new developments due to their inability to evaluate the risks. This paper made a proposal to this, that in our point of view is already sound. We hope to further improve that in the future, and that sponsors use that to choose what to give money. Better sponsorship will improve technical, scientific, economic and social development.

5. CONCLUSION

Innovation is the motor of the progress and economic growth and welfare. At the starting of a new project to cope with an opportunity in a market niche, the company has two options, to develop a conventional solution and eventually face the original producer of this solution as soon this producer notices the activity in the niche, or to develop a brand new solution, that may be even the platform to products in traditional niche in the futures, as the digital camera today. The decision is hard, and may be done with the methodology presented in this paper with a good degree of certainty. By having reasonable estimates of effort, risks a comparison among the traditional and innovative paths is possible. This is done by exploring, under adequate quality control, the space of possible concepts of solution, evaluating with statistical tools the maturity of each activity before going ahead, using idea generation tools, and many Multi-Criteria Decision Methods and multiple sources of data together with the *Kendall* correlation to evaluate the quality of all choices. The *Pugh Method* forces a productive debate and turns manipulation more difficult. It turns easy to see what is desirable in a new solution. Though the *Pugh Method* dynamics helps ideas generation, much more powerful ideas comes with its association with TRIZ, as proposed in this paper. The development effort may be achieved by evaluating the entropy of information with correlations variances, material properties and tolerance statistics, and counting equations, couplings and trade offs. With more precise effort evaluations the resource shortage chances, including time and money, is reduced. If any important issue isn't well evaluated, as for instance discharge, the risk of a wrong choice is very high. So it’s very important to have statistical measures of the maturity of each phase, as here proposed. Regarding wind generation, it's clear the airborne systems advantage, in special the *Air Strip* one. It’s also possible to see that existent wind turbine systems have a very high information entropy to any company that doesn’t work directly on it. On the other hand, airborne systems doesn’t impose a big information barrier to the entrance of any new producer of it, and is protected only by patents.

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