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Creativity: The Critical Element for Mission Success

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ABSTRACT

Can creativity be the critical element for the success of a Space Mission? Problem solving methodologies, as brainstorming, are familiar for finding solutions to technical problems. The analytical skills to solve problems and the creativity required to invent new products may appear similar, but they are profoundly different. Creativity requires a different mindset than problem solving. In sectors where the engineering process depends on creative thinkers new ways of technology development need to be defined.

The objective of the mission Rosetta to land on a comet is well defined. For most of cubesat missions, the problem is posed the other way around: to find an interesting application achievable with the strict resources of a cubesat. Creativity, more that problem solving, is the 'rule of the game' of cubesat.

This paper presents how conventional approaches to problem solving can lead, for cubesat missions, to deadlock situations. Creativity, coupled with high tech engineering process, becomes a critical piece for finding new uses of cubesats, and therefore critical for securing the new missions.

Moving from problem solving to a creative process has been experimented on the Hypercube, a hyperspectral instrument in a cubesat. The paper presents how to bring a mentality shift to evolve from problem solving to a creative environment, instrumental to face the challenges of the evolution of the small satellites.

INTRODUCTION

Small satellites face a game-changing era where creative thinkers are as important as innovators. In some high technology sectors, as videogames or computer-animated movies, creative talents work in cooperation with engineers to develop new products. Successful companies in these sectors are defining new ways of product developments.

Problem solving capabilities, 'thinking outside the box', brainstorming are all familiar terms in the small satellites business to refer to ways of finding effective solutions to technical problems. The analytical skills to solve problems and the creativity required to invent new products may appear similar, but they are profoundly different. Creativity requires a different mindset and company procedures than problem solving.

The process for designing cubesat missions is similar to the creation of apps for tablets: the resources are defined by the hardware, but there is unlimited space for the creation of new applications. Very different is the situation when developing a satellite: technical problems, although very difficult, are clearly identified.

The objective of the mission Rosetta to land on a comet, for challenging it may look, is well defined. For most of cubesat and nanosatellites missions, the problem is posed the other way around: if a team of students finds an interesting application achievable with the strict resource of a cubesat, they may be given a chance to fly. Creativity, more that problem solving, is the 'rule of the game' of cubesat and of other nanosatellites programmes.

As new apps for 2.99US$ are released every day for smart phones and tablets, new cubesats missions are presented at every workshop, spanning from in situ analysis of the mesosphere, not possible with conventional satellites, to precision farming, where hourly revisit is commercially viable only with cubesats. The rate of growth of participants to Cubesat workshop and the amount of new and fresh ideas surprises any 'old folk' in the space business.

'Thinking outside the box' to find technical solutions does not help to find new cubesat applications. It is rather by 'thinking inside the cube', i.e. working within strict boundary conditions that sparks the creative process that differs from problem solving. Similarly to art production, where authors are bound by tight constrains, as rhymes for the poets, or the rhythm of a genre for songwriters, cubesat teams are bound to the cubesat tight engineering constraints.

This paper presents how conventional approaches to problem solving can lead, for cubesat missions, to deadlock situations. Creativity coupled with high tech becomes a critical piece for finding new uses of cubesats, and therefore critical for securing new missions.

Moving from problem solving to a creative process has been experimented on the Hypercube, a hyperspectral instrument in a cubesat. A creative process has been used to unleash creativity: the focus was not on how to resolve the limitation of the hardware, but to identify creative ways of using an underperforming hardware. This experiment gave insights on the design process of high-tech systems and a methodology that can be also used for larger systems.

The paper concludes with considerations on how to bring a mentality shift to evolve from problem solving to a creative environment, instrumental to face the challenges of the evolution of the small satellites, where possibilities are limited only by the creativity that will give solutions to problems we did not know existed.

WHY A PAPER ON CREATIVITY?

The technology development of the large majority of space missions is driven by ‘application pull’. The objective of the mission is well specified, as the challenging scientific missions as Rosetta that recently landed on a comet, or the improvement of performance of the next generation meteorological satellites.

The engineering process on these projects is well defined and it is based on the experiences gained on the last five decades. It does not mean that developing the next challenging mission would become simple, but the process of defining the requirements and the handling the technology developments does not vary a lot.

Project milestones, design reviews, risk definition, risks management, cost and schedule analysis: all of these are common practice and based on consolidated tools. However, to the knowledge of the Authors, none of the aerospace companies or institutions uses standard methodologies for fostering creativity. Even the term ‘Creativity’ is not common in the aerospace communities.

Artistic and engineering professions have been until recently two independent professional paths. University curricula reflect the work environment: a student pursuing a master in engineering unlikely would attend a master in liberal arts. Similarly, persons willing to become a music composer most probably will not study electrical engineering.

Developments of technologies applied to the consumer products started to make the boundaries between art and engineering less defined. Initially the contribution of artists to a product was limited to the aesthetic. For example in the car industry, the contribution of a designer was limited to the body of the car, and not to identify technical solutions for the engine.

Nowadays, the engineering team designing a car gives great consideration to the input coming from the stylist of the car, not only for the body, but also many of the details that define the ‘perceived quality of the object’. Already the use of terminology ‘perceived quality’ indicates that perceptions are important as much as quantitative engineering parameters.

In other sectors, as for example music and literature, creativity is a measure of the talent of composers or writers. In the graphic design, film, fashion, advertising, or entertainment industries, some jobs have in their title the word ‘creativity’, for instance ‘creative director’.

In the video game industry, for example, the development of a new product is a significant effort and requires a mix of people with skills in art and engineering. The role of the creative director becomes very important. He/she has the responsibility to lead a video game project forward, working with teams including motion graphic artists, 2D/3D animation developers, illustrator artists, software engineers and much more. A creative director must have knowledge of art, graphics, computer science and math; often he/she is required to have proficiency in computer programming, and most importantly he/she needs to have in place a production process that fosters creativity and still delivers the product in time and within budget. To give a scale of the complexity, the production of a computer-animated movie, as one of the top hits of Pixars, involves a team of 800 people and it lasts over a year.

If we consider one step further in the development of consumer goods, such as the video games and computer animated movies, it is clear that the creative process leading to generation of the idea is the fundamental step to be taken. The implementation of the idea, e.g. the coding of the software of a video game, is a continuous interaction between creative people and engineers that it requires a new methodology of work.

The interaction in these types of team is very different from the processes seen in aerospace. The question is the following: can the methodology of production of video game industry, just to use the same example, be used in the nanosatellites business to foster creativity to find new applications for nanosatellites? And even further, can a new approach stemming from a creative environment help space project in general?

And also, why should an aerospace company bother about using creative process?

The kick for a change of the way of doing space business comes from the Cubesats.

Cubesats have very tight constraints in terms of power, volume, and hardware performance. The objectives focus on identifying applications that may be attractive to a user community. For the first time in space engineering, rather than finding the solution of a well-defined problem we are faced with the opposite challenge: to find a problem for the solution.

Before trying to answer these questions, it is interesting to see how much students and young engineers have been creative in finding new applications of cubesat in the last few years.

A FEW CREATIVE IDEAS

The following does not want to be a review about the most interesting or promising ideas, but it is rather a list that makes us reflect that creativity is an asset on which we can leverage to achieve new astonishing missions.

Planetary Hitchhike

One of the last applications one could imagine for a Cubesat is planetary exploration. A few papers have been presented to propose Cubesats as deployable daughter spaceship of a larger mission.

Irrespective of the scientific relevance and the feasibility of such a concept, the idea is the result of a creative process. The authors of papers on ‘Planetary Hitchhiking’ concept made the connection between two worlds that are disconnected: interplanetary probes and the tiny Cubesat usually bound to low Earth orbits. The idea doesn’t come from the problem on how to perform better science with an interplanetary probe; it spurs from the creative push of finding new applications for cubesats.

In situ analysis of the mesosphere

The idea to launch a satellite and use it for in-situ analysis of the mesosphere proposed for the QB50 is one more example of a non-conventional application for satellites. Due low cost of a Cubesat when compared to other satellites, the possibility to launch a swarm of approximately 50 3U cubesats makes this type of vehicle the ideal investigation tool for in-situ analysis of the mesosphere, namely the part of Earth atmosphere that is too high to be reached with high-altitude balloons and too dense to be explored with conventional satellites.

These are just two examples, one very far from Earth and the other one very close, where cubesat developers, with their creative minds, have proposed new utilization of a space vehicle.

With more that 100 launches per year scheduled [1], there are surely many more examples of creative use of the space asset.

THE HUMAN BRAIN IS THE TOOL

The progress of neuroscience of the last two decades is impressive. Thanks to new diagnostic methodologies we now understand how the different parts of the human brain get activated when we are trying to solve different problems.

We have now a reasonably good understanding of the mental processes needed in the different phases our activities and we are able to separate which part of the brain is involved in solving tasks requiring an analytical thinking versus which are the parts used when we are making connections of apparently unrelated information.

Similarly to what a couch does with an athlete, i.e. exercising the muscles to reinforce a specific part of the body to excel in the sport activity, managers in the engineering work should start considering training on how to better use the brain in the different situations.

Nowadays neuroscience can be useful to a team of engineers as the knowledge physiology of muscles became important in the eighties for the preparation of athletes.

Making the right exercise

There are some persons that are naturally creative talents, others that have more analytical skills. Most likely an engineering team will be predominantly composed by persons with analytical skills, partly because that is the way engineers are selected, but also because creative persons that work in engineering tasks are ‘educated out’ of the creativity, to use the expression of Ken Robinson [2].

A simple test, called Remote Associates Test (RAT), [3] can be used not only to verify the attitude and the capability of each one of the team members, but also to introduce the concept that it is possible to approach a problem using our brain in a different way.

Once it's understood, providing simple test becomes a way to train ourselves.

It is now clear to neurophysiologists that the left part of our brain is normally used to problem solving, while the right part is used to make weak connections. The weak connections are those important for gaining a system thinking, to see the problem from a different point of view, or even to see the humoristic side of a situation. The latter perhaps is not fundamental for problem solving, but surely instrumental to open up connections in other people brain.

A simple and very famous RAT is to find a solution to the following problem:

Move one segment to make the equation below an identity.

IV = III + III

Not very difficult, once you solved try the following:

III = III + III

Only a small percentage of the persons that took this test identified the solution.

III = III = III

RAT can be tried the following link [3]:

The test consists in finding the forth word that can be associated to the previous three, for example:

cottage / swiss / cake

the solution is "cheese". One a little more difficult:

opera / hand / dish

Answer: soap.

There is a wealth of possibilities to test our capabilities to perform remote associations. The interesting discovery of modern neuroscience is knowing that the part of the brain that perform remote associations is the same that sparks the solution to an apparently insolvable problem.

The other interesting discovery is the way a group of people interacts in finding the solution. Studies done by sociologists show that the solution is very often found only after having discussed the problem and not during the session where the problem is discussed.

It seems that once the right part of our brain has been activated, it is able to look for the solution with a process in the background. So the brainstorming sessions, where a group of persons is requested to discuss until a solution is found, are less effective than a number of short sessions where the problem is presented discussed but not solved. The team members leave with an indication of the type of solution needed. The team will reconvene a few days after giving time to the right part of the brain of each of the team members to process the problem and make the necessary associations.

One more interesting part of the creative process is the Q defined by the sociologists Uzzi and Spiro. It is demonstrated that a team of very good and creative persons loses the creativity after working together for long time. Equally inefficient in proposing creative solution is a newly formed team, where interactions among the individuals are not yet well devised.

Injecting in a well established team some persons from a different environment is a good way to rebalance the Q-factor: this technique may be effectively used when forming advisory committees to discuss and review R&D plans.

THE HYPERCUBE EXPERIENCE

The Hypercube is an R&D project to develop a compact hypespectral pushbroom instrument in a 3U cubesat.

The Hypercube is composed of a small fully reflective telescope and a detector with a linear variable filter to separate the chromatic components of the incoming light. When flying on a LEO orbit, the instrument can deliver a SNR of approximately 50, a ground sampling distance of 80 meters and a spectral resolution of approximately 5nm. The system will generate something like 500 GB of data per orbit.

The project started as technology push stemming from a combination of recent developments: mirror manufacturing, CMOS detectors, filter deposition and on-board processing of cubesat.

The two evident pitfalls of the system are: the limited radiometric performance, when compared with large instruments that are typically in excess of 100, and definitively the limited bandwidth that will allow to downlink only a fraction of the data.

Engineers and scientists were given the task to find a few useful applications for this type of systems. In case no interesting application had been identified the project would have been terminated.

The very first question that arose at the opening of the first brainstorming session was: how can we improve the downlink capacity?

Here the experiment started: scientists were given the task to find an application where the requested information could be calculated in near real time on board. Only the relevant information will be downlinked, and not the data that were used to generated it.

Let us consider the example of a fire alarm installed in houses. It does not deliver any data about the temperature of the fire or the composition of the smoke: it just sends one bit of information "something is burning". Similarly the scientists were asked to find an application where the Hypercube spectro-radiometric performance will be 'good enough' to extract a useful information.

The consequent question arose: what is the computing power of the on-board computer?

The team was asked to find applications with the following boundary conditions:

a) Data rate: few kB / orbit

b) Computing Processing Power of the on-board compute and on board memory: unlimited

c) Revisit / access time: as fast as required.

The team was left with an open problem, very strict boundary conditions (data rate and spectro-radiometric performance) and completely open boundaries: memory, computing power and revisit time. The process of finding the problem for the Hypercube solution followed the four Phases of Intuition (1926 Wallas Stage Model):

1. Preparation: conscious work on a creative problem. The team was made aware of the creative problem and on the un-negotiable boundaries. As the rhyme for a poem.

2. Internalisation and Incubation. Each team of scientists was given the opportunity to contribute with many ideas, and all good ideas will be pursued.

3. Illumination (the emergence – perhaps dramatically – of the creative insight to consciousness as an 'aha!' experience).

4. Verification and Elaboration. Checking the applicability of the idea and then mitigating the problems and the pitfalls.

One of the most interesting applications that emerged was precision farming, in particular to monitor extensive cultivation to precisely define which part needs to be irrigated.

Saving even a few percentages of water to be used for irrigations will give a great help in food production. This application is surely interesting, useful and perhaps commercially viable.

It was immediately clear that, if the Hypercube can deliver the required radiometric performance, a small constellation of Hypercubes will provide the required revisit time to satisfy the timeliness of precision farming.

What about the unlimited computing power and on-board memory? How can that be accommodated on board of a cubesat?

In reality, precision farming is done only in a small fraction of the land, so the memory required to map the areas that are dedicated to extensive cultures is small. Furthermore, the areas that require 'precision irrigation' are usually dry, so cloud coverage is less frequent, therefore a constellation of six Hypercubes can provide enough probability of good observation and therefore the required timeliness.

The last issue to solve was to check if the on-board computer is capable of processing all the data to extract the information. The problem was solved by turning it the other way around: how big is a piece of land that can be processed with a typical computer on board of a cubesat? Seen from this perspective the problem seems more manageable: it will not be to full globe, but surely good enough to serve a few customers.

Scientist and engineers of the Cubesat team are currently busy to breadboard the hardware and to arrive to the first quantitative results.

For the purpose of this paper, what is most interesting is not understanding how large will be the land that will be served by a constellation of Hypercubes, or how many satellites will be necessary. The most interesting part is the creative process that has been followed for the first time by one project sponsored by the European Space Agency: give no requirements, give tight non-negotiable hardware limitation and, at the same time, completely loose boundaries for exploring new ideas.

At the moment of writing, the scientific team is still at work for generating and validating new ideas for the use of the Hypercube. The interaction between scientists, engineers and farmers to explore the applicability of the Hypercube has resulted in field experiments using small UAV. Prototypes with performance similar to the Hypercube have been already flown on board of octocopters spurring a number of applications that were 'out of sight' before the project was launched.

CONCLUDING REMARKS

The final considerations are on how to bring a mentality shift to evolve from problem solving to a creative environment, instrumental to face the challenges of the evolution of the small satellites, where possibilities are limited only by the creativity that will give solutions to problems we did not know existed.

The work presented in this paper is surely not covering exhaustively the topic of creativity, but it would like to bring the attention of the readers to a few relevant points: analytical skills are very different from creativity. A 'tiger team' able to resolve the most complicated technical challenges may get to an impasse when asked to propose a creative solution, simply because the path followed by our minds in solving problems is based on the experience.

It is necessary to gain a different point of view to find the unexpected solution. To quote Dilbert's words: "Because engineers can find the solution, it does not mean they have to be prosecuted". We need to inhibit the part of the brain in which our experiences are hard coded; these are the neurological mind paths we use to find the shortest way to the immediate solution. Imposing non-negotiable constraints is a way to inhibit these paths. Similarly to write a poem, where the poet is forced to find a word in rhyme, that is often not the most obvious, non-negotiable constraints a are pushing thoughts outside the domain of the common experience.

One-session brainstorming is not the way to spark new ideas. A longer, more distributed effort is needed. Last but not least: people should be given enough lee way to explore solutions that are at first sight disregarded.

The lateral thinking, or 'thinking outside the box', in reality is the result of a collective work which steps can be defined in a process.

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The book Imagine [4] by Jonah Lehrer provided a lot of inspiration to set a new way of working together in finding creative solution. It is a recommended starting point for all those people willing to inject a creative process in the *modus operandi* of a high-tech team.

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