NDTM

SUMMARY REPORT

EUROPEAN **S**PACE **A**GENCY CONTRACT REPORT

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LIST OF ABBREVIATIONS

CDF	Concurrent Design Facility
CNES	Centre National d'Etudes Spatiales (FR)
IXO	International X-ray Observatory
EADS	European Aeronautic Defence and Space Company
ESA	European Space Agency
NASA	National Aeronautics and Space Administration
NDTM	New Design Methodologies and techniques
ROI	Return on investment
SSC	Swedish Space Corporation

A. INTRODUCTION

The past few years the space industry has been faced with contrasting requirements and constraints. On the one hand it has been affected by significant budget reduction, on the other hand it was required to produce more complex systems in less time with higher quality standards. These contradictory aspects have impacted many other industries as well. In order to cope, these industries have developed and adopted radically new approaches in order to design, analyze, develop, manufacture and test their products/systems more efficiently.

In order to stay at the forefront of space system design this study explores new design methods and techniques and assesses their capabilities towards space system design. This research study is merely a conceptual study outlining the principles, major gains and potential hurdles. It does not focus on developing a detailed implementation plan, nor does it detail e.g. legal & policy issues.

The study had different phases from scouting to assessment eventually investigating 5 high-potential NDTM's more in-depth.

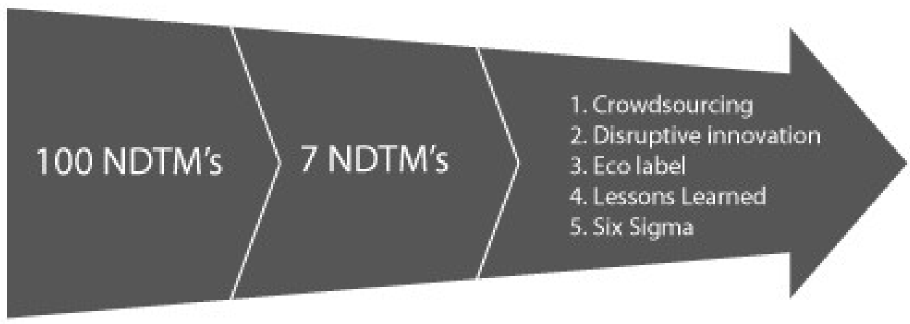

Figure 1 : Project Flow

This research gives a compelling overview of solutions to tap into radically new technology used by non space industries. During the first phase the study focused on the analysis of some key sectors: Automotive, Aerospace (aircraft, …), Life sciences & care (medical equipment, pharma, …), Materials & machining industry, Marine and Consumer products. In these fields more than 100 NDTM's were found that could be relevant for the ESA.

These NDTM's can be clustered in different groups:

A. Agile Development
B. Risk Management and planning

C. Design Strategies
D. Modularisation
E. Rapid /Virtual Manufacturing
F. Self-Healing
G. Smart System
H. Agile Development
I. Risk Management and planning
J. Design Strategies
K. Modularisation
L. Rapid /Virtual Manufacturing
M. Self-Healing
N. Smart System

Subsequently a selection was made. As a result 7 NDTM's were retained by ESA categorized into an A-list and a B-list. NDTM's of the B-list had some question marks that were further investigated before taking them into the short list.

Group A: Most interesting towards the ESA

1. Crowdsourcing
2. Disruptive innovation
3. Eco Green

Group B:

1. Six Sigma
2. Dual Vee model
3. Lessons learned by means of Triz and reverse engineering
4. Hoshin Kanri

Eventually Hoshin Kanri and the Dual Vee Model were eliminated and focus was kept on the remaining NDTM.

B. NEW DESIGN TECHNIQUES AND METHODS

Crowdsourcing

Crowdsourcing is a neologism for the act of taking a task traditionally performed by an employee or contractor, and outsourcing it to an undefined, generally large group of people or community in the form of an open call. For example, the public may be invited to develop a new technology, carry out a design task (also known as community-based design and distributed participatory design), refine or carry out the steps of an algorithm (see Human-based computation), or help capture, systematize or analyze large amounts of data (see also citizen science).

The term has become popular with business authors and journalists as shorthand for the trend of leveraging the mass collaboration enabled by Web 2.0 technologies to achieve business goals. However, both the term and its underlying business models have attracted controversy and criticisms.

For this research 2 different tracks with a slightly different focus were defined.
Track 1 consists out of a market place for engineering solutions. If a player from the space industry would need a technological solution they could post this to an online platform in the form of a “challenge”. By using a prize competition scheme “solution providers” can gain a reward. Industrial suppliers can post challenges from technical nature both in bid phase as in the execution of the project. A rating/ranking system should help to select the most valuable solutions.

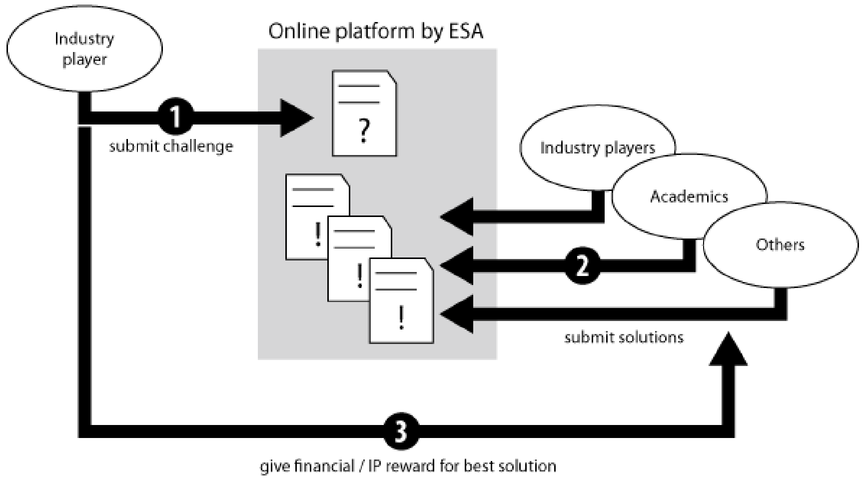

Figure 2 : Flow diagram: crowdsourcing track 1

Track 2 has different approach to crowdsourcing. System Engineering could make use of crowdsourcing in phase A studies. Whether by posting mission descriptions and requesting potential mission architectures, hence providing valuable inputs to CDF, or by posting preliminary architectures requesting feedback, improvements or alternatives. Instead of rewarding contributors in terms of cash, we suggest a rewarding in terms of recognition, e.g. exposure on the ESA-website.

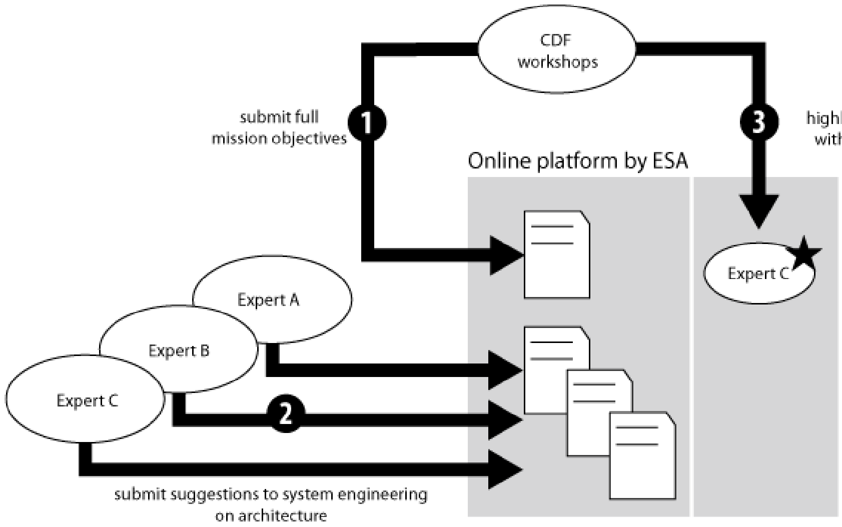

Figure 3 : Flow diagram: crowdsourcing track 2

Green eco development

Sustainable design (also called environmental design, environmentally sustainable design, environmentally-conscious design, etc) is the philosophy of designing physical objects, the built environment and services to comply with the principles of economic, social, and ecological sustainability.
The intention of sustainable design is to "eliminate negative environmental impact completely through skilful, sensitive design". Manifestations of sustainable designs require no non-renewable resources, impact on the environment minimally, and relate people with the natural environment.

Eco research and Eco technology have both gained enormous influence on many industries in the last years. Therefore an incentive system should be worked out to stimulate an eco-mindset throughout the ESA structure at each level. A dedicated toolbox can be built based upon the VERHAERT eco-toolbox. This set can then be used to facilitate the eco-project within ESA and System engineering. When people are actively making use of eco development tools or contribute to eco research they can be rewarded with an ESA eco label. This could be a stimulus for others to pay more attention to these aspects as well. Another way to receive such a label is working on valuable eco-technology. When technology can be spun-out to third parties they could be awarded as well.

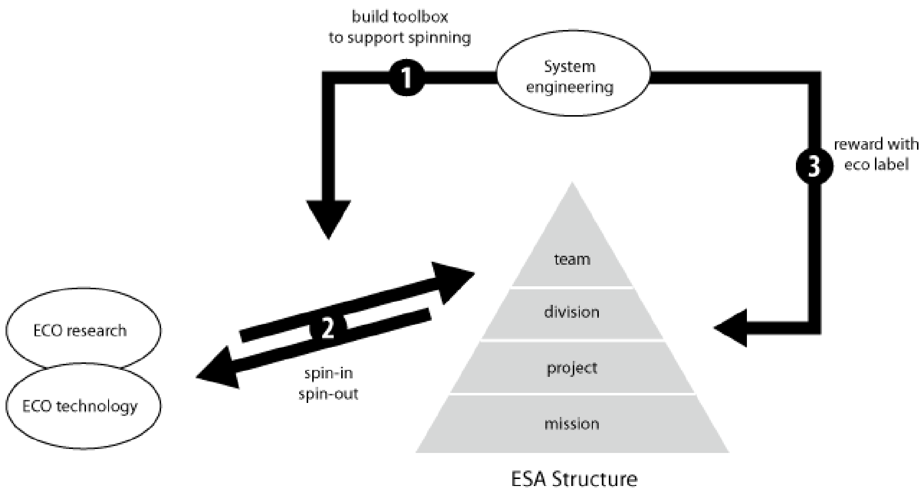

Figure 4 : Flow diagram: Eco label

Disruptive innovation

Disruptive technology and disruptive innovation are terms used in business and technology literature to describe innovations that improve a product or service in ways that the market does not expect, typically by being lower priced or designed for a different set of consumers. Disruptive innovation is a design method delivering cheaper, but better systems.

Disruptive innovation has for space a huge untapped potential in terms of sustainable financing, risk management and contingency planning in the form of providing a method to make space designs less complex, less expensive and e.g. more focused on a specific mission. ESA has already outlined the problem of sustainable funding, especially for scientific mission as they are less appealing to European citizens. But also other flagship projects, e.g. new space transportation systems like Hermes face a difficult trajectory. Often the programs are cancelled in their original format because too expensive. Disruptive innovation can solve this challenge.

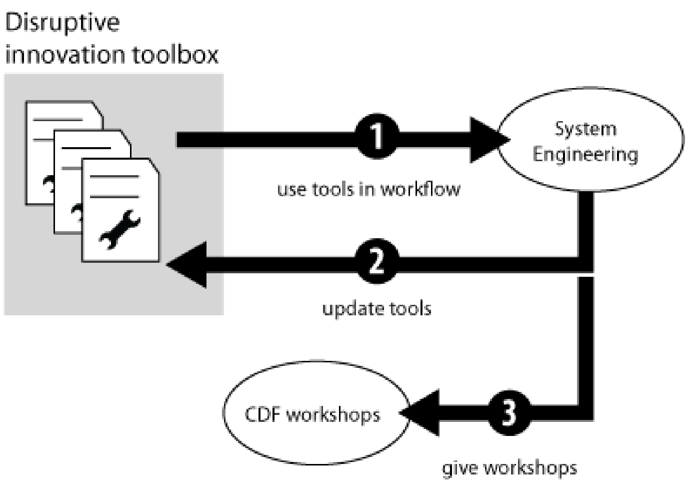

Figure 5 : Flow diagram: disruptive innovation

Disruptive innovation is a method typically applied in collaborative workshops. It is easy to implement, but requires expert assistance as it requires inherently requires radically different thinking.

Lessons learned

Lessons learned is actually the historical expertise gathered on a subject in order to prevent the same events, mainly negatively impacting a (business) process again. It is in fact the do’s and don’ts, the key learnings often coming from failures but also from things that went well.

By using a systematic way of storing all the lessons learned in projects a company can manage to improve future development projects. A central database and uniform method should be applied to make such a system usable.

We believe the idea of lessons learned is quite simple and in fact on 'old' principle, however, the implementation of a system that is effective and is therefore widely used is in fact the major challenge. This study focused on conceptualising around this bottleneck instead of detailing the infrastructure required to roll out this business process.

Experience outlined that lessons learned are hardly actively consulted; hence the impact is limited to almost nil. This happens for many reasons. First of all there is no general standardised way to report these lessons. The reviews that are being made are not centralised. This makes it difficult for all employees to find the information they are looking for. Therefore we could set up an improved system and process to manage all the lessons learned. Secondary, how will you enable pro-active use of such a system? This is probably even a larger challenge than the first one. This angle forces us to take a different viewpoint; hence conceptualising on a creative problem solving tool based upon lessons learned information. From an engineering perspective it seems to have fewer barriers to use and more direct value.

One way of promoting the use of the system is to make it part of the DRL reviewing system that is currently used at the ESA. This would lead to a standardised way to handle all the inputs what makes it possible to input it in some sort of general list.

Each item should be described in a consistent manner, e.g. similar to a patent structure where you would see an abstract of the problem visually supported to make it more understandable to others. A third part can be a further explanation of the encountered problem with remarks and suggestion on how to avoid this problem in the future.

When the amount of 'lessons learned' files becomes significant important it can be useful to work on a system similar to Triz (Theory of Inventive Problem Solving). This is a model-based technology tool-set for generating innovative ideas and solutions, especially used in problem solving areas. By using a structured, more algorithmic approach, Triz can help to solve complex problems. Triz originated in research that was done on a patent database; hence correlating its inventions to 40 physical principles. Typically each physical principle has one or more contradictions (other principles that get worse or worsen the effect). The space related information can be coupled as well towards these principles, in a way similar to how it has been done for the patents, then it would be possible to find similar contradictory relations between them, hence facilitating search functionality to users and interconnect with solutions and things that get worse through them. This would mean that doing research on all these given problems could lead to some general principles that would result in a more efficient way of handling Lessons Learned.

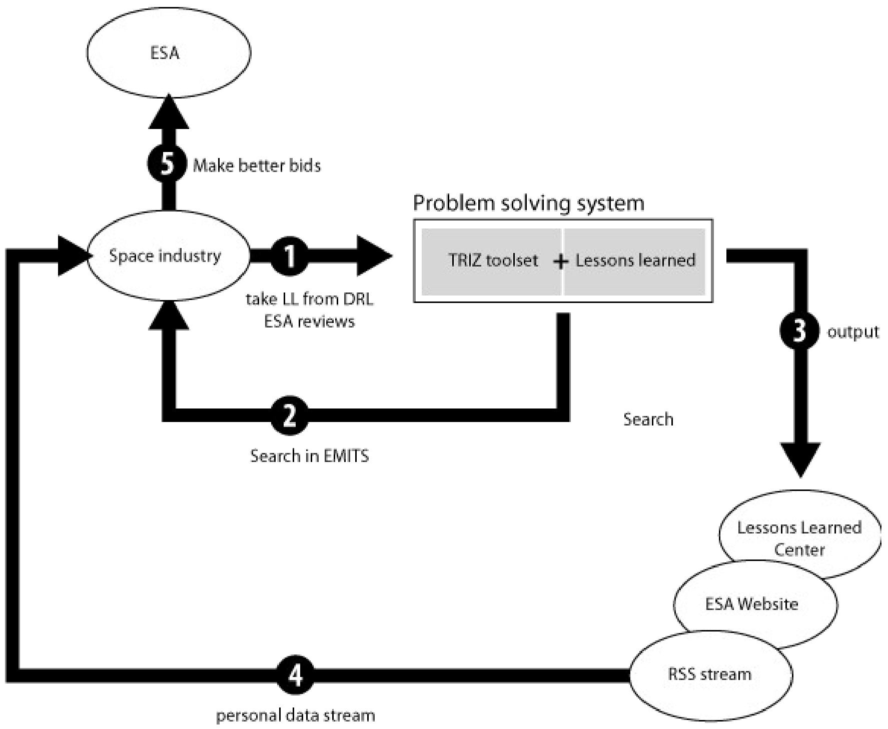

Figure 6 : Flow diagram: lessons learned

Six sigma

The fundamental objective of the Six Sigma methodology is the implementation of a measurement-based strategy that focuses on process improvement and variation reduction through the application of Six Sigma improvement projects. This is accomplished through the following steps (which can be used during all design stages (system, preliminary and detailed design or even during manufacturing).

Based on the information we have, we see that six sigma has the biggest potential in the latest phases of the development cycle.
Design for Six Sigma (**DFSS**) is a separate and emerging business-process management methodology related to traditional Six Sigma. While the tools and order used in Six Sigma require a process to be in place and functioning, DFSS has the objective of determining the needs of customers and the business, and driving those needs into the product solution so created. DFSS is relevant to the complex system/product synthesis phase, especially in the context of unprecedented system development. It is more relevant to the early stages of system engineering.

The main added value is the use of the statistical tools. The approach is that one performs a number of simulations (in the case of converging solutions) and statistics is used to derive the variance and to calculate the Cpk (process capability index). This avoids guessing work and allows you to set a realistic design goals, already during early design/concept!

6 sigma is a tool that relies on a rigid structure and a statistical approach and therefore it will be easy to implement in the current ESA and System Engineering structure. There, people are used this way of working so the internal rollout will not face many big hurdles. Six Sigma is merely an incremental improvement of the existing design process.

C. CONCLUSION

This study outlines that ESA and the system engineering division can rather straightforwardly improve its existing approach with Six sigma. Six sigma, however, is a rather incremental improvement as some of its fundamentals have been applied already within space system design. Within the scope of this study, indentifying new techniques and methods that keep space system design at the forefront, Six Sigma has to be seen as less compelling.

Crowdsourcing and the Eco toolbox are both interesting tools, however, disruptive innovation and lessons learned score profoundly better on the different evaluation criteria used within the scope of the study.

The lessons learned is basically an existing concept with the challenge to make it applicable for the space industry, e.g. actively used by the engineering community. It still poses some challenges on procedural changes and building up the databank, but also the pilot program requires important investments in order to test further its applicability. Our consortium focused on embedding the use of such a tool as the advantages are clear and the IT-infrastructure can be seen as not critical. We believe that this is still a challenging project in the long term. The short term challenges can be found more in the introduction of new business processes (e.g. to provide inputs to the system) and the fact it reaches beyond the system engineering department.
Gains are to be found in performance improvement and better controlling costs through a high speed learning curve, even for non experienced space engineers. Time gain is considered secondary.

Disruptive innovation is a totally new concept, however, strategically in line with e.g. smaller, faster, cheaper strategies or systems of systems architectures. This thinking method has a strategic fit with managing risks and options of complex systems, more specifically in providing fall-back options for step stone projects in order to find sustainable funding for these programs. In our viewpoint this method has the equivalent potential of concurrent design, a method incorporated by ESA and rolled out in the form of a concurrent design facility in Estec and at member institutes. Disruptive innovation has a scalable pilot program delivering important strategic advantages to both ESA and to member states. Because of its novelty and potential benefits it is the one with the highest potential to keep system engineering at the forefront of space system design while being compliant with all methods and infrastructure applied today. Moreover, the fact that it has a huge effect and is easy and cost efficient to implement make it the best new design technique for the ESA system engineering.

It is clear that this exploratory study is still at conceptual level, and selected tracks might have to be researched further to demonstrate their vast effects. This study revealed some interesting viewpoints to the consortium and some unexpected methods with unmatched potential. Out-of-the-box thinking has been used throughout the research in order to find and explore potential step stones for engineering. Further exploration of this journey is required but will definitely inject a novel élan to space system design.