Development of Future Space Concept Options Using Creative Thinking Techniques in Workshops

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Abstract: The Joint Operations Division (JOD) has been using a Concept Option Development (COD) process in order to provide early systems and technology options for Defence to consider in the Needs Phase of capability development. The COD process was presented at the Systems Engineering and Test & Evaluation conference 2010 by the author. COD is used to assess the upgradeability and flexibility of our force structure design in order to influence capability decisions.

This paper discusses the approach and the methods employed to insert concept options in the needs phase for space capability. JOD has provided science & technology support to the development of ADF Space operations since 2008, thus providing a starting point for the Future Space Concept (FSC study). In the FSC study, the COD process has been applied in a different context with groups of Space Subject Matter Experts (SME), brought together specifically for a workshop event to develop FSC options.

The COD methodology aspires to promote insertion of novel concepts to meet potential gaps through the use of creativity and conceptual design. The creative approach adopted in the COD process contrasts with the incremental improvement approach typical of capability development, in which improvements to operational capability are made by applying analytical thinking skills to identify evolutionary performance gains using existing types of systems solutions. The COD process informs the development of space capability through the insertion of concept options and assessment of how these might be integrated in a future context. Early capability option advice allows the customer / operator communities to assimilate possibilities, different avenues and opportunities available to meet capability gaps or to improve military capability.

Two workshop case studies are described. Creative thinking techniques were used, in conjunction with drawing from the considerable depth of expert knowledge available at the events. The lessons learnt and the types of results gained from using creativity and conceptual design with groups of SMEs are presented and discussed. The case studies provide insight into how a group of highly experienced SMEs can be brought together to perform innovation in a small amount of time and in a structured format.

Keywords: *Innovation, Conceptual design, Early technology insertion, Applied creative thinking techniques*

1. INTRODUCTION

From 2008 to 2010, the JOD Space Science & Technology task conducted a scoping study, Defence Capability Plan dependency analysis, a holistic strategy-to-task analysis (Ng et al, 2011) and a trends and drivers study. This prior effort provided a starting point for the Future Space Concepts (FSC) study discussed herein. The concept options developed under the FSC Study provide input to concepts during strategy development prior to capability development (see Figure 1). COD early in the capability development process can mitigate against technology obsolescence and mitigate or remove capability interoperability and integration issues.

Novel and disruptive uses of space identified by the FSC study can:

- provide the Australian Defence Force (ADF) with a capability advantage during military operations
- provide ADF with opportunities for high Return On Investment space capability

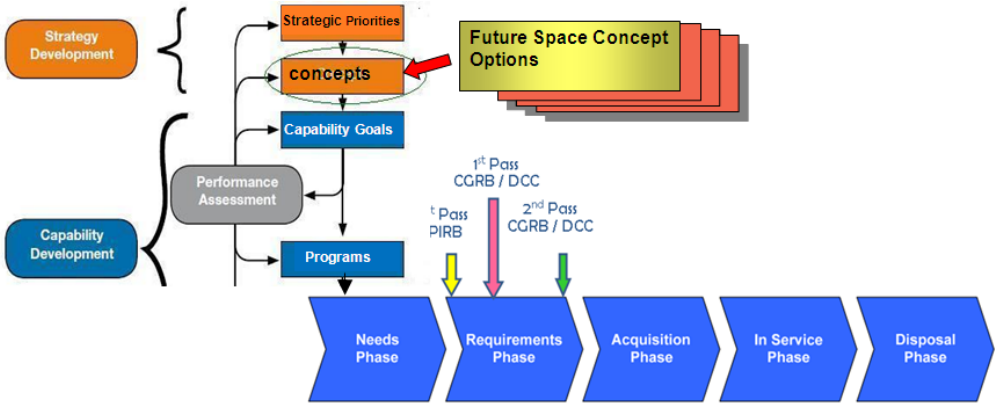

Figure 1 FSCO in context of ADO Strategy and Capability Development.

The COD product – concept options – contributes to what (Dahmann et al, 2011) call "SoS capability-based information", which provides the context for Systems of Systems engineering in the SoS Wave Model, see Figure 2. The ADF's space capability is becoming an "acknowledged System of Systems (SoS)"(Guide to SEBoK, 2012), and so the FSC study was an opportunity to introduce the COD product into current ADF thinking about future space capability. The DSTO has conducted similar COD for the Force Level Electronic Warfare (FLEW) SoS over a number of years (Jakobsson and Kingston, 2010), with a synectics process (Tuttle, 1997) providing the structured mechanism for creatively generating FLEW concepts.

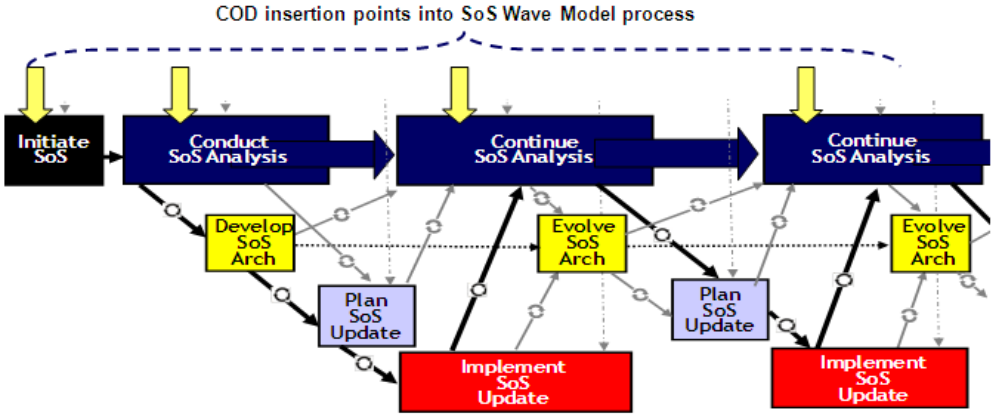

Figure 2 *COD input to SoS "Wave Model" (Dahmann et al, 2011).*

Methods for generating early systems options are of interest to the Defence scientific community. The Technical Cooperation Program (TTCP) Joint Systems Analysis (JSA) group, Technical Panel 4 (Systems Engineering for Defense Modernisation) conducted a themed session "Approaches to Generate Early Systems Options" in September 2012, covering the UK "Bluebox" initiative, the TRAiDE approach and Canada's approach. All of these approaches are iterative and the steps or activities are not necessarily

conducted in any particular order. The objectives and characteristics of all four approaches are summarised in Table 1.

The UK initiative "Blue Box" (Oxenham, 2010) focuses on concept definition for a particular design area, Unmanned Combat Air Vehicles. The initiative is led by Defence Science & Technology Laboratory (dstl), and draws from a continuous creative design process enacted through a group of companies. The complementary capabilities and skills between them has reduced conflicts and eased constructive interaction. The concept definition and the analysis are integrated and iterative. A Blue Box concept definition encompasses a physical concept, architecture and battlespace integration, concept of use, training and integrated survivability.

BAE Systems is evolving two complementary aspects (Harding, 2012), namely SoS engineering and capability decision-making. The capability decision-making aspect applies SE principles to enable evidenced based capability decision-making and uses the TRAiDE (Through Life Capability Management (TLCM) Robust Acquisition inclusive Decision Environment) approach (Barton and Whittington, 2010). The TRAiDE project process consists of two parallel processes with stakeholder engagement throughout – the Development of Opportunity and Scoping process and the Project Delivery process. TRAiDE is used at a very different scale for SoS development compared to the COD process. The TRAiDE project delivery process is data and product focused, which supports a model-based approach for the problem structuring, data collection, synthesis and analysis from the start of a SoS evolution project.

The Royal Canadian Airforce (RCAF) used architecture analysis, dual use fleet analysis and specific equipment analysis and trials to generate early systems options (Fleurant and Brown, 2012). The intent of the architecture analysis was to establish the As-Is and the To-Be of the C4ISR capability to support capability decision making. The objective of the dual use analysis was to provide feasibility analysis. RCAF used a framework (Deptula, 2008) to conduct a systematic, although subjective, assessment of the strengths and weaknesses of a system. Finally, the objectives of the trials were to demonstrate utility, determine requirements and thus reduce integration and interoperability risks.

Table 1: Objectives and Characteristics of Approaches for Early Systems Options.

Approach	Objectives	Characteristics
Concept Options Development Approach	Provide opportunities for high Return On Investment. Provide ADF with a capability advantage. Promote insertion of novel solutions.	Intense stakeholder engagement, operators, customers, industry and academia. Creative thinking techniques.
Blue Box	Understand a highly integrated design problem. Understand/realise the potential of this design area. Understand the art of the possible in order to identify credible designs. Develop robust user requirements.	Trust-based relationships between resources. Exchanges through shared understanding. Continuous commitment from dstl and from the specific companies.
TRAiDE (Harding, 2012)	Effective decision support in the acquisition. Better value for money.	Active learning from experience. Exploitation of relevant sources. Visualisations and experimentation techniques. Joint industry, operator SME.
RCAF	Support capability decision making. Provide achievable and operational relevant options. Provide systematic assessment. Identify critical requirements.	Combined top down, bottom up analysis and solutions of opportunity approach. Unified approach to the development and integration of new and existing capabilities. Clarity for leadership and decision makers Provide trust in information provided – current, accurate and consistent.

None of the three approaches from dstl, BAE Systems and RCAF mentions specific creative thinking techniques. All of them, including the COD process, have a strong motivation to improve and determine requirements, provide decision support and provide communication and engagement with the stakeholders, in

particular the customer /operator, throughout a development process. These motivations align with the FSC study and with the purpose and aim of the COD process.

2. METHODOLOGY

Using the COD process (Figure 3), the FSC study team conducted and iterated steps A, B, C and to some extent step D. A steering group (drawn mainly from the operator community) oversaw each stage of the study.

Space SME and operator stakeholders provided the primary sources of data (step E) and also feedback on findings from the various steps of the process.

Space SME engagement took place through a workshop format (Step F) designed specifically to encourage creative / divergent thinking and ideas generation. The objective of SME creative workshops were to:

- Harvest creative ideas from a heterogeneous group.
- Identify and develop concept options for space within respective SME domain
- Evolve concept options conceived by SMEs from other domains.

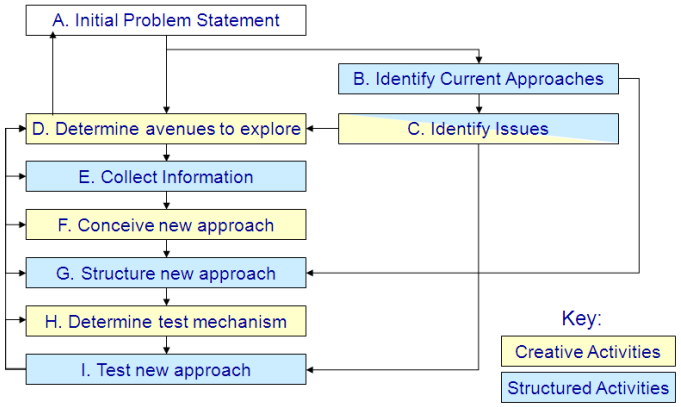

Figure 3. Concept Options Development Process (Jakobsson and Kingston, 2010).

Initial short-form workshops were held with ADF and DSTO participants. 5 months later 18 SMEs invited from Industry and Academia (I&A) were engaged in two full day workshops separated by one month. Figure 4 shows how the I&A workshop structures differ from the short-form workshops. In this paper, we are only going to describe the I&A workshop because it applied the most mature technique.

The key question for the I&A workhop was:

> Looking ahead 20 years, what novel capabilities might we develop in the space domain to enhance the effectiveness of the Australian Defence Force and to promote Australia's national security?

In the I&A workshop we used a diverse set of SMEs to develop FSCO. They were sourced by invitation.

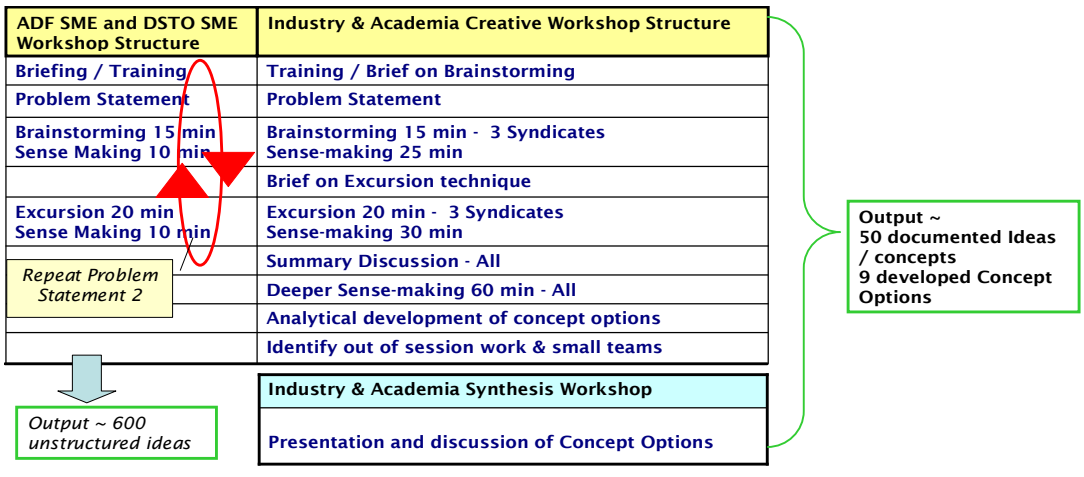

Figure 4 *Workshop Structures.*

We used the Brainstorming and the Excursion techniques to elicit responses to the key question. Both of these are intuitive creative thinking techniques, which are best suited to addressing ill-defined questions (Sefertzi, 2000).

At the workshop, the participants were briefed on the question, the approach and the techniques. Time was allowed for them to ask clarifying questions.

The workshop was then conducted, consisting of four phases. The phases were time limited events rather than attempting to exhaust one activity before starting the next since research shows that most actual creative thinking takes place in a matter of 15 minutes (Tuttle, 1997).

2.1. Brainstorming / Idea Writing (In Syndicates)

In the first phase, three syndicates of six SMEs undertook a brainstorming session using the brain writing format. In this method, participants in each syndicate were asked to write three original responses to the key question on a sheet of paper. When completed, participants passed their sheet to the person on their right, who then attempted to add a further three responses suggested after reading those from the preceding contributor. This was repeated twice, so that each participant had three opportunities to contribute.

Sense-making. Upon completion of the rotation, each syndicate undertook a sense making session. Participants were given the opportunity to read and explain their ideas, providing more context where possible. Duplicate ideas were also removed and/or combined through this process.

2.2. Excursion (In Syndicates)

In the second phase, the excursion technique was used to extend and expand upon the ideas generated in brainstorming. Participants were taken on a virtual excursion to a time and place unrelated to the key question. Participants worked independently to record their impressions and observations of their excursion, including, sights, sounds, smells and emotions. They then mapped their recorded observations onto analogies in the real problem space. Each resulting analogy was subsequently examined for potential approaches and solutions to the real problem. Once the individual work was complete, the participants shared their results within syndicate, writing these results in three columns on a white-board. Participants used this sharing process to remove duplicates, to combine and refine ideas and explain ambiguities.

Sense-making. Upon completion of the rotation, each syndicate again undertook a sense making session.

2.3. Deeper Sensemaking (In Plenary)

In the third phase, the syndicates combined in plenary for a more comprehensive Deeper Sense Making session. In this session, duplications between syndicates were resolved and the remaining ideas were discussed collectively. The plenary named and described each idea, giving it more depth and context, and further resolved ambiguities and definitions. As part of this process, the participants were asked to prioritise the refined ideas to determine which concepts were to be further developed.

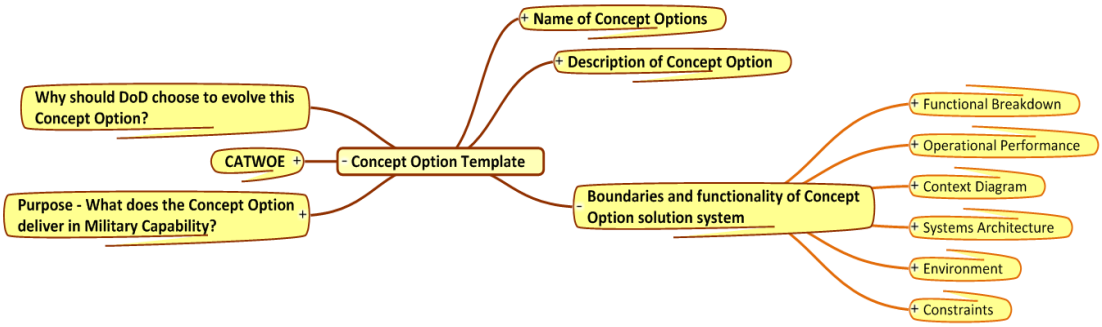

Figure 5 *FSCO template.*

2.4. Analytical Development of Concept Options (In Syndicates)

The fourth phase consisted of a synthesis session. The group was divided into two syndicates to further develop one concept option respectively, to illustrate the application of a FSC option template, see Figure 5. The syndicates addressed the concept option in terms of Description (What is the Concept Option?), Purpose (What does it deliver in Military Capability), Implementation (Technology Readiness Level?), Context diagram (How would the concept relate to existing or planned capabilities?) Architecture (What kind of system design solution is envisaged for this concept option?), and Stakeholders (CATWOE = Clients, Actors, Transformation, Weltanschauung, Owner, Environmental Constraints (Checkland, 1993)).

With this additional information a concept option can be discussed, criticized and evaluated as a first cut by SMEs and other stakeholders to determine if further investment is merited.

2.5. I&A "Homework"

The I&A group selected 9 concept options through voting and teams of 3-4 people that wanted to work on 2-3 of the 9 concepts for the next month were formed. The time expended ranged from a few hours up to a few days, as reported by the participants.

2.6. I&A Academia Synthesis Workshop

A Synthesis workshop was held a month after the Creative workshop. All 9 concept options were briefed back by each team leader and discussed in plenary for a full day. The facilitators collected SME feedback and additional data for the 9 concept options during this workshop.

3. RESULTS

15 complete concept options were fully developed by the study. The FSC study team combined ideas and concepts that were similar and used some of the 600 ideas in combination with some of the 9 concepts developed by the Industry and Academia team as well as added operational context and utility. The 15 concepts were subsequently used in a stakeholder workshop, where a mixed set of Defence space stakeholders (operators, technology SMEs, customer) evaluated the concepts from a decision maker's perspective. Further research is being conducted for a small number of concepts as directed by the steering group. Figure 6 shows an example of a FSCO developed in the FSC study.

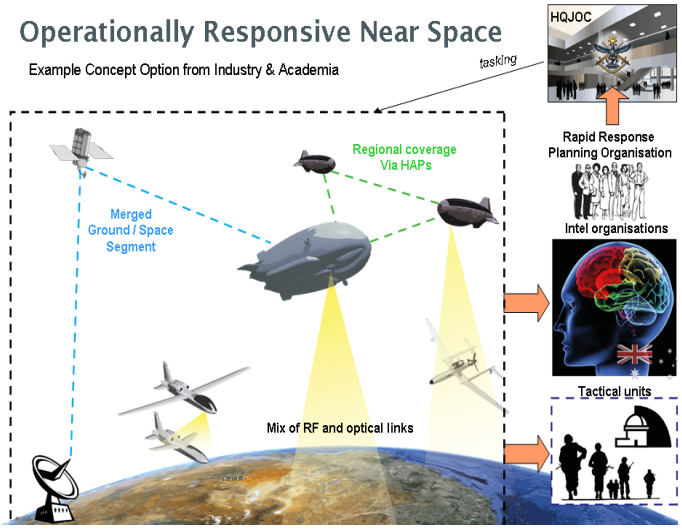

Figure 6 Concept Option developed in the FSC study (graphic design Diana Rigg).

4. DISCUSSION

Knowledge and information are the basis for creativity (Sefertzi, 2000). The COD process brings knowledge together, predominantly by engaging SME in a structured process and presenting that knowledge to stakeholders, be they decision makers or part of the creative team. The FSC Study workshops were designed to draw out SME knowledge, enable connection making between various ideas and to remove self-imposed constraints.

4.1. Individual and Team Creativity

(Sferetzi, 2000) notes (from (Higgins, 1996)) that improving creativity in groups requires team building and the use of group dynamics, whereas "Improving personal creativity for individuals involves enhancing the individual's use of intuition and reducing mental blocks [to] creativity, such as fear of failure". The FSC study applied specific creative thinking techniques to allow groups of people that may not know each other previously and were not an established team, to work together on ideas that they collectively or individually create during the workshop. There was no time allowed for team building during the workshop. The participants needed to approach the event with a positive frame of mind and to be prepared to accept the "strange and unfamiliar". To compensate for this, all the workshop participants had to volunteer after having been informed that creative thinking techniques would be used. The participants were also asked to suspend critical thinking and to adhere to "actions that move toward Cooperation & Synergy" (Prince, 2012) for the period of the workshop and thus avoid self-imposed constraints. Based on observation, this was achieved with nearly 100% compliance rate, which perhaps is a reflection of their commitment to the task at hand.

The implementation of the creative thinking techniques was tailored to allow individuals to express their ideas and to avoid dominance by a small number of vocal individuals. The I&A creative workshop was

structured to alternate between individual expression using pen and paper for the creative actions, with facilitated sharing and discussion of ideas. Based on observation, these strategies worked well in most of the creative workshops and exceptionally well in the creative workshop with I&A.

4.2. SME contact time constraints

The ADF and the DSTO workshops were limited to 3 hours each, whereas the I&A workshops consisted of approximately 15 hours contact time and additional homework. The extra time resulted in better developed concept options with a substantial amount of additional information and data supplied by the SMEs. In order to develop some of the 600 ideas from the ADF and DSTO workshops, additional SME engagement were needed and used. The lessons learnt for the study team was to provide at least three times more time for sense-making and discussion of ideas than the time allocated for creative ideas generation.

4.3. SME Diversity

For the ADF and DSTO workshops, the participants for each specific workshop was not as diverse as for the I&A workshops. For example in the ADF workshops, although the participants would have had extensive experience in problem solving, the participants would have had little systems design experience, whereas the I&A group have a mix of engineers, scientists and managers. In addition, during the I&A workshop, the syndicates were reformed from three to two and there were plenary sessions allowing immediate feedback between SMEs. This created better opportunity for ideas exchange from a greater instantaneously available pool of expertise. The lessons learnt for the study team was that a larger group divided into syndicates allow for greater flexibility to leverage from the available expertise, compared to having a number of workshops with a smaller group of participants in each.

4.4. Paradoxes and Constraints

Cropley and Cropley (2011) introduce the extended phase model of innovation. They identify seven phases of innovation; Preparation, Activation, Generation, Illumination, Verification, Communication and Validation. They argue that in addition to invention and implementation there needs to be a phase of communication to customers and that the product must also be accepted by the customer, validation. They use the seven phases together with the paradoxes of the 6 Ps – Process, Personal properties, Personal motivation, Personal feelings (linked to Invention), and Product, and Press (involves innovation implementation) – to formulate a taxonomy for diagnosing innovation in organisation.

When engaging individuals in innovation, within a group context or by themselves, understanding the paradoxes of the first four Ps is of great importance. To exploit innovation or to gain acceptance and resources to conduct innovation, understanding the paradoxes of Press and Product during the seven phases is paramount.

The COD process as applied for the FSC study contained activities aimed at dealing with the paradoxes of Product and Press, such as the use of a customer/operator populated steering group. The FSC study also applied two specific strategies to gain acceptance by the customer/operator. Firstly, the concept options development was applied at an early explorative phase – the Needs Phase – in the Australian Defence Capability Development Process (DCDP). In this phase, novel products are not threatening relevance and effectiveness. An argument for suspending judgement can successfully be made with the understanding that evaluation will be applied before any notable investment of time and funds are made. Secondly, the customer was directly involved in the COD process through the steering group, the ADF creative workshops, and the stakeholder evaluation workshop.

(Tuttle, 1997) discusses creative concept development in the context of engineering, pointing out that most engineers are skilled in critical (convergent) thinking, but that creative (divergent) thinking skills are often not implemented by the engineer. This may also be the case in the DCDP due to an inherent cultural desire for a product (concept, capability, major or minor system being acquired) to conform to the Routine product characteristics, see Table 2 from (Cropley et al 2012). The DCDP itself may also encapsulate some of the Necessity-oriented management characteristics, such as “assigns highly specific responsibility” or very few of the Freedom-oriented management characteristics. This would be a natural consequence for a large organisation which has the responsibility for managing a large budget and for minimising risks. Paradoxically this approach also minimises the opportunities for discovering novel and innovative solutions that may reduce both risks and costs as well as improve performance.

Table 2 Paradoxes of Product and Press from (Cropley et al 2012).

	Paradox	
Product	Radical product vs. Routine product	
	A product is: -novel -elegant -seminal -germinal	A product is: -relevant (matches task specification) -correct -effective
	Freedom-oriented management vs. Necessity-oriented management	
Press	A manager: -defines tasks broadly -assigns responsibilities loosely -offers opportunities for acquiring broad knowledge and skills -makes available time for analyzing and ruminating -is open to novelty -rewards generation of novelty -delays sanctions against lack of success -respects and protects those who do not conform -stands up to external pressure	A manager: -defines tasks narrowly -assigns highly specific responsibility -insists on deep specialized knowledge -demands rapid solutions -is suspicious of novelty -rewards "not rocking the boat" -quickly sanctions lack of success -sidelines or ridicules those who do not conform -gives in to external pressure

5. CONCLUSION

The FSC Study aimed at inserting creative thinking at the front end of the capability development process to overcome cultural and institutional constraints that may detrimentally affect force structure upgradeability and flexibility. It is too early to determine whether this approach is successful for that purpose. However, a methodology was developed and implemented that addressed some of the paradoxes and constraints of innovation, creating a non-threatening "environment" to think about Radical products as potential future solutions.

In addition, the creative thinking techniques, the workshop format and the tools addressed the problem of engaging a number of experts not normally part of an established development team in a structured creative activity and produced high value knowledge products.

There is currently no explicit path from concept options to the development of actual novel systems or the implementation of novel usages. As such, the FSC study can be considered an experiential learning activity rather than an innovation activity, with the main purpose of improving Defence concept development and acceptance of potential novel solutions.

6. ACKNOWLEDGEMENTS

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BIOGRAPHY

Åse Jakobsson graduated from Chalmers University of Technology, Gothenburg, Sweden in 1984 with a M.Sc. in the school of Electrical and Electronic Engineering. She worked for Ericsson Radar Systems AB, Sweden, for 10 years including a 3 year posting at DSTO, Australia. Her work included design of microwave antennas and phased arrays radars. She worked for AWA Defence Industries from 1994 to 1997 engineering radar warning receivers and defining standard procedures for systems engineering. In 1997 Åse joined DSTO, and has since worked with radar systems, multi-sensor integration, science policy and organisational change, C4ISR integration, complex problem structuring and concept development for Defence systems. Her research interests are development of complex systems and system-of-systems design and integration.