Active Brainstorming: -

A systemic and systematic approach for idea generation

Joseph E. Kasser
Visiting Associate Professor
Temasek Defence Systems Institute
National University of Singapore
Block E1, #05-05, 1 Engineering Drive 2,
Singapore 117576
Telephone +65 6516 4604, Fax +65 6778 9656
Cell/mobile/hand phone +65 9776 7464
Email joseph.kasser@incose.org

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Abstract. Many systems engineers and other problem solvers practice some aspects of idea generation when problem solving but tend not to practice it systemically and systematically. This paper addresses that aspect of problem solving and introduces a systemic and systematic way of idea generation via four new problem solving idea storage templates similar in concept to the Strengths, Weaknesses, Opportunities and Threats (SWOT) template using a combination of:

1. Three new problem solving templates which have been successfully used in several iterations of a postgraduate introductory course on systems engineering (Kasser, et al., 2008) and several one-day workshops on applying systems thinking to problem solving and managing research.
2. A standard set of system thinking perspectives (STP) (Kasser and Mackley, 2008) arranged around a perspectives perimeter which provide anchor points for viewing and discussing issues noting that combinations of the STPs are also useful.
3. A fourth template in the form of a work sheet for triggering ideas based on a combination of the STPS and the six questions “who”, “what”, “where”, when, “why” and “how” introduced by (Kipling, 1912).

Introduction

This paper introduces three new problem solving idea storage templates similar in concept to the Strengths, Weaknesses, Opportunities and Threats (SWOT) template used in management when performing strategic planning. These templates are used to facilitate storing ideas generated when considering an issue in a systemic manner. The first template helps to focus on the real problem or root cause, the second template stores ideas about how the solution will work, and the third template stores ideas pertaining to the implementation of the solution. Once the initial rush of ideas has ceased, the issue is considered from the perspective of the STPs arranged on the perimeter of a circle with the issue at the centre. The paper then introduces a fourth template for active brainstorming as a way to move around the perspectives perimeter generating ideas proactively. These ideas are also stored in the same three problem solving idea storage templates.

The modern systems engineering problem management approach

The modern systems engineering problem management approach[1] can be stated as follows:

1. Understand the whole situation before trying to solve anything.
2. Define the real problem.
3. Translate the problem into verifiable requirements.
4. Propose feasible alternative solutions (systems) to requirements.
5. Examine all feasible alternatives before selecting a solution.
6. Work with a process architect from project management to design the implementation process for producing the solution (Kasser, 2005) and then hand it over to project management to implement.
7. Test the whole system before delivering it.

This systems engineering problem management approach is often described as a sequential process in a Waterfall format. An awareness that the sequential process takes time and that the problem may change while the solution is being implemented is often added to the sequence and feedback lines representing this change are added to the Waterfall diagrams. However, what does not appear to be recognised is that there are also feed forward aspects of the process. The feed forward aspects need to be considered because the act of thinking about an apparent problem produces a wealth of ideas not only about the problem but also provides additional information that might include assumptions, symptoms, causes, solutions, factors involved in implementing the solutions, relationships, structures, functions, and physical aspects. This additional information may influence the understanding of the problem or the selection of a solution and needs to be stored in a manner that facilitates later use during the process of providing the solution to the problem. The generic process of developing an understanding of the problem situation can be stated as:

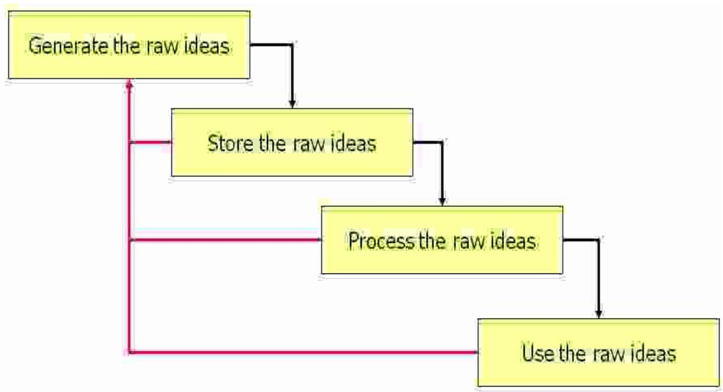

Figure 1 Developing an understanding of the situation

1. Generate the raw ideas.
2. Store the raw ideas.
3. Process the raw ideas.
4. Store the processed ideas in a form in which they can be used to determine the underlying real problem.

Again this is not a sequential process as shown in Figure 1 because ideas can be triggered by any stage of the process, and depending on the idea generating technique employed, some stages can be combined or bypassed.

[1] Adapted from Brain Mar.

Problem solving idea storage templates

The ideas produced by this process are generally documented in a problem solving template if one exists for the type of problem being solved. Problem solving templates have been used as a blackboard style multiple person access working memory (Nii, 1986) for storing information generated in the initial flow of information pertaining to the problem, the solution, and ways of implementing the solution etc. in different applications. One such reasonably well known template is the SWOT analysis template for strategic planning for a project or business venture.

The SWOT template is basically a piece of paper or whiteboard divided into four areas corresponding to the letters in the acronym used as a blackboard style multiple access working memory (Nii, 1986). As ideas are generated they are stored into the appropriate area.

Systems engineering problem solving templates. The SWOT template is only one such example. Consider the following new three blackboard style multiple person access parallel working memory templates for storing that initial burst of ideas when solving systems engineering problems introduced to a postgraduate students in systems engineering (Kasser, et al., 2008) in the manner shown in Figure 2:

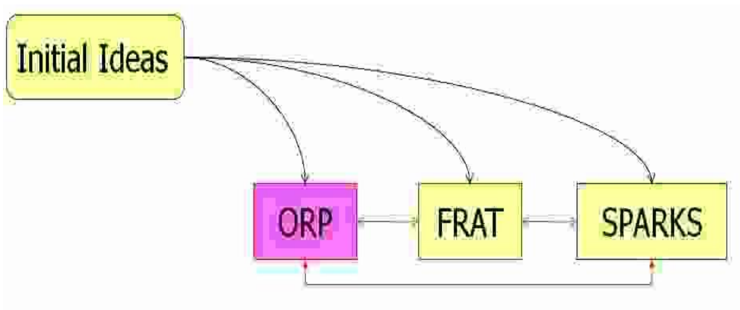

Figure 2 Initial flow of ideas into working memory templates

- The ORP template for information pertaining to the problem.
- The FRATS template for information pertaining to the solution.
- The SPARKS template for information pertaining to implementing the solution.

The ORP template is a template for helping to determine the underlying or real problem. In electrical engineering terms it helps sort out the signals from the noise. It consists of three parts:

- **O**bservations – this part contains observations relating to the need, problem and symptoms. This part of the template helps to develop understanding of situation by containing questions, answers, analyses and other relevant information. It may also contain analyses of ideas.
- **R**isks - this part contains identified reasons the activity (or activities if ideas about more than one solution are generated) to resolve the problem could fail. During the discussion of the problem, there are bound to be concepts that incorporate solutions since we often use solution language instead of problem language, namely we say “we need a car” when we should be saying “we need transportation”. By identifying risks associated with the car solution we can more readily identify solution related concepts and transform them to problem related concepts and focus on the underlying problem.
- **Real P**roblem also known as the root cause – this part contains a clear and concise statement of what has to be done to change the situation. It is gener-

ally developed after considerable discussion. The properties of a good problem statement are similar to those of a good requirement, namely the problem statement is:

- Answer implementation independent in that it does not tell one what the answer is.
- Quantitative.
- Unambiguous.
- Concise.
- Pertinent.
- Complete.

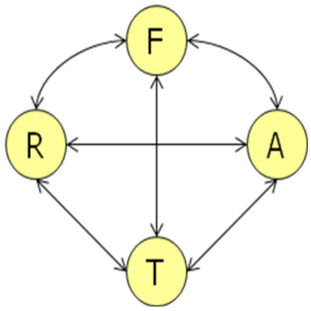

Figure 3 The FRAT approach

The FRAT template is based on Functions Requirements Answers and Test (FRAT) (Mar, 1994; Mar and Morais, 2002) which was introduced as four views of a system. However, in this instance FRAT has been adapted to store information about:

- **Functions** - the functions the solution performs (operational and functional perspectives (Kasser and Mackley, 2008)).
- **Requirements** - how well each function must be performed (quantitative perspective (Kasser and Mackley, 2008)).
- **Answers**[2] -feasible answers, how the answers will function and risks associated with that answer will be managed.
- **Tests** – the evaluation criteria for selecting answers, and descriptions of how what will be done to determine how well the answers perform the needed functions.

The SPARKS template – contains information pertaining to the implementation of the answer or solution namely the project management type of information:

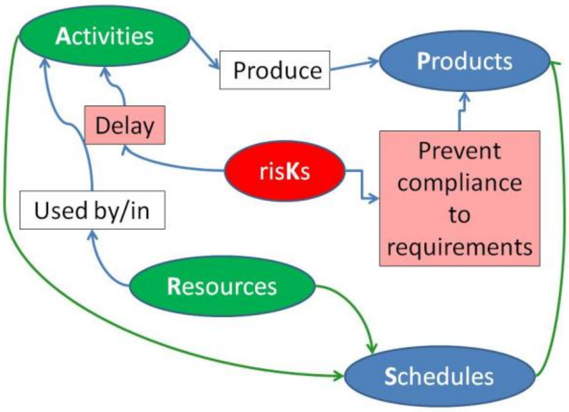

Figure 4 SPARKS

- **S**chedules – the time to be taken by the activities.
- **P**roducts – the products to be produced.
- **A**ctivities – the activities which produce the products.
- **R**esources – the resources used in or by the activities to produce the products
- ris**K**s – anything that could prevent or delay the production of the products. These may be product or process related.
- relation**S**hips between the SPARK elements as shown in Figure 4 – this is a checksum to remind users to identify which products are produced by which activities, over what period of time (schedules), which risks are associated with what product. If an item stored in the template does not have a relationship with another item, then it does not belong in the template.

[2] The word “answer” is used instead of “solution” in the template because (1) it keeps the original MAR acronym and (2) there are already two “S” characters in the SPARKS template.

The ORP, FRAT and SPARKS templates are temporary or working memories used blackboard style (Nii, 1986) to store and share information between people working on an issue. Their contents can be expanded in the later design and implementation phases of the project. At the time the issue is being examined, the focus will be on filling in the ORP template to reach the 'P'. However, during this process, ideas pertaining to the solution and its implementation will be generated and discussed and should be stored in the FRAT and SPARKS templates. Some of these ideas will reflect on the feasibility of answers or on the understanding of the underlying real problem. During each phase of the systems engineering process, various tools are used to generate ideas and information depending on the domain and the problem being faced. The ORP, FRAT and SPARKS templates can provide temporary storage of information which is then used to produce the traditional systems engineering process products. For example

- The combination of "F" and "R" in FRAT feeds into requirements documents.
- The content of the SPARKS template gets incorporated into the systems engineering management plan (SEMP).

The relationship between the ORP, FRAT and SPARKS templates is shown in Figure 5. The real problem in the "P" of ORP feeds the "F" and "R" of FRAT. The selected "A" of FRAT is implemented using SPARKS. If the "T" in FRAT is complicated enough a separate SPARKS template may be employed to store information pertaining to the implementation of the Test and Evaluation activities. The feedback lines from the SPARKS and FRAT templates to the ORP template contains information pertaining to the identification of the real problem. The "R" in the ORP template contains information pertaining to risks associated with all the answers that come to mind while discussing the issue. The "R" in the SPARKS template contains the risks associated with the selected answer/solution being implemented.

Systems thinkers will observe that the transformation from need to answer in a project takes place in each stage of the waterfall representation and Figure 5 can be used to represent the activities performed in the systems engineering process. For example:

- The requirements phase focuses on the ORP template with some data in the FRAT and SPARKS template, e.g. information in the FRAT and SPARKS

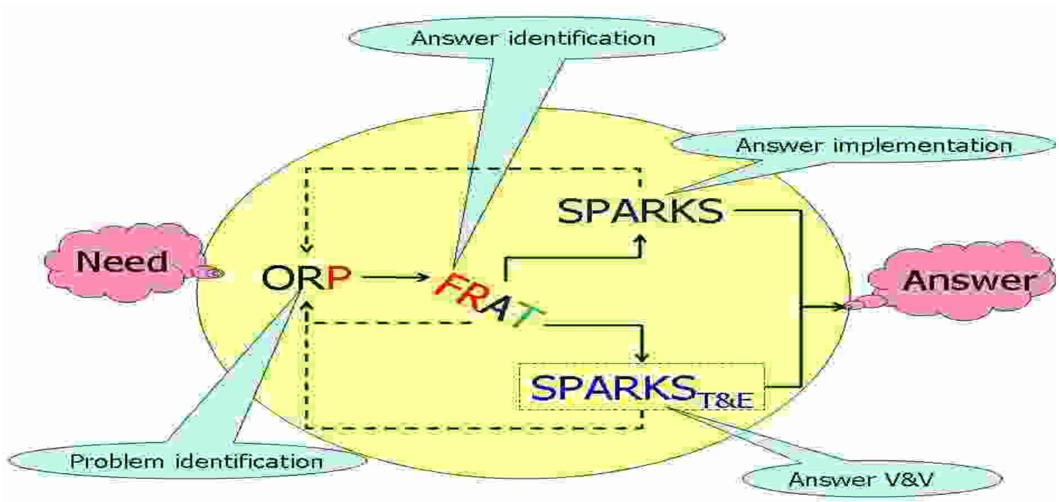

Figure 5 The relationship between the three problem solving templates

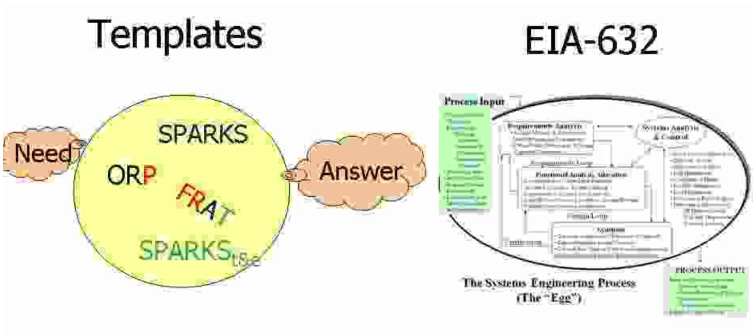

Figure 6 Similarity between the three templates and EIA-632

templates are used to determine the feasibility of requirements before they are accepted for implementation.

- The design stage focuses on the FRAT template. Yet information in the SPARKS template is used to choose between design alternatives if schedule and cost are evaluation factors. Similarly, if analysis of the "A" shows that there is a risk that the requirement cannot be met, this information goes back to the "R" in the ORP template and the requirement may have to be negotiated.
- The activities performed in generating the information that populates the ORP, FRAT and SPARKS databases in any phase of the systems development life cycle (SDLC) should be managed according to a plan generated from information in the SPARKS template for the previous phase of the SDLC.
- The similarity between the use of the three problem solving idea storage templates and the EIA-632 Egg diagram is shown in Figure 6. The EIA-632 drawing seems to show "what" needs to be done, while the three problem solving idea storage templates are associated with the "how", namely the activities in the systems engineering process.

The perspectives perimeter

Consider the act of thinking about a problem. In general, the thinking process performs a sequence of tasks, each of which views the issue from a different perspective on the perimeter of the circle in the metaphoric representation depicted in **Figure 7**. Note however, that some minds[3]:

- Seem to be fixed at one point on the perimeter and observe the issues from a single fixed perspective.
- Seem to only range over a limited part of the perimeter and view the issues from a limited number of perspectives.
- Seem to range over the entire perimeter and view the issues from the set of perspectives but do not seem to do so in a systemic and systematic manner.

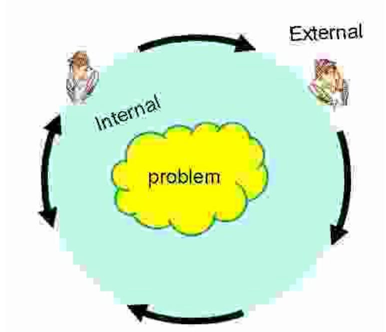

Figure 7 The perspectives perimeter

[3] The continuum STP suggests that this might be situational for an individual for various reasons and the same mind in different situations may view problems in different ways according to the list.

- Seem to range over the entire perimeter and view the issues from the set of perspectives and seem to do so in a systemic and systematic manner.

Since there are no standard stopping points along the perspectives perimeter, each time communications between two parties takes place time is spent ensuring that both parties to the communication are viewing the issue from the same perspective (stopping point on the perspectives perimeter). This situation can be observed by the use of phrases such as "are we on the same page?" and "are we on the same wave-length?" etc. A standard set of perspectives or "anchor points" are needed to facilitate communications.

The systems thinking perspectives

Traditional systems engineering problem solving has focused on analysis which has three steps as shown in Table 1 (Ackoff, 1991). Systems thinking on the other hand focuses on the system in its context and also has three steps as shown in Table 1 but they are slightly different (Ackoff, 1991). Indeed, comparing the two sets of steps performed in analysis and systems thinking in the manner shown in Table 1, one can see that the focus of analysis or reductionism is to look inwards (a white box approach) while the focus of systems thinking is to look outwards from the system (a black box approach). Both the white box and black box approaches have their place in developing an understanding of a system (Hitchins, 1992) page 14). Multiple perspectives are needed, but which perspectives should be used?

Table 1 Analysis and Systems Thinking

Analysis (Machine Age)	Systems Thinking (Systems Age)
1. Take apart the thing to be understood	1. A thing to be understood is conceptualized as a part of one or more larger wholes, not as a whole to be taken apart;
2. Try to understand how these parts worked	2. An understanding of the larger system is sought;
3. Assemble an understanding of the parts into an understanding of the whole.	3. The system to be understood is explained in terms of its role or function in the containing system.

A number of perspectives or models of hardware and software systems have been proposed over the last twenty years or so such as (Ward and Mellor, 1985; Hately and Pirbhai, 1987) the (DoDAF, 2004) and others. Other "systems" views include the Soft Systems Methodology (Checkland, 1993), the need for considering operational and functional relationships and feedback loops in systems dynamics (Senge, 1990; Clark, 1998). A literature review showed that (Richmond, 1993) seems to be the first attempt at providing a consistent set of perspectives with his introduction of seven streams of system thinking. (Kasser and Mackley, 2008) described a similar set of streams or viewpoints called System Thinking Perspectives (STP) which can be used to provide stopping points and anchor points on the perspectives perimeter for thinking and communications in a systemic manner. These anchor points, shown in Figure 8 are the:

- **Operational perspective.** The operational perspective is the manner in which the system operates or will operate (in the case of a new system). The system is viewed as a black box.

- **Functional perspective.** The functional perspective describes the functions or activities performed by the system without reference to which of the elements of the system perform those functions. This corresponds to the traditional 'closed system' view and includes the cause and effect feedback loops. The system is viewed as a white box.

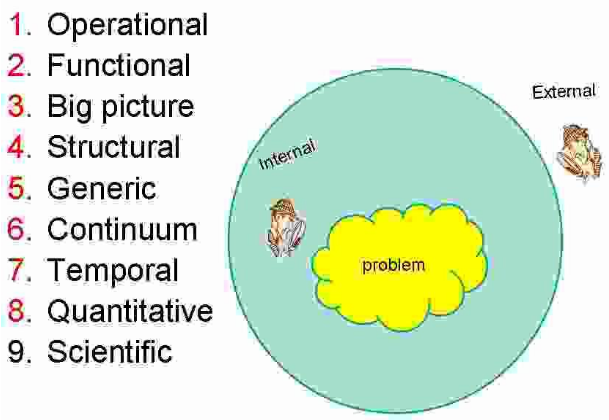

Figure 8 System Thinking Perspectives Anchor Points

- **Big picture perspective**. The big picture perspective provides a view of the forest rather than the trees. It views the system within the context of its containing system – its environment, the closely coupled adjacent systems with which it interacts and any loosely coupled more distant systems.
- **Structural perspective.** The structural perspective views the systems' architecture and the internal subsystem partition boundaries and any effects on the system due to its internal structure. This perspective incorporates the traditional physical, technical and architectural framework views.
- **Generic perspective.** The generic perspective looks for similarities between the system and other systems in the same or other domains, in the present or in the past.
- **Continuum perspective.** The continuum perspective recognizes that (1) things are not necessarily 'either-or', there may be states in between and (2) changing conditions may cause movement along the continuum.
- **Temporal perspective.** The temporal perspective looks at how the system behaves over time.
- **Quantitative perspective.** The quantitative perspective relates to the big picture and to the operational and functional perspectives to develop the performance requirements. According to (Richmond, 1993), the quantitative perspective however is not about the need to measure everything, "it is more the recognition that numbers must be useful, not necessarily perfect and need not be absolute". The quantitative STP leads to the question "how will we know the system solves the problem or meets our needs?" This generates both the performance requirements and the acceptance criteria for the system should bring Test and Evaluation (T&E) into the SDLC at the beginning of the project.
- **Scientific perspective.** Whereas the other descriptive perspectives are used to examine (and document) a system, problem or situation, this prescriptive perspective covers the formulation and testing of hypothetical candidate representations of the system to meet the need that will be constructed in the design and implementation phases of the system development life cycle (SDLC), and the construction of the tests used to validate the representation by T&E function of systems engineering.

Combinations of perspectives. Since the boundaries of the STPs are artificial for the benefit of applying and communicating about systems thinking, combinations are also useful (Kasser and Mackley, 2008).

Active brainstorming

As mentioned above, when a problem or issue is first thought about there is an initial flow of ideas, which in the systems engineering context can be stored in the ORP, FRAT and SPARKS temporary working memory templates shown in Figure 2. These ideas can be spontaneous or generated within the context of a brainstorming or similar idea producing session. Brainstorming is a technique for generating ideas that has a number of variations. However all the variations suffer from a number of defects which include:

- Being a generally passive approach because they are based on waiting for the ideas to be generated before writing them on the whiteboard[4].
- Being prone to capture by the most opinionated person in the brainstorming session.
- Being unstructured, while allowing free range of ideas, tends to fail to focus of issues pertinent to the session.
- Being less productive of ideas when performed in a team than when performed by an individual, while providing a social setting.

Active brainstorming on the other hand can produce more ideas relating to the problem or issue in a systemic and systematic manner. It does this in a systematic manner by examining the issue from each of the STPs and triggering ideas by asking questions beginning with or incorporating the words “who”, “what”, “where”, “when”, “why” and “how” (Kipling, 1912). However, since the boundaries of the STPs are artificial for the benefit of applying systems thinking, the understanding gained from one of the STPs might generate a scientific perspective (hypothesis or solution) documented in a different STP or even a mixture of them.

Active brainstorming uses Table 2 as a template to trigger to generate ideas from each STP as follows. When the session begins, there will be a natural tendency to generate spontaneous ideas in an unstructured manner, particularly in a session containing newcomers to the technique. The ideas will include answers, further questions, names of people to contact for more information, and the need for further analysis. The facilitator should not attend to stem the flow and ask the participants to wait for the appropriate question[5]. The facilitator should ensure the ideas are documented in the working memory templates namely the ORP, FRAT or SPARKS templates when examining systems engineering issues. Ideas should not be stored in the active brainstorming template shown in Table 2 during the session since doing so tends to divert the session into a discussion (argument) as to which area to store the idea, and interferes with the flow of ideas.

[4] There are some variations which trigger ideas using ‘what’ and ‘why’ questions.
[5] Which is one reason the ideas are not documented in the STP matrix of Table 2.

Table 2 Active Brainstorming Idea Triggering Worksheet

STP Matrix	1	2	3	4	5	6
	Who?	What?	Where?	When?	Why?	How?
Operational						
Functional						
Big picture						
Structural						
Generic						
Continuum						
Temporal						
Quantitative						
Scientific						

Once the initial flow of ideas stops, the facilitator starts the true active brainstorming process using the active brainstorming template at the operational perspective row of Table 2 and poses questions from column 1 beginning with or related to the word "who". The responses are written down in the working memory templates as depicted in Figure 9. When the ideas stop flowing, the facilitator moves on to the next question in the row. At the end of the flow of ideas from the last question in a row, the facilitator moves down to the first question in the next row. Expect a question in posed one area of Table 2 to sometimes generate ideas that pertain to other areas. If no ideas come forth immediately since not all areas are pertinent to every problem, the facilitator should skip to the next question. Examples of typical questions posed from the operational and generic STPS are shown in Table 3. The facilitator should ensure that the discussions triggered by each question are terminated when the flow dries up or starts generating redundant information.

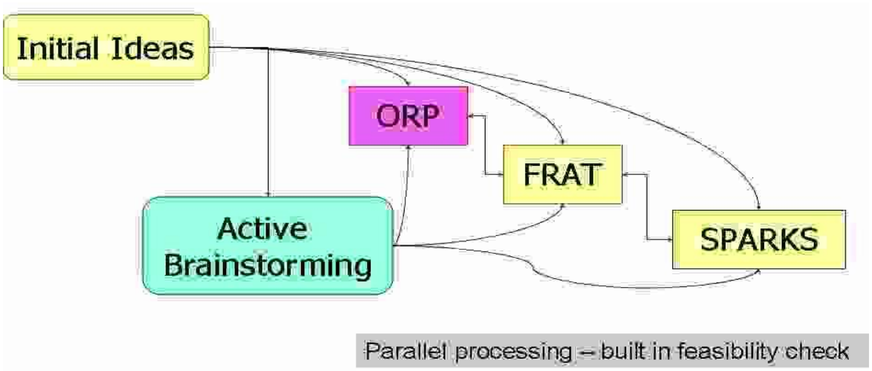

Figure 9 Active brainstorming triggers more ideas after the initial flow has dried up

Results in the classroom

Active brainstorming was introduced to students as part of teaching systems and critical thinking in a new postgraduate immersion course in systems engineering in 2008 and 2009 (Kasser, et al., 2008), other classes and various workshops. Student and workshop participant feedback on the tool has been very positive. The post course survey contained one question which asked to students to state the best thing in the course and another question which asked them to state the three most useful things they learnt. Invariably, active brainstorming and the templates showed up in the answers to those questions.

Table 3 Typical perspective questions

Operational perspective	Generic perspective
• Who is going to operate it? • What do they need to operate it? • Under what conditions will it be operated? • Where will they operate it? • When will they operate it? • Why will they operate it? • How will they operate it? • How will they gain access to it?	• Who has had a similar problem? • What is this similar to? • What applies to both situations? • Where can I find a similar situation? • When was there/will there be a similar situation? • Why is this similar/different? • How is this similar/different?

Examples of active brainstorming

Two examples of active brainstorming have been written up at this time; one herein. The other is an example of active brainstorming in early stage systems engineering that applies the technique to conceptualising a whole functional and purposeful solution to the problem of vertically integrating Taiwan's Small and Medium Enterprises (SME) with minimal disruption to the working of individual SMEs given in (Kasser and Peng, 2009).

The following example of active brainstorming is provided by mapping a few of the questions that were asked in conceptual early stage systems engineering of the LuZ Solar Electrical Generating System in the early 1980's (Kasser, 2007). At the concept phase in its system life cycle, as the first of its kind, SEGS-1 initially only existed as a vague concept and met (Donaldson and Siegel, 1997)'s definition of a (very) high risk project. SEGS-1 was installed in the Mojave Desert in California and the Research and Development was in performed in Jerusalem. SEGS-1 was intended to generate electrical power from the sun by focussing the sun's rays on about 600 parabolic mirror trough reflector collectors each about 40 meters long. The operation of each parabolic trough reflector would be monitored and controlled by a microprocessor based local controller (LOC). Each LOC would control a motor that would position the parabolic mirror, receive information about the angle of elevation of the mirror and the temperature of the oil in the pipe positioned at the focus of the trough. Oil would be pumped through the piping, and as long as the LOC would keep the reflector pointed at the sun within an accuracy of ±0.2 degrees, the oil would be heated. The hot oil would be pumped around the field and into a heat exchanger to generate steam. The steam would then drive a turbine that generated up to 15 Megawatts of electrical power. Although it would be a complicated system, it would still have a conversion efficiency of about 40%, greater than any alternative method of harnessing solar energy at the time. A few of questions and responses that were posed are shown in Table 4 as if they had been posed an active brainstorming session.

Table 4 Extract from Typical Active Brainstorming Session

STP	Question	Answer	Stored in	
Operational	What initiates the deployment?	Manual and automatic	A	FRAT
Functional	What functions are the	Deploying, tracking, stowing, idle	A	FRAT

STP	Question	Answer	Stored in	
	LOCs performing?	and resting		
Functional	What stops the system locking onto the neighbouring Heliostat tower instead of the sun?	Functionality to calculate the position of sun at that time of the day, compare it with the actual pointing angle of the mirrors and make sure they are within ±0.2 degrees?	R	FRAT
			R	ORP
Big Picture	What must the system do?	Generate as much energy from the sun as it can.	P	ORP
Big Picture	What can inhibit energy production?	Clouds, rain, dirt on mirrors, loss of vacuum in heat flow elements	O	ORP
Big Picture	What is the electro-magnetic interference situation?	Don't know. It is a large field with long cables.	R	ORP
		Use shielded cables and bury them in the ground	A	FRAT
Structural	What are the conceptual subsystems?	LOCs, central processor, power distribution units	A	FRAT
Generic:	What is this similar to?	(1) A constellation of satellites and their central control station. (2) The neighbouring Heliostat system which could provide ideas for control displays	A	FRAT
		Action item: arrange visit to Heliostat control centre.	A	SPARKS
Continuum	What are the alternative conceptual solutions?	Central processing - minicomputer and dumb LOCs, distributed processing – microcomputer and intelligence in the LOCs.	A	FRAT
Temporal	When does it need to operate?	Daily when the sun shines.	A	FRAT
Temporal	When does it have to be installed?	In two years	S	SPARKS
Quantitative	How accurate must the mirror pointing be?	±0.2 degrees (based on other calculations)	A	FRAT
Quantitative	What is the spec on the vibration of the mirror, given the sun sensor has to be mounted on it (track ±0.2 degrees)?	Don't know	R	ORP

Summary

This paper has shown one way of how idea generation can be achieved in a systemic and systematic manner by thinking about an issue from the set of standard STPs depicted in Figure 8 (systemic) using the active brainstorming template after the initial generally unstructured flow of ideas dries up (systematic) to store the ideas in the OPR, FRAT and SPARKS problem solving templates. These three problem solving idea storage templates provide temporary storage for ideas generated when considering an issue in a natural manner without trying to sort and reject ideas when generated. They also provide temporary storage during discussions about the ideas. Data in the templates can be moved into traditional systems engineering process-products and management documents as and when appropriate. Active brainstorming based on a combination of the STPs and the (Kipling, 1912) questions provides a fourth template for triggering ideas in a proactive manner.

Conclusion

Results in the classroom and workshops indicate that these templates should provide the systems engineer with a useful mind tool.

Author's biography

Joseph Kasser has been a practicing systems engineer for 35+ years and an academic for about 10 years. He is an INCOSE Fellow, the author of "A Framework for Understanding Systems Engineering" and "Applying Total Quality Management to Systems Engineering" and many INCOSE symposia papers. He is a recipient of NASA's Manned Space Flight Awareness Award (Silver Snoopy) for quality and technical excellence for performing and directing systems engineering and other awards. He holds a Doctor of Science in Engineering Management from The George Washington University, and is a Certified Manager. He has also served as the initial president of INCOSE Australia and Region VI Representative to the INCOSE Member Board. He gave up his positions as a Deputy Director and DSTO Associate Research Professor at the Systems Engineering and Evaluation Centre at the University of South Australia in early 2007 to move back to the UK to develop the world's first immersion course in systems engineering as a Leverhulme Visiting Professor at Cranfield University. He is currently a principal at the Right Requirement Ltd. in the UK and a Visiting Associate Professor at the National University of Singapore.

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