27th Annual INCOSE International Symposium (IS 2017)

Adelaide, Australia, July 15-20, 2017

The myths and the reality of problem-solving

Joseph Kasser
The Right Requirement
Adelaide, Australia; KungMin, China
jkasser@iee.org

Yang-Yang Zhao
Norwegian Institute of Systems Engineering
University College of Southeast Norway
yangyang.zhao@hbv.no

Abstract. Observations of the ubiquitous problem-solving process have identified the existence of six myths and their corresponding realities. These myths hamper the problem-solver and an understanding of the reality will help the problem-solver to solve problems in a more effective and innovative manner. This paper documents and discusses six myths and their corresponding realities.

Introduction

When faced with complex and insolvable problems, the best way to approach them is to absolve the problems or bypass them by finding an alternative paradigm. The search for an alternative paradigm begins with a change of perspective. Perceptions from the *Generic* perspective indicate that in mathematics, complex numbers consist of a real and an imaginary component. An inference from the *Scientific* perspective in the problem-solving domain using the (*Generic*) similarity to the components of a complex number in mathematics is that the complexity in the problem-solving domain may contain an imaginary or mythical component. This led to the research question of "*are there myths in the problem-solving process that hinder the solving of complex problems and increase the complexity of the problem solving process?*" Research based on this question led to the findings documented in a set of three papers. This paper being the first, documents observations of the ubiquitous problem-solving process from the *Operational* and *Functional* Holistic Thinking Perspectives (HTP) (Kasser, 2015) which have identified the existence of six myths and their corresponding realties. Problem-solving a key function in management and systems engineering, is hampered by these myths which increase the complexity of the problem solving process. An understanding of the reality will help to solve problems in a more effective manner.

The myths and the reality

Observations of the problem-solving process from the *Operational* and *Functional* Holistic Thinking Perspectives (HTP) (Kasser, 2015) have identified the following myths associated with problem-solving, namely:

1. The myth that the word 'problem' has an unambiguous meaning.
2. The myth that there is always a single correct solution.
3. The the myth that the problem solving process starts with a defined problem.
4. The myth that a single pass through the problem-solving process will [always] provide an optimal solution to the problem.
5. The myth that a single problem-solving-problem approach fits all types of problems.
6. The myth that all problems can be solved.

An understanding of the reality will help to solve problems in a more effective manner.so, consider each myth and the corresponding reality.

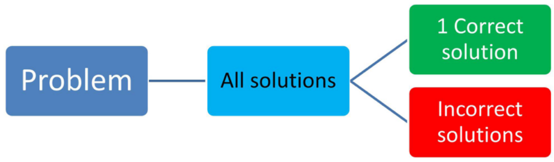

Figure 1. The single correct solution

The word 'problem' has an unambiguous meaning

The myth is that the word 'problem' has an unambiguous meaning, The reality is that the word 'problem' has at least three different meanings in the literature since the word 'problem' has been defined or used to mean (Dictionary.com, 2013):

1. A question proposed for solution or discussion.
2. Any question or matter involving doubt, uncertainty, or difficulty. For example, this type of problem might be:
   - ***An undesirable situation.*** You might hear someone end a sentence with, *"... and that's the problem*" when they mean, *"... and that's the undesirable situation*".
   - ***The underlying cause of an undesirable situation,*** usually a failure of some kind. For example, one may hear someone say, *"my phone stopped working; the problem was a discharged battery"*. In reality, they mean that the cause of the phone stopping working was a discharged battery; the symptom or effect was that the phone stopped working.
3. The need to determine the necessary sequence of activities to transform an initial undesirable situation into a desirable situation[1].

The fixation on a single correct solution

The myth is that there is always a single correct solution. The reality is that most of the time there is more than one acceptable solution.

In school, generally, we are taught to solve problems by being given a problem and then asked to find the solution as shown in Figure 1. The assumption being that there is a well-defined problem with a single well-defined correct solution. This is a myth that does not apply in the real world.

The reality is that systems engineering deals with undesirable situations that generally have more than one equally acceptable solution. For example, you are hungry which is generally an undesirable situation. The problem is to figure out a way to remedy that undesirable situation by consuming some food to satisfy the hunger. There are a number of solutions to this problem including cooking something, going to a restaurant, collecting some takeaway food, and telephoning for home delivery. Then there is the choice of what type of food; Italian, French, Chinese, pizza, lamb, chicken, beef, fish, vegetarian etc. Now consider the vegetables, sauces and drinks. There are many solutions because there are many combinations of types of food, meat, vegetables and method of getting the food to the table. Which solution is the correct one? The answer is that the correct solution is the one that satisfies your hunger in a timely and affordable manner[2]. If several of the solution options can perform this function and you have no preference between them, then each of them are just as correct as any of the other ones that satisfy your hunger. The words 'right solution' or 'correct solution' should be thought of as meaning 'one or more acceptable solutions' as shown in Figure 2.

1 Once the necessary sequence of activities is determined, the subsequent problem is to plan the process to perform the necessary sequence of activities. Once the plan is created, the subsequent problem is to realize the desirable situation by carrying out the plan.

2 and does not cause any gastric problems.

Conventional systems engineering and project management wisdom based on the mythical need for a single correct solution suggests that when a decision cannot be made because two choices score almost the same in the decision making process, the decision maker should perform a sensitivity analysis by varying the parameters and/or the weighting to see if the decision changes. By recognizing the reality that there may be more than one acceptable solution, the "don't care which solution option is chosen" may eliminate the need for the sensitivity analysis.

Figure 2 can also be used to explain the dictionary definitions of 'satisfy' and 'satisfice' where:

- ***Satisfy*** means provide solutions that are optimal.
- ***Satisfice*** means provide solutions that are acceptable.

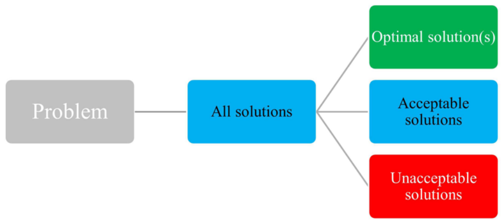

Figure 2. The full range of solutions

The incomplete problem-solving process

The myth is that the problem solving process starts with a defined problem. The reality is that the problem needs to be explored, and understood before it can be defined (Fischer, et al., 2012).

In school, generally, we are taught to solve problems by being given a problem and then asked to find the solution as shown in Figure 1. The assumption in this situation is that someone has already defined the problem. While in the real world, *"Problems do not present themselves as givens; they must be constructed by someone from problematic[3] Situations which are puzzling, troubling and uncertain"* (Schön, 1991). Accordingly, in reality, the problem-solving process must start with steps that define the problem. The extended holistic problem-solving process accordingly begins with an undesirable situation which has to be converted to a Feasible Conceptual Future Desirable Situation (FCFDS) and ends when the undesirable situation no longer exists as shown Figure 3 (Kasser, 2015). In this extended holistic problem-solving process, an entity becomes aware of an undesirable situation. A project is authorized to do something about the undesirable situation[4]; the problem. Systems engineers in their role as problem solvers:

1. Collect and analyse the information about the situation.
2. Gain an understanding of the situation.
3. Determine what makes the situation undesirable.
4. Determine if someone has faced a similar problem, what they did about it, and the similarities and differences between the other situation and the current undesirable situation and how those affect the problem and solution in this instance.

3 or undesirable
4 Often made up of a number of related factors

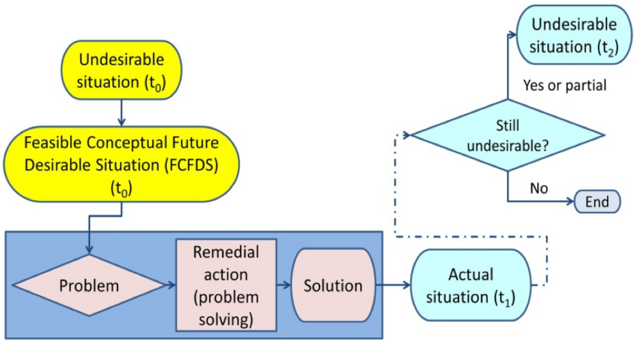

Figure 3. The extended holistic problem-solving

5. Gain stakeholder consensus on the cause or causes of the undesirability of the situation by an understanding of human nature as well as the problem, implementation and solution domains. However, in the current paradigm, this may not be feasible.
6. Conceptualize and then create a vision of a FCFDS; the solution system operating in its context.
7. Plan the transition from the undesirable situation to the FCFDS.
8. Realise the solution system operating in the FCFDS. If the situation is complex, this remedial action transformation process often takes the form of a System Development Process (SDP).
9. Determine how much of the undesirably in the actual situation at the time the solution system is deployed in the FCFDS has been remedied. If the undesirable situation is remedied, then the process ends; if not, the process iterates from the new undesirable situation at t_2.

The descriptions of the extended holistic problem-solving process in Figure 3 are notional. That means the description is the way things should be done. Perceptions of the real world indicate that not all projects perform all the activities described in the notional process. Figure 3 includes the time dimension, because the remedial action or problem-solving process takes time[5], and during that time the original undesirable situation which existed at time t_0 may have changed, which means that the solution system operating in the context of the actual situation at time t_1 may not have remedied the changed undesirable situation as it exists at time t_1 because of one or more of the following:

- The solution system operating in its context does not remedy the entire original undesirable situation.
- New undesirable aspects have shown up in the situation during the time taken to develop the solution system.
- Unanticipated undesired emergent properties of the solution system and/or its interactions with its adjacent systems may produce new undesirable outcomes.

- Replace the problem-remedial action solution block in Figure 3 by the more detailed *Functional* perspective of the systems engineering decision-making/problem-solving process based on Hitchins (Hitchins, 2007) page 173) shown in Figure 4[6]. Hitchins' version of the systems engineering decision-making/problem-solving process stops before the realisation and validation steps because Hitchins holds that those steps are engineering not systems engineering.

5 For large scale systems the development process can take years.
6 Hitchins' version process has been modified to add milestones at the beginning and end of the process.

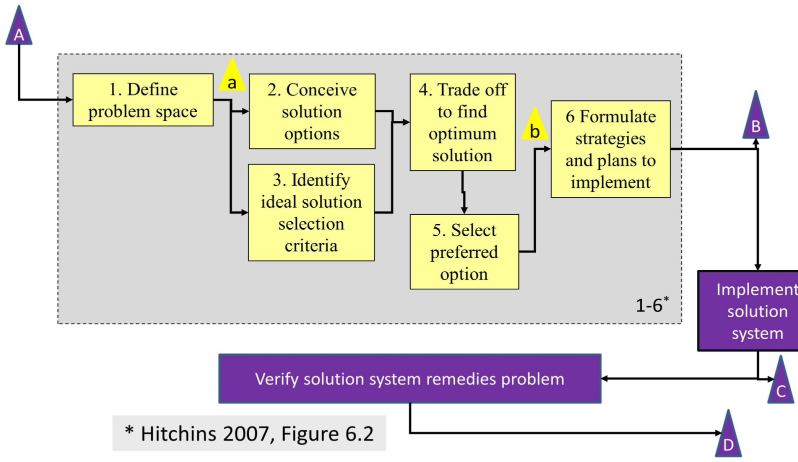

Figure 4. Modified Hitchins' view of the problem-solving decision making process

A single pass through the problem-solving process leads to an optimal solution to the problem

The myth is that a single pass through the problem-solving process leads to an optimal solution to the problem. The reality is that some types of problems require more than one pass to solve. Figure 3 is shown as a linear process with a start and an end. It reflects the myth that a single pass through the problem-solving process will normally remedy the undesirable situation and that the need for multiple passes are the exceptions.

The reality is that in systems engineering dealing with complex problems, the single pass through the problem-solving process is the exception and the multiple pass through the problem-solving process is the reality.

A single problem-solving approach fits all types of problems

The myth is that a single problem-solving problem approach fits all types of problems. The reality is different types of problems require different problem-solving approaches even though at the conceptual level the process is identical.

The current problem-solving paradigm seems to imply that a single problem-solving approach fits all types of problems as represented in Figure 4. The reality is that the different types of problems need different problem-solving approaches; namely the functions performed in each of the boxes in Figure 4 are different.

Consider the following aspects of problems:

1. Research problems.
2. Intervention problems.
3. Level of difficulty of the problem.
4. Technological Uncertainty of the problem.
5. Structure of the problem.

Research problems. This type of problem manifests when the undesirable situation is the inability to explain observations of phenomena or the need for some particular knowledge. In this situation, applying the Problem Formulation Template (Kasser, 2015):

- *The undesirable situation* is the inability to explain observations of phenomena or the need for some particular knowledge.

- *The FCFDS is* the ability to explain observations of phenomena or the particular knowledge.
- *The problem* is how to gain the needed knowledge.
- *The solution* is the knowledge often in the form of the supported hypothesis.

The problem-solving process in this instance, is commonly known as the Scientific Method, and works forwards from the current situation in a journey of discovery towards a future situation in which the knowledge has been acquired. The Scientific Method:

- Is a systemic and systematic way of dealing with open-ended problems.
- Has been stated in different variations as the following sequence of activities:
  1) Observe an undesirable situation.
  2) Perform research to gather preliminary data about the undesirable situation.
  3) Formulate the hypothesis to explain the undesirable situation.
  4) Plan to gather data to test the hypothesis. The data gathering may take the form of performing an experiment, using a survey, reviewing literature or some other approach depending on the nature of the undesirable situation and the domain.
  5) Perform the experiment or otherwise gather the data.
  6) Analyse the data (experimental or survey results) to test the hypothesis.
  7) If the hypothesis is supported, then the researcher often publishes the research. If the hypothesis is not supported, then the process reverts to Step 2.
- Uses inductive reasoning to create the hypothesis and deductive reasoning to support it.

In the real world, the hypothesis is often created from some insight or a “hunch” in which the previous steps are performed subconsciously. The researcher then designs the data collection method, collects and examines the data to determine if the hypothesis is supported or refuted.

Intervention problems. *This type of problem manifests when a current real-world situation is deemed to be undesirable and needs to be changed over a period of time into a FCFDS. In this situation:*

- *The undesirable situation:* may be a lack of some desirable functionality that has to be acquired or created, or some undesirable functionality that has to be eliminated.
- *The FCFDS:* one in which the undesirable situation no longer exists.
- *The problem:* how to realize a smooth and timely transition from the current situation to the FCFDS minimizing resistance to the change.
- *The solution:* the transition process to move from the undesirable situation to the FCFDS together with the solution system operating in the situational context.
- *The problem-solving* process first uses the research problem-solving process working forwards to produce concepts of a number of FCFDS that will remedy the current undesired situation, selects the best one, and then works backwards to the current problematic or undesirable situation determining conceptually how the transition was implemented by working back from the answer (Ackoff, 1978; Hitchins, 1992) page 120) (the FCFDS). The information created in this backwards looking process is then used to document the:
  - FCFDS.
  - Realization plans documented as a forward process starting from the current situation and ending with the deployment of the FCFDS.

The decision makers or problem-solvers are faced with an undesirable situation. Once given the authority to proceed:

- They use the research problem-solving process to conceptualize a vision of the solution system operating in the FCFDS which becomes the target or goal to achieve.
- Then the intervention problem they face is to create the transition process and the solution system that will be operational in the FCFDS.
- They then work backwards from the FCFDS to the present undesirable situation creating the transition process.
- They then document the process as a sequential process working forwards from the present undesirable situation to the FCFDS.

Both the research and intervention problem-solving processes contain a series of sub-problems[7] each of which have to be solved in turn to arrive at the solution.

Level of difficulty of the problem. *Ford introduced four categories of increasing order of difficulty for mathematics and science problems: easy, medium, ugly, and hard (Ford, 2010). These categories may be generalized and defined and solved by a slightly different problem-solving process as follows:*

1. ***Easy:*** problems that can be solved in a short time with very little thought.
2. ***Medium:*** problems that:
    1) Can be solved after some thought.
    2) May take a few more steps to solve than an easy problem.
    3) Can probably be solved without too much difficulty, perhaps after some practice.
3. ***Ugly:*** problems are ones that will take a while to solve. Solving them:
    1) Involves a lot of thought.
    2) Involves many steps.
    3) May require the use of several different concepts.
4. ***Hard:*** problems usually involve dealing with one or more unknowns. Solving them:
    1) Involves a lot of thought.
    2) Requires some research.
    3) May also require iteration through the problem-solving process as learning takes place (knowledge that was previously unknown becomes known).

Classifying problems by level of difficulty is difficult in itself because difficulty is subjective since one person's easy problem may be another person's medium, ugly or hard problem. For example, consider an undesirable situation faced by Fred who arrives in a foreign country for a visit and lodges in an apartment where he has to do his own cooking. As Fred cannot speak the local language, he is in a number of undesirable situations. Consider the one in which the kitchen has a gas cooker but he has no way to ignite the gas. The corresponding desirable situation is that Fred has something to ignite the gas[8]. Assuming Fred has local currency or an acceptable credit card, is the difficulty of the problem of purchasing something that will ignite the gas easy, hard or something in between? The answer is 'it depends'. Classifying the difficulty of the problem depends on a number of issues including:

- If Fred has faced this problem before in the same country? If so, what did he do then?
- If Fred knows where to purchase matches or a gas lighter.
- If Fred even knows how to say "matches" or "gas lighter" in the local language. If he does not know the words, he may not be able to ask anyone to provide the items.

---

7 Which can in turn be research or intervention.
8 Note the use of functional language instead of 'matches' in solution.

Thus as far as Fred is concerned, the problem is:

- *None existent:* if Fred already has matches, a gas lighter, a cigarette lighter or another instrument with which to light the gas.
- *Easy:* if Fred knows where to purchase matches or a gas lighter and knows the local words.
- *Medium:* if Fred knows where to purchase matches or a gas lighter and does not know the local words. After all, he can go to the store or relevant location and look around until he sees matches or lighters on a shelf and then purchase them.
- *Hard:* if Fred does not know where to purchase matches or a gas lighter and does not know the local words. The problem is hard because two unknowns have to become known for a solution to be realized.

The different levels of technological uncertainty. *Shenhar and Bonen characterised projects in the following four-level scale of technological uncertainty (Shenhar and Bonen, 1997):*

- *Type A: Low Technological Uncertainty.* Typical projects in this category are construction, road building, and other utility works that are common in the construction industry that require one design cycle or pass through the Waterfall development methodology.
- *Type B: Medium Technological Uncertainty.* Typical projects of this kind tend to be incremental improvements and modifications of existing products and systems.
- *Type C: High Technological Uncertainty.* Typical projects of this kind tend to be high-tech product development and Defence state-of-the-art weapons systems.
- *Type D: Super High Technological Uncertainty.* These projects push the state-of-art and are few and far between in each generation. A typical example from the 20th century is the NASA Apollo program which placed men on the moon.

Each Type requires a different approach to solving the associated problems.

The Structure of the problem. *Perceived from the* Continuum *perspective, problems lie on a continuum which ranges from [1] 'well-structured' through [2] 'ill-structured' to [3] 'Wicked' where the solution to each type of structured problem is achieved by a different version of the problem-solving process. Consider each of them.*

1. ***Well-structured problems*** are problems where the existing undesirable situation and the FCFDS are clearly identified. These problems may have a single solution or sometimes more than one acceptable solution. Examples of well-structured problems with single correct solutions are:
   - Mathematics and other problems posed by teachers to students in the classroom. For example, in mathematics, 1+1=2 every time.
   - Making a choice between two options. For example, choosing between drinking a cup of coffee and drinking a cup of tea. However, the answer may be different each time the problem is faced..

   Examples of well-structured problems with several acceptable but different solutions are:

   - What brand of coffee to purchase? Although the solution may depend on price, taste and other selection criteria, there may be more than one brand (solution) that meets all the criteria.
   - Which brand of automated coffee maker to purchase?

2. ***Ill-structured problems***, sometimes called 'ill-defined' problems or 'messy'[9] problems are problems where either or both the existing undesirable situation and the FCFDS are unclear (Jonassen, 1997). Examples of ill-structured complex problems are:
   - The initial feeling that something is wrong and needs to be changed which triggers the problem-solving process.
   - Where to dispose of nuclear waste safely? This is where the FCFDS is unclear.
   - How to combat international terrorism? This is where different stakeholders perceive different causes of the situation and different ways of dealing with the causes.
3. ***Wicked problems*** are extremely ill-structured problems[10] first stated in the context of social policy planning (Rittel and Webber, 1973). Wicked problems (Shum, 1996):
   - Cannot be easily defined so that all stakeholders cannot agree on the problem to solve.
   - Require complex judgements about the level of abstraction at which to define the problem.
   - Have no clear stopping rules (since there is no definitive 'problem', there is also no definitive 'solution' and the problem-solving process ends when the resources, such as time, money, or energy, are consumed, not when some solution emerges).
   - Have better or worse solutions, not right and wrong ones.
   - Have no objective measure of success.
   - Require iteration - every trial counts.
   - Have no given alternative solutions - these must be discovered.
   - Often have strong moral, political or professional dimensions.

All problems can be solved

The myth is that all problems can be solved. The reality is that problems are either solved, resolved, dissolved or absolved (Ackoff, 1978)page 13) , where only the first three actually remedy the problem. The word 'solve' is used to mean solved, resolved or dissolved, when a better word would be 'remedy'. The four ways of remedying a problem are:

1. *Solving the problem* is when the decision maker selects those values of the control variables which maximize the value of the outcome (optimal solution).
2. *Resolving the problem* is when the decision maker selects values of the control variables which do not maximize the value of the outcome but produce an outcome that is good enough or acceptable (satisfices the need) (Acceptable solution).
3. *Dissolving the problem* is when the decision maker reformulates the problem to produce an outcome in which the original problem no longer has any meaning. These are generally the innovative solutions.
4. *Absolving the problem* is when the decision maker ignores the problem or imagines that it will eventually disappear on its own. Problems may be intentionally ignored because they are too expensive to remedy, or because the technical or social capability needed to provide a remedy is not known, unaffordable or not available.

Summary

This paper has documented and discussed the following six myths and corresponding realities associated with problem-solving:

9 When complex

10 Technically there is no problem since while the stakeholders may agree that the situation is undesirable, they cannot agree on the problem.

1. The myth that the word ‘problem’ has an unambiguous meaning.
2. The myth that there is always a single correct solution.
3. The myth that the problem solving process starts with a defined problem.
4. The myth that a single pass through the problem-solving process will [always] provide an optimal solution to the problem.
5. The myth that a single problem-solving problem approach fits all types of problems.
6. The myth that all problems can be solved.

Conclusion

In conclusion, problem-solving a key function in management and systems engineering, is hampered by at least six myths which increase the complexity of the problem solving process. An understanding of the reality will help the problem-solver to remedy problems in a more effective and innovative manner.

References

Ackoff, R. L., The Art of Problem Solving, John Wiley & Sons, New York, 1978.

Dictionary.com, 2013, http://dictionary.reference.com/

Fischer, A., Greiff, S. and Funke, J., The Process of Solving Complex Problems, The Journal of Problem Solving 4 (2012), no. 1, 19-42.

Ford, W., Learning and teaching math, 2010, http://mathmaine.wordpress.com/2010/01/09/problems-fall-into-four-categories/, accessed on 8 April 2015.

Hitchins, D. K., Putting Systems to Work, John Wiley & Sons, Chichester, England, 1992.

---, Systems Engineering. A 21st Century Systems Methodology, John Wiley & Sons Ltd., Chichester, England, 2007.

Jonassen, D. H., Instructional design model for well-structured and ill-structured problem-solving learning outcomes, Educational Technology: Research and Development 45 (1997), no. 1, 65-95.

Kasser, J. E., Holistic Thinking: creating innovative solutions to complex problems, vol. 1, Createspace Ltd., 2015.

Rittel, H. W. and Webber, M. M., Dilemmas in a General Theory of Planning, Policy Sciences 4 (1973), 155-169.

Schön, D. A., The Reflective Practitioner, Ashgate, 1991.

Shenhar, A. J. and Bonen, Z., The New Taxonomy of Systems: Toward an Adaptive Systems Engineering Framework, IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans 27 (1997), no. 2, 137 - 145.

Shum, S. B., "Representing Hard-to-Formalise, Contextualised, Multidisciplinary, Organisational Knowledge," Workshop on Knowledge Media for Improving Organisational Expertise, 1st International Conference on Practical Aspects of Knowledge Management, Basel, Switzerland, 1996.

Biography

Joseph Kasser has been a practicing systems engineer for more than 45 years and an academic for about 20 years. He is a Fellow of the Institution of Engineering and Technology (IET), a Fellow of the Institution of Engineers (Singapore), an INCOSE Fellow, the author of “*Perceptions of Systems engineering*”, “*Holistic thinking: creating innovative solutions to complex problems*”, “*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. He is a Certified Manager and holds a Certified Membership of the Association for Learning Technology (CMALT). He also started and served as the inaugural president of INCOSE Australia and served as a Region VI Representative to the INCOSE Member Board. He has performed and directed systems engineering in the UK, USA, Israel and Australia. 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 to the UK to develop the world's first immersion course in systems engineering as a Leverhulme Visiting Professor at Cranfield University. His last full-time position was as a Visiting Associate Professor at the National University of Singapore.

Yang Yang Zhao is currently an Associate Professor at the Norwegian Institute of Systems Engineering in the University College of Southeast Norway. She jointed the institute after her Ph.D. in technology management from the National University of Singapore in 2013. She has industrial experience in process management and business development and been an entrepreneur in IT solutions in Asia Pacific. Her research in human- centered design, system engineering, innovation strategy and emerging markets, has appeared in the Journal of System Engineering, Journal of Technology & Engineering Management, Journal of Chinese Economics & Business Studies, Total Quality Management & Business Excellence Journal and many refereed international conferences.