The United States Airborne Laser Test Bed program: A case study

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Abstract. This paper provides an example of applying holistic thinking to a case study situation: the Airborne Laser (ABL) Test Bed program (ABLT). After a brief introduction to the holistic thinking perspectives (HTP) on the perspectives perimeter (Kasser, 2013b), the paper lists some perceptions of the ABLT from the perspectives perimeter. The paper then goes beyond systems thinking and identifies a number of lessons that can be learned from the project and suggests ways that systems engineers might have prevented much of the effort wasted in the program. These suggestions can lead to further research as well as providing exercises and discussions in the classroom. The paper also couples Technology Readiness Levels (TRL) with Shenhar and Bonen's differential management approach to projects with four levels of technological uncertainty (Shenhar and Bonen, 1997).

INTRODUCTION

The first part of this paper provides a quick summary of the holistic thinking perspectives (HTP) (Kasser, 2013b). The bulk of the paper provides a number of perceptions of the ABLT from the eight descriptive holistic thinking perspectives on the perspectives perimeter. The Generic and Continuum perspectives provide some perceptions that go beyond systems thinking and allow TRLs to be associated with Shenhar and Bonen's levels of technology uncertainty (Shenhar and Bonen, 1997). The paper then poses a key question, discusses the answers and concludes with some observations from the Scientific perspective which provide some suggestions for further research and which can also be used as discussion points and exercises in the classroom. Table 1 provides a list of acronyms used more than once to facilitate reading the paper.

Table 1 Acronyms used in paper

ABL	Airborne Laser
ABLT	Airborne Laser Test Bed
BCS	Beam Control System
BIL	Beam Illuminator Laser
BMC4I	Battle Management/Command, Control, Communications, and Computers & Intelligence
COIL	Chemical Oxygen Iodine Laser
CONOPS	concept of operations
DOD	Department of Defense
EVA	Earned Value Analysis
dTRL	Dynamic Technology Readiness Level
GAO	Government Accounting Office
GDL	Gas Dynamic Laser
ICBM	Intercontinental ballistic missile
MDA	Missile Defense Agency
MIRACL	Mid-Infrared Advanced Chemical Laser
R&D	research and development
S&T	science and technology
SDLC	system development life cycle
SRL	System Readiness Level
TBM	Theater Ballistic Missile
TMD	Theater Missile Defense
TIL	Track Illuminator Laser
TRL	Technology Readiness Level
US	United States of America
USAF	US Air Force

THE HOLISTIC THINKING PERSPECTIVES

The nine holistic thinking anchor points on the perspectives perimeter (Kasser and Mackley, 2008) which provide external, internal, progressive and other perspectives shown in Figure 2, are:

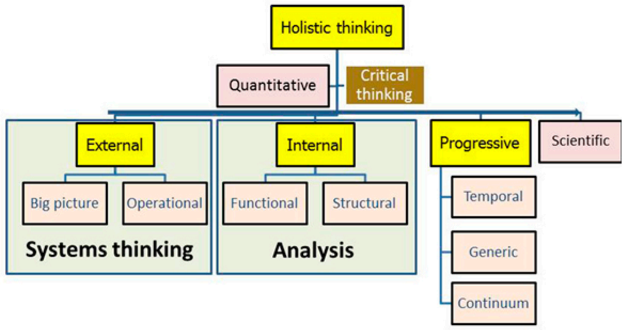

Figure 2 Holistic thinking perspectives (structural view)

External perspectives

The External perspectives are:

1. ***Big Picture:*** the context for the system.
2. ***Operational:*** what the system does.

Internal perspective:

The Internal perspectives are:

3. ***Functional:*** what the system does and how it does it.
4. ***Structural:*** how it is constructed and organised.

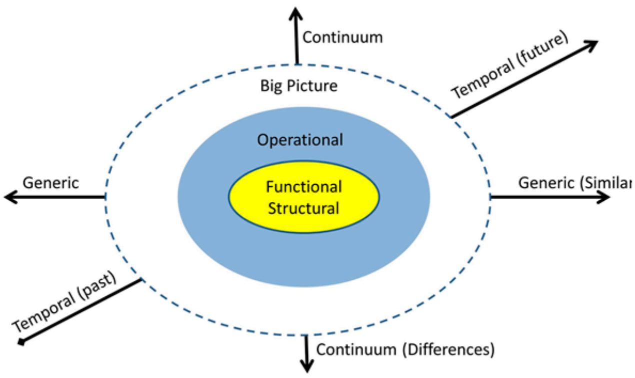

Figure 1 Holistic thinking perspectives

Progressive perspectives

The Functional and Structural perspectives provide internal views, the Big Picture and Operational perspective provide external views. The progressive perspectives are where holistic thinking begins to go beyond analysis and systems thinking and are orthogonal to the internal and external perspectives as shown in Figure 1. The progressive perspectives are:

5. ***Generic***: where the system is perceived as an instance of a class of similar systems.
6. ***Continuum:*** where the system is perceived as but one of many alternatives.
7. ***Temporal:*** which considers the past, present and future of the system.

Other perspectives

The other perspectives are:

8. ***Quantitative:*** the numeric and other quantitative information associated with the system.
9. ***Scientific:*** the hypothesis or guess about the issues.

THE AIRBORNE LASER TEST BED PROGRAM

Once the United States of America (US) recognized that:

1. The probability of a hostile nation developing an Intercontinental Ballistic Missile (ICBM) was very high.
2. An ICBM carrying ten megaton range fusion warheads could inflict trillions of dollars in damage as well as a possible return of the nation to the Stone Age.

The US embarked on a program to develop a Theater Missile Defense (TMD) family of systems. One of these systems was the Airborne Laser (ABL) Test Bed program (ABLT), an advanced platform for the US Department of Defense (DOD) directed energy research program that ran from 1996 to 2012. Perceive the ABLT from the different holistic thinking perspectives.

Consider the mass of information about the ABLT and ABL from the perspective perimeter as follows.

Temporal perspective

This perspective covers the timeline. Chronologically, precursors to the project were:

- ***1973:*** The US Air Force (USAF) shot down a winged drone at their Sandia Optical Range, New Mexico, using a carbon dioxide Gas Dynamic Laser (GDL) and a gimballed telescope (Kopp, 2012).
- ***1976:*** the USAF launched their Airborne Laser Lab (ALL) program. The aim of this effort was to construct a technology demonstrator, carried on a modified NKC-135 Stratotanker, which could successfully track and destroy airborne targets (Kopp, 2012).
- ***1992:*** the USAF planned the ABL as a technology development project to be managed to high readiness levels by a science and technology (S&T) organization. The project was started as an advanced technology transition demonstration to design, fabricate, and test a single demonstrator weapon system and was to take eight years to complete. The pacing technologies were to be matured to a high level - equivalent to Technology Readiness Level (TRL)[1] 6 or 7 - before being included in a product development program. Requirements had not been fixed. In other words, the planned approach was that adopted by successful projects (GAO, 1999).
- ***1993:*** The concept of destroying a missile at a distance using a directed energy weapon was demonstrated during two separate tests at White Sands Missile Range (WSMR), New Mexico, in October 1993. A one-megawatt Mid-Infrared Advanced Chemical Laser (MIRACL) was used to destroy a number of pressurized tanks which simulated SCUDs at the High Energy Laser System Test Facility. In each test the MIRACL and its associated optics were used to rapidly target and destroy several fuel tanks which were sized and pressurized differently. The tests demonstrated a laser's ability to destroy a Theater Ballistic Missile (TBM) as well as the capability to retarget quickly in a multiple-launch situation (Wirsing, 1997).
- ***1996:*** the USAF abandoned this approach.

Project significant events were:

- ***1996:*** the USAF decided to launch ABL as a weapon system development program, not because technologies were sufficiently mature but because of funding and sponsorship concerns. At this time, the two key technologies were at TRLs 3 and 4. According to the retired manager of the S&T project, a product development program was deemed necessary to make the technology development effort appear real to the users and not a scientific curiosity (GAO, 1999). The USAF awarded a product definition risk reduction contract to Boeing, TRW and Lockheed-Martin. The Boeing team were to deliver two prototypes. The plan was to follow up the success of the contract by purchasing five operational aircraft.
- ***1997:*** invention of the Chemical Oxygen Iodine Laser (COIL) by the US Air Force (USAF) Weapons Laboratory.
- ***2000:*** the ABL development program faced a number of technical challenges including (DOT&E, 2000):
    - Development of an autonomous surveillance system onboard the ABL that would provide timely, accurate missile targeting information required to meet stressing ABL engagement timelines.
    - Contractor's ability to build COIL flight modules that would provide adequate power for the operational system and would be sufficiently low weight to fit within the 747-400 aircraft platform capabilities.
    - Development and demonstration of a laser beam compensation and tracking system that would meet stringent pointing and tracking requirements for engaging ballistic missiles.
    - Demonstration of a fully capable Battle Management/Command, Control, Communications, and Computers & Intelligence (BMC4I) system that would interact in real-time with other TMD systems for cross-cueing and fire control.
    - Ability of the contractor to successfully integrate all of the above systems into the finite weight and volume limitations of the 747-400 aircraft.

[1] See Quantitative perspective.

- o The ABL's ability to meet the reliability and maintainability requirements without excessive contractor support.
- o Limitations and vulnerabilities of the planned ABL lethality mechanisms against all threat missiles, and the potential effects and responses to predicted enemy countermeasures.

- ***2001:*** The ABL development program was converted into an ABL acquisition program and transferred to the Missile Defense Agency (MDA). Boeing became the integrating and platform development contractor for two prototype ABL systems; a learning prototype, and an operational prototype.
- ***2006:*** Due to delays and major technical problems, the ABL program was relegated to a technology demonstration status while the planned five-aircraft purchase by the USAF was put on hold.
- ***2009:*** The ABL acquisition program was eight years behind schedule and $4 billion over cost. Moreover, the program's proposed operational role was highly questionable because of significant affordability and technology problems. This led to the acquisition program being shifted back to a research and development (R&D) effort during a major Defense budget reduction and the acquisition of the second ABLT aircraft was cancelled. A GAO report stated that "*none of the ABL's seven critical technologies were fully mature. Program officials assessed one of the ABL's seven critical technologies – managing the high-power beam – as fully mature, but the technology had not yet been demonstrated in a flight environment. The remaining six technologies – the six-module laser, missile tracking, atmospheric compensation, transmissive optics, optical coatings, and jitter control were assessed as nearing maturity*" (GAO, 2010).
- ***2010 and 2011:*** The ABLT was able to prove that the concept of destroying unprotected missiles in their boost phases at a distance using a high power directed energy weapon was feasible by shooting down a number of targets, however the concept was not operational in that ABLT configuration.
- ***2012:*** The ABLT was flown to Davis-Monthan Air Force Base on February 14, put in storage, and retired from active service.

Big Picture perspective

Perceptions from this perspective include the context in which the system is used. Ballistic missile weapons pose a threat that is difficult defend against. The first use of a ballistic missile weapon was the V-2 rockets used by Nazi Germany against London during World War II when the missiles were undetectable. There was no possible way to detect, let alone intercept, the incoming missiles in real time at that time, so the defence technique developed by the British, was (1) to attempt to destroy the launch sites and (2) to provide disinformation that the missiles had overshot their target in an effort to make the Nazis shorten the range so the V-2s would land in the countryside south of London. Since then, the concept of real-time defence against ballistic missiles in-flight has focused on intercepting the incoming missile during the three phases of its flight[2].

- ***The launch or boost phase.*** The best time to destroy the missile since the missile is relatively slow moving and the debris will fall on territory close to the launch site.
- ***The in-flight or ballistic phase.*** Debris will fall on countries who may not be involved in the conflict.
- ***The descent or terminal phase.*** The worst time to destroy the missile since the debris may fall on friendly territory. However, Patriot missile systems were deployed in Kuwait by US forces during Operation Iraqi Freedom in 2010 against descending SCUD missiles with some degree of success.

Conceptually, destroying a rocket during its launch phase can be achieved in a number of ways. The ABLT was designed to test the concept of achieving that destruction using an airborne directed energy weapon in the form of an ABL system. The ABL system would be networked to the adjacent TMD family of systems that would also provide sensor information about launches and command authorization to destroy what would be perceived as a first strike launch by a potentially hostile

[2] Other methods such as destroying the launch sites are out of the scope of this story.

nation. For example, information about a launch could also be received from an orbital satellite, airborne early warning and control (*AEW&C*) system or from an unmanned aerial vehicle (UAV) (Kopp, 2012).

Operational perspective

Perceptions from this perspective include the scenarios in which the system is used. The ABL was conceived as being rapidly deployable and adding a boost-phase layer to the TMD Family of Systems. It was to be positioned behind the forward line of friendly troops and moved closer towards enemy airspace as local air superiority was attained. The USAF proposed a seven-aircraft fleet, and envisioned that five aircraft would be deployed to support two 24-hour combat air patrols in a theatre. Pairs of aircraft would fly patrols over friendly territory close to the borders of a potentially hostile nation scanning the horizon for a rocket launch. Once a launch is detected, the ABL tracks the missile, illuminating the missile with a tracking laser beam while onboard computers lock onto the target. After acquiring target lock, a high power laser fires a three- to five-second burst of directed energy destroying the missile over the launch area. However as the laser beam is distorted by atmospheric turbulence caused by fluctuations in air temperature [the same phenomenon that causes stars to twinkle], the focus of the beam must be adjusted in real time to compensate for the fluctuations.

Structural perspective

Perceptions from this perspective include physical components that make up the system and their architecture. The ABL weapon system consists of the following systems:

1. ***The weapons platform:*** the YAL-1, a modified 747-400F (freighter). The modifications caused changes to the aerodynamic profile of the aircraft.
2. ***Six COIL modules:*** based on an improved version of the COIL invented in 1977. The COIL's fuel consists of hydrogen peroxide, potassium hydroxide, chlorine gas and water. Each COIL operates at an infrared wavelength of 1.315 microns and vents toxic materials in operation.
3. ***The turret ball*** on the nose of the 747-400F has a +/-120 degree field of regard in azimuth and is used to point the 1.6 metre primary laser mirror produced by Corning Glass and Contraves.
4. ***The Beam Control System*** (BCS): ensures that the laser's power can be effectively delivered to the target by compensating for atmospheric distortion. The BCS comprises the wave front sensor and control system for beam distortion control, the systems for beam jitter control, beam alignment and beam 'walk' control, calibration hardware, and target acquisition and tracking equipment. The deformable mirror has 341 actuators which update the shape of the mirror 1,000 times a second. This means that the time required to measure the atmospheric distortion, perform the calculations and control the mirror actuators is less than 1/1000 sec.
5. ***The Track Illuminator Laser*** (TIL): consists of three low powered Kilowatt-class Ytterbium – Doped: Yttrium Aluminium Garnet (Yb:YAG) solid state diode-pumped lasers developed by Raytheon and Northrop Grumman Space Technology.
6. ***The Beam Illuminator Laser*** (BIL): measures atmospheric disturbances providing the information to the BCS also consists of three low powered Kilowatt-class solid state diode-pumped lasers developed by Raytheon and Northrop Grumman Space Technology.
7. ***The Battle Management/Command, Control, Communications, and Computers & Intelligence*** (BMC4I) system manages the weapon system and its operator console and also the supporting communications.

Functional perspective

The ABL performs a set of mission and support functions as discussed below.

Mission functions: The mission functions include:

- Scanning the horizon looking for a missile launch.
- Acquiring a target missile in its boost stage.
- Detecting, tracking and prioritizing the target

- Directing the high energy laser onto the target missile for a long enough time period to damage the missile so that it self-destructs or falls back to Earth.
- Report target events and status of the ABL systems.

Support functions: The support functions include:

- Managing the health and status of ABL operations.
- Monitoring/ engaging warning and self-protection measures.
- Maintaining theatre situational awareness.

Continuum perspective

Perceptions from this perspective include information about the functions that the system cannot perform. For example, the ABL cannot distinguish between the boost phases of a rocket launching a space satellite and the launch of an attacking missile in a first strike sneak attack. Destroying a space satellite launch would have undesirable political consequences as well as probably being considered as an act of war.

Quantitative perspective

Perceptions from the quantitative perspective include perceptions about the numbers associated with the functions performed by the system, costs and other quantitative data including:

- ***Operational range:*** The ABL was expected to achieve effective range of at the most 400 Km (GAO, 2004).
- ***Fuel needed:*** One of the design aims of the ABL system was to carry enough laser fuel to destroy twenty to forty missiles during a single 12 to 18 hour sortie (Kopp, 2012).
- ***Number of ABLs needed:*** Patrolling an operational theatre 24 hours a day 7 days a week would require seven aircraft. The US Defense concept of being able to support two simultaneous theatres would need a fleet of 14 aircraft.
- ***Costs of the system:*** The cost of a single operational aircraft was estimated as $1.5 Billion. The support costs could run an additional $100 million cost per each aircraft per year. Multiply these numbers by 14 for the cost of an operational system.
- ***Technology Readiness Level (TRL):*** US DOD established nine levels of TRLs or maturity as shown in Table 2 (GAO, 1999).

Table 2 Technology readiness levels and their definitions (GAO, 1999)

	Technology readiness level	Description
1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2	Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4	Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.

	Technology readiness level	Description
5	Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6	System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
7	System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed aircraft.
8	Actual system completed and "flight qualified" through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9	Actual system "flight proven" through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.

Generic perspective

Perceptions from this perspective identify similarities between the system and others of the same type. For example, projects such as the ABL acquisition program can be characterised in several ways. Since the success of this project and many other similar acquisition and development project depend on immature technology becoming mature during the project development, consider characterising the project according to Shenhar and Bonen's four-level scale of technological uncertainty (Shenhar and Bonen, 1997) which comprises:

- ***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 (Royce, 1970).
- ***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.

The differences between the four types of projects are summarized in Table 3. Since success was dependent on the development to maturity of at least five immature technologies The ABL project can be classified as a Type D project.

Table 3 Shenhar and Bonen's project classification by Technology Uncertainty

	Type A	**Type B**	**Type C**	**Type D**
	Low - Tech	Medium - Tech	High - Tech	Super – High - Tech
Technology	All exist	Integrates some new with mostly existing	Integrates mostly new	Key technologies do not exist at

	Type A	Type B	Type C	Type D
			with some existing	project's initiation
Development	None	Some	Considerable	Extensive
Testing	None	Some	Considerable	Extensive
Prototyping	None	Some	Considerable	Extensive
Requirements	Known prior to project start	Joint development effort between customer and contractor	Strong involvement of contractor	Extensive contractor involvement many changes and iterations
Design cycles	1	1 or 2	At least 2	2 to 4
Design freeze	Prior to project start	1st Quarter	1st or 2nd Quarter	2nd or 3rd Quarter
Changes	None	Some	Many	Continuous
Management and systems engineering style	Firm and formal	Moderately firm	Moderately flexible	Highly flexible

KEY QUESTION

After thinking about the ABL program information perceived from the HTPS, consider the following key question.

What was the goal of the program?

Was the goal of the ABLT to be an R&D system to prove that the concept of shooting down a missile in its boost phase was feasible, or was it to develop an operational ABL weapons system?

As an R&D system it demonstrated that unprotected missiles in their boost stage could be destroyed at a distance under controlled conditions.

As the development of an operational ABL weapons system, not only was the project a failure, it also seems to be a classic example of how not to manage a development acquisition project with uncertainty in the TRLs for the following reasons:

1. The project should have been cancelled in the early stages once the initial concept of operations (CONOPS) had been developed.
2. The choice of the wrong development strategy.

Early cancellation

The combination of the Functional and Quantitative perspectives in the CONOPS would have shown that the maximum range was less than 400 Km. Most potential hostile nations have positioned fixed launch sites further than 400 Km from their borders, so there is no way the ABL could acquire a target in its boost stage launched by those nations.

The Continuum perspective would show that even if the ABL can acquire a target in its boost stage, and the ABL flies a random schedule to avoid its position being predicted, its position can be detected by radar and it can then be attacked, destroyed, damaged or forced to withdraw by conventional aircraft and missiles in the count down phase preceding a first strike ICBM attack.

From the Operational perspective, the ABL would produce large amounts of toxic waste that would need to be disposed of. Friendly governments on the borders of potentially hostile nations would have difficulty explaining the environmental impact of stationing of the ABL on their territory to their public.

From the Quantitative perspective, the cost of the ABL would prohibit the system being placed into operation even though the cost of not having a defence against an ICBM attack, should it be needed, could be trillions of dollars in damage as well as a possible return of the nation to the Stone Age.

The wrong development strategy

Even if the system would have worked, the development strategy guaranteed that the ABL acquisition project was doomed to failure. Success was dependent on the development to maturity of at least five immature technologies, yet the project was planned and managed as a Shenhar and Bonen Type A and so was doomed to failure[3].

SCIENTIFIC PERSPECTIVE:

AREAS FOR DISCUSSION and FUTURE RESEARCH

Perceptions from this perspective include lessons learned and issues arising from inferences from the case data, hypotheses for discussions and areas for future research such as:

1. The need for and suggestions for upgrading the TRL.
2. The dual technology development approach in the early stage of the acquisition.
3. Changing the project cycle from a single Waterfall to a series of Waterfalls at project planning time.
4. Was the ABL a spoof project?
5. How much of systems engineering is overly complex and complicated or even wrong because people have used techniques[4] do not want to admit they don't understand?

Consider each of these issues.

The need for upgrading the TRL

Deficiencies in the TRL have already been pointed out. For example, Sauser et al. wrote (Sauser, et al., 2006) "*it has been stated that TRL:*

1. *does not provide a complete representation of the (difficulty of) integration of the subject technology or subsystems into an operational system (Dowling and Pardoe, 2005; Mankins, 2002; Meystel, et al., 2003; Valerdi and Kohl, 2004),*
2. *includes no guidance into the uncertainty that may be expected in moving through the maturation of TRL (Cundiff, 2003; Dowling and Pardoe, 2005; Mankins, 2002; Shishkio, et al., 2003; Smith, 2005; Moorehouse, 2001), and*
3. *assimilates no comparative analysis technique for alternative TRLs (Cundiff, 2003; Dowling and Pardoe, 2005; Mankins, 2002; Smith, 2005; Valerdi and Kohl, 2004)".*

Sauser et al. proposed a System Readiness Level (SRL) incorporating the current concept of the TRL scale with the addition of an Integration Readiness Level (IRL) to dynamically calculate a SRL index. Their SRL index approach is both complex and complicated. In addition, Kujawski argued that the SRL index approach is also fundamentally flawed (Kujawski, 2010). This paper suggests an alternative simpler approach for upgrading the TRL by adding a time element directly to the TRL in the manner of Earned Value Analysis (EVA). Each technology would not only have a TRL number in the traditional manner but would also have a dynamic component would show the planned and actual rate of change of the technology from TRL level 1 to TRL level 9 over time as shown in Figure 3. The TRL becomes a dTRL. Figure 3 shows that the technology under consideration was at TRL level 1 in 2006 and was planned to reach TRL 9 in 2016 but has been lagging behind that estimate. A re-planning took place in 2011 but only changed the rate of change in TRL level for a short period of time[5]. So given the re-planning effort had little impact on the rate of advance, the probability of the technology reaching TRL 9 by 2016 unless something changes is extremely low. The dTRL component would make adoption choices simpler. Prospective users of the technology could look at their need by date, the expected date for the technology to achieve TRL 9 and the past progress through the various TRLs. Then the prospective users could make an informed decision as the reality of the estimate based on the historical curve in the figure. If they really needed that technology they

[3] In addition, some of the potential risks in the program from a test and evaluation (T&E) schedule perspective were pointed out in 1999 (DOT&E, 2000) and were effectively ignored.
[4] They just follow the process.
[5] For unknown reasons.

could investigate further and determine if they could help increase the rate of change of TRL.

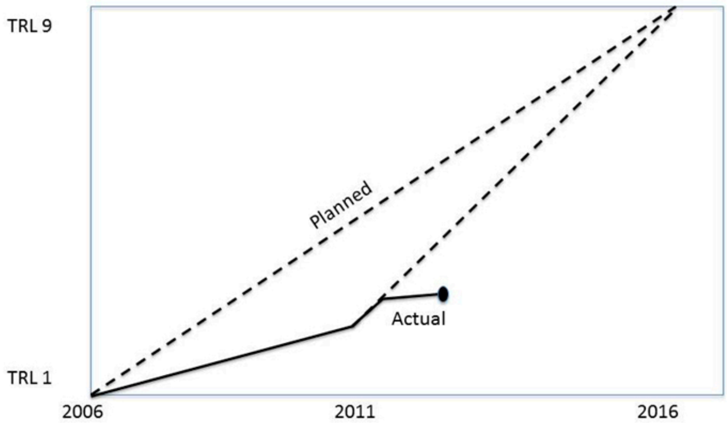

Figure 3 Sample of a dTRL

The dual technology development approach in the early stage of the acquisition

Underpinning systems engineering is the examination and selection of alternative solutions. The current system development lifecycle (SDLC) for Shenhar and Bonen's Type B though D projects is based on maturing a single technology through the TRLs during the development and acquisition phase. Consider adapting another approach in the research and development phase: a dual technology research approach to prototype development similar to the approach already used by the DOD in competitive prototype development procurements such as the Joint Strike Fighter (JSF)[6] where the research phase contractors Boeing and Lockheed-Martin produced two viable radically different approaches. So instead of focusing on a single solution such as in the ABL, the research phase would develop more than one approach based on different technologies until some time when one or more of the proposed solutions reach a point where it can be shown to be practical. The decision as to which technology to use in the actual system would then be made.

Changing the project cycle from a single Waterfall to a series of Waterfalls at project planning time

The traditional SDLC is based on a single pass through the Waterfall. Given that most weapons systems development are Shenhar and Bonen's type B and C systems (Shenhar and Bonen, 1997) the traditional timeline needs to be changed from one pass through the Waterfall to at least two passes for Type B projects and three for Type C projects. This concept already exists in the context of evolutionary acquisition as shown in Figure 4 (DERA, 1997) and the Cataract approach (Kasser, 2002). However all passes through the Waterfall after the first have to take in account changes in user needs during the development time which are not shown in the figure in addition to the changes based on feedback on the earlier versions of the system in the manner of the PRINCE 2 project management methodology (Bentley, 1997).

Was the ABL a spoof project?

Given the vast amount of non-classified information freely accessible on the ABL and its precursors, the possibility arises that the research program was one that the experts knew could never produce an operational airborne system, but looked so promising that a potential adversary would be persuaded to fund development work on a similar project instead of spending resources on projects that could succeed to the detriment of the US. One wonders if the ABL began as such a project during the Cold War, but with that aspect of the project being classified, it was overlooked when key personnel transferred out and the project then undertook a life of its own.

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[6] While the JSF is a predictable failing project in its post research phase (Kasser, 2001), the research phase did produce two viable alternatives.

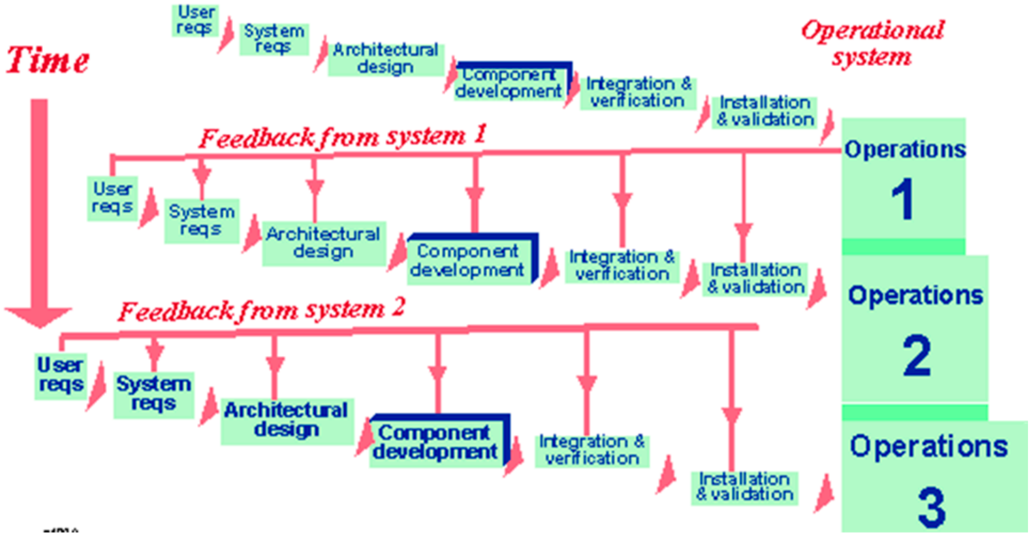

Figure 4 Evolutionary acquisition (DERA, 1997)

How much of systems engineering is overly complex and complicated or even wrong?

Jenkins roles of a systems engineer include challenging the status quo and developing an understanding of the situation (Jenkins, 1969) page 164) however, few if any do. Perhaps they are too busy doing systems engineering to think about what they are doing. Or are they? Perhaps do not want to admit they don't understand what they are doing and are just following the process, exhibiting Type II behaviour (Kasser, et al., 2009);(Kasser, 2013a) Chapter 23). Examples of challenging aspects of systems engineering include:

- Is systems engineering a myth or a reality? In the course of researching that question pointed out seven myths of, and seven defects in, systems engineering (Kasser, 2010; 2007; 1996);(Kasser, 2013a) Chapters 2, 20 and 26).
- The DODAF was designed to be used to "*provide correct and timely information to decision makers involved in future acquisitions of communications equipment*" (DoDAF, 2004). Volume i contains 83 pages of definitions, guidelines, and background; volume ii contains 249 pages of product descriptions. The Deskbook contains 256 pages of supplementary information to framework users. The underlying data model comes with 696 pages and over 1200 data elements. The degree of micromanagement is phenomenal and expensive. Even a limited subset of the required information took 45,000 man-hours to produce (Davis, 2003).
- The SRL (Sauser, et al., 2006) is fundamentally flawed (Kujawski, 2010).

These issues could be, and should be, discussed in postgraduate classes to help students develop and understanding of the 'why' as well as the 'what' and the 'how' of systems engineering and develop an attitude that challenges waste.

SUMMARY

The first part of this paper provided a quick summary of the holistic thinking perspectives. The bulk of the paper provided a number of perceptions of the ABLT from the eight descriptive holistic thinking perspectives on the perspectives perimeter. The Generic and Continuum perspectives provided perceptions that went beyond systems thinking and allowed TRLs to be associated with Shenhar and Bonen's levels of technology uncertainty. The paper then posed a key question, discussed the answers and concluded with some observations from the Scientific perspective which provide some suggestions for further research and which can also be used as discussion points and exercises in the classroom.

BIOGRAPHIES

Joseph Kasser has been a practicing systems engineer for 40+ years and an academic for about 14 years. He is a Fellow of the Institution of Engineering and Technology (IET), 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. He is a Certified Manager and holds a Certified Membership of the Association for Learning Technology. 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. He is currently a Visiting Associate Professor at the National University of Singapore.

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