NPS-AM-10-060

EXCERPT FROM THE PROCEEDINGS

OF THE

SEVENTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM THURSDAY SESSIONS VOLUME II

Acquisition Research
Creating Synergy for Informed Change

May 12 - 13, 2010

Published: 30 April 2010

Prepared for: Naval Postgraduate School, Monterey, California 93943

The research presented at the symposium was supported by the Acquisition Chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

To request Defense Acquisition Research or to become a research sponsor, please contact:

NPS Acquisition Research Program
Attn: James B. Greene, RADM, USN, (Ret.)
Acquisition Chair
Graduate School of Business and Public Policy
Naval Postgraduate School
555 Dyer Road, Room 332
Monterey, CA 93943-5103
Tel: (831) 656-2092
Fax: (831) 656-2253
E-mail: jbgreene@nps.edu

Copies of the Acquisition Sponsored Research Reports may be printed from our website www.acquisitionresearch.net

Funding for Life: When to Spend the Acquisition Pot

Kate Gill—Kate Gill joined the Defence Science and Technology Laboratory (Dstl) in 2005; Dstl is part of the UK Ministry of Defence. Gill has had a career in engineering management, including various posts in commercial aviation and defence companies. She has an Aeronautical Engineering degree from Southampton University, UK, which was followed by a technical apprenticeship at BAE Systems (Warton, Lancashire). This role included structural assessment, stores release, trials planning and flight line operations. Subsequent roles have included technical lead on weapons and navigation systems for the design, build, test and commissioning of corvette class ships for the Middle East (Vosper Thornycroft, Southampton) and trials design, implementation and Military Aircraft Release (MAR) authority for weapons trials (QinetiQ, Boscombe Down). Interspersed with the military domain were periods of employment with commercial aviation companies (Meggitt Avionics, Penny and Giles Aerospace). These included CAA and FAA signatory responsibilities for software and hardware development. She has an MBA and is currently studying towards an Engineering Doctorate in Systems (Eng.D.) with Bristol and Bath Universities, based on research on systems-related issues affecting UK Defence. Gill would like to acknowledge support and guidance from Prof. Patrick Godfrey and Prof. Jan Noyes, both from the University of Bristol, UK.

Contact Details: Defence Science and Technology Laboratory (Dstl), Naval Systems Department, Maritime Systems Engineering Group, Portsdown Hill Road, Portsmouth, PO17 6AD, England, kmgill@dstl.gov.uk

Kirsty Carter-Brown—Dr. Kirsty Carter-Brown, Dstl Associate Fellow, Naval Systems Department, Defence Science and Technology Laboratory (Dstl); Dstl is part of the UK Ministry of Defence. Dr. Kirsty Carter-Brown is a Dstl Associate Fellow and joined Naval Systems Department (NSD) in November 2005, following 10 years as a published academic researcher in Biological Sciences and 2 years as a Dstl Knowledge Agent. She has been involved in a variety of programmes including research on the management and development of Ministry of Defence (MoD) acquisition processes, enterprise and benefits modelling and providing advice for the longer-term technical planning for the Modular Open Systems Architecture (MOSA) programme, the Coalition Warrior Interoperability Demonstration (CWID) and the Future Mine Countermeasures Capability (FMCMC). She is currently seconded to the Systems Engineering Integration Group (SEIG), which is part of DE&S at Abbey Wood, Bristol, UK.

Contact Details: Defence Science and Technology Laboratory (Dstl), Naval Systems Department, Maritime Systems Engineering Group, Portsdown Hill Road, Portsmouth, PO17 6AD, England. kcbrown@Dstl.gov.uk

Abstract

The UK Ministry of Defence (MoD) spends £2.6 billion per year (MoD, 2008, Section 1.2; 2007, p. 2) on research and development (R&D) ("Defense Technology," 2009, p. 22). The figure is technically correct, but it conceals more than it reveals. Of the total, the MoD spends around £500 million (MoD, 2006, p. 8) on laboratory research and on taking what emerges from the lab in its first few steps down the long road that leads eventually to mature technology embedded in military equipment. Analysis based on UK National Audit Office (NAO) data (Stationery Office, 2006, November 24; 2008, p. 5) shows that about half of project timescale overruns are due to technology maturation occurring too late (Jordan & Dowdy, 2007, p. 16). US evidence shows that defence projects that get all their technology mature before the equivalent of Main Gate suffer only very small time and cost overruns thereafter (GAO, 2007, pp. 14-15).

The first hypothesis would be that funding for technology development occurs too late in the acquisition process, when the problems that inevitably occur have a disproportionate effect on project timescales and costs. However, is this construct based on project failings or funding process failures? To improve the outcome, could we simply improve the timing allocation of funds? This research examines the profile of funding as aligned to maturity levels of technology and system and integration readiness, and makes proposals on the improvements that could be made.

Keywords: Finance, acquisition, maturity, maturity levels, timescales, system readiness, audit, MoD; ministry of defence; defence, defense, systems engineering, Dstl; Defence Science and Technology Laboratory, National Audit Office, NAO.

When is the Best Time to Spend—Globally?

Organisations that procure products or services through contracts are routinely involved in costing and estimation efforts. Defence Acquisition is a long-term activity, and the success or failure of the endeavor can, in part, be related to the stability of the aims and contributory components.

Economic growth has been driven by globalisation over the last 30 or more years, generating networks of connections and interdependencies between the major economic powers that are unprecedented in extent and pervasiveness (DCDC, 2009). The economic landscape has evolved rapidly with the demise of centrally planned economies, such as the Soviet Union; the rise of Asian economies, particularly China, which has embraced a market aware philosophy; and the maturation of the European Union as a cohesive economic market. These changes have created a multi-faceted economic landscape that is intimately interconnected and influential.

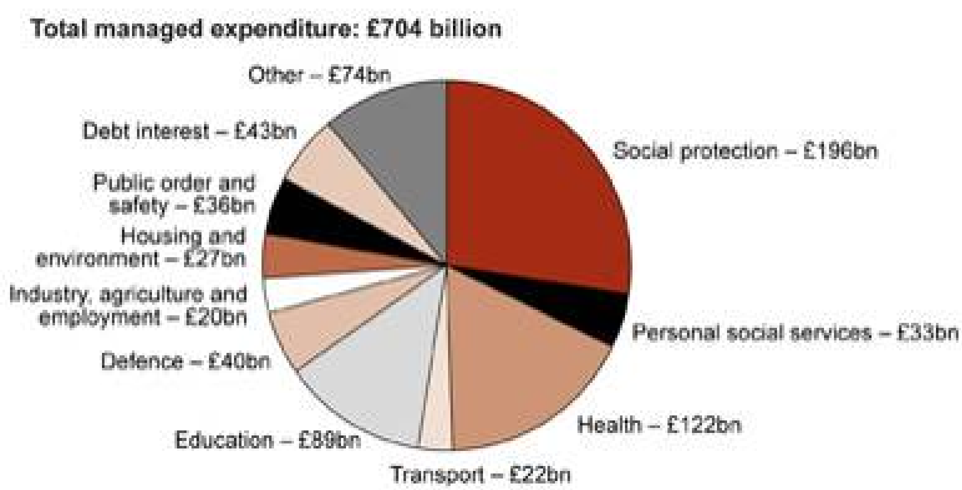
Over the last 30 years, the global economy has grown at a trend rate[1] of 3-4% (IMF, 2008), and output has seen a greater-than four-fold increase. Economic growth, combined with the continuing rise in the global population, will intensify the demand for natural resources, minerals, and energy. It will continue to be uneven, fluctuating over time and between regions (Goldman Sachs, 2007). This global economic context places more pressure on all dimensions of UK government funding, and with the economic recession being felt in the homeland environment, defence focus shifts from operational reach to border security. Operational reach is the defensive objective of nations in times of affluence; border security is the focus during recession.

The IMF considers there have been five global recessions in the last 30 years (IMF, 2008). Global economic recessions will happen over the next few decades, and governments are likely to respond to them with protectionist policies, designed to shield their own economies and workforces from global competition. The global recession that started in 2008 is illustrative of the likely response to, and effects of, future recessions. One outcome of a global recession is an expected increase in the incidence of poverty, which will promote grievance and dissatisfaction among those who suffer economic hardship, in turn breeding political violence, criminality, societal conflict and the destabilization of states and regions unable to cope. This type of economic crisis will produce pressures on government finances that, considered in isolation, will place downward pressure on global defence spending.

1 Trend economic growth refers to average growth of an economy over a cycle of expansion and contraction. It is a moving average. Global recession is defined as annual world growth (based on purchasing-power-parity weights) falling below 3%. By that measure, four periods since 1980 qualify: 1980-1984, 1990-1993, 1998, 2001-2002, plus 2008 onwards. The figure of 3% is a rough correlation to negative global GDP per capita growth (IMF, 2008).

In September 2009 (“Britain’s Sharp,” 2009), the UK Chancellor of the Exchequer forecasted that in April 2010 public borrowing would exceed 12% of GDP. This projection would give Britain the biggest debt build-up between 2007 and 2014 in the G7 economies. Gaining credibility will require clear targets to cut the deficit, together with detailed and transparent plans on how to achieve them. A crucial decision will be the mix of spending cuts and tax rises. In the UK, public spending represents close to 50% of GDP, according to the Treasury. In the March 2010 UK Budget, the plan proposed was to halve the level of borrowing, to 5.2& of national income, by 2013-14 (“Economic,” 2010). The chancellor stated that spending plans from 2011 will be “*very tough—the toughest for decades*,” but refused to outline how this will affect public services, except to say that the Government would “*protect spending on those frontline public services on which we all depend*.” The annual funding review effects all government departments and has inter-related impacts on the services and support that can be offered. In the US, the current focus has been on the US health systems and associated reforms. In the UK, balancing the books and the impending election process has raised the level of scrutiny and resulted in long-term plans being put on hold until the political direction and stability have been secured (Arron, Gale & Orszag, 2004).

In March 2010, UK expenditure per government department can be represented as a pie chart showing the key funded government departments (Figure 1) (“HM Treasury,” 2010). The allocation of spending to functions is largely based on the United Nations’ *Classification of the Functions of Government (COFOG)* guidelines. Other expenditures include general public services, including international services, recreation, culture and religion, public service pensions, plus spending yet to be allocated and some accounting adjustments. The Defence spending is £40 billion, which represents 5.6% of the £704 billion total.



UK Government Spending Allocation 2009/10

Looking at the global and national data, it could be argued that “no” it is not the time to spend. Any expenditure commitments at this time will disappear into the deficit arrears, and any actual gains will be lost. However, funding streams need to be spent to ensure that the position does not regress, and so investment is required to ensure the maintenance of current position and level of capability and service.

In the current global and national climate, it is not a good time to spend. However, to maintain capability in defence and other sectors, spending has to be sustained to ensure stability and maintenance. In terms of defence projects, some projects are pending approval, some projects are committed by still under development and some projects are further down the in-service and support stage. For committed projects, the global and national situation can be considered as relevant, but not a significant issue. The national situation will determine the size of the overall budget, but how and when it is spent is an issue for the project team. Systems engineers often serve as technical points of contact throughout the entire system lifecycle (Smartt & Ferreira, 2010); as such, they are one of the critical repositories of project life knowledge, technically and financially (Valerdi, Rieff, Roedler, Wheaton & Wang, 2007). Using the natural holistic skills of a systems engineer, and applying those inherent skills to costing, has been the basis of this research.

To date, there has been significant research into through life costing (Haskins, Forsberg & Krueger, 2007; Valerdi & Miller, 2007),[2] and the projection of through life implications is based on existing data, extrapolated to a conclusion. This method is well documented and appealing, as it reinforces the view that we can corporately learn from experience and that costing is achieved within a defined set of rules. It, therefore, follows that if we can define the rules, then we can define the outcome (Stationery Office, 2007; 2008). This research examines the project costing profile, as related to three measures of readiness that are well defined in the systems domain. These three were selected because they represent a global viewpoint and are used in a number of multinational and multilingual programmes.

Optimum Technology, System and Integration Investment Date

Technology assessment of a complex system requires the assessment of all of its systems, sub-systems and components. Technology Readiness Levels (TRLs) can be used to determine the current component maturity. Although broadly similar, different international agencies use different definitions for TRLs; the most common definitions are those used by the Department of Defense (DoD) (DoD, 2006) and the National Aeronautics and Space Administration (NASA) (Mankins, 1995) (Table 1 and Figure 2). In Europe, the European Space Agency’s (ESA) definitions of TRLs are often used as contractual baseline criteria for project acceptance (ESA, n.d.). A TRL calculator has been developed for the United States Air Force by Nolte et al. (2003). As with all assessments, this TRL calculator provides a snapshot of technology maturity at a given point in time. The Technology Program Management Model (TPMM) was developed by the United States Army by Craver et al. (2006). The TPMM is a TRL-gated high-fidelity activity model that can be used as a management tool to assist in planning, managing, and assessing technologies for successful technology transition. The model provides a core set of activities, including systems engineering and program management tasks, that are tailored to the technology development and management goals.

2 Through Life Costing is a defined UK Ministry of Defence (MoD) process (*Acquisition*, 2009).

Table 1. Table of TRL Descriptions

National Aeronautics and Space Administration (NASA) Technology Readiness Level
1. Basic principles observed and reported
2. Technology concept and/or application formulated
3. Analytical and experimental critical function and/or characteristic proof of concept
4. Component and/or breadboard validation in laboratory environment
5. Component and/or breadboard validation in relevant environment
6. System/subsystem model or prototype demonstration in a relevant environment (ground or space)
7. System prototype demonstration in a space environment
8. Actual system completed and 'flight qualified' through test and demonstration (ground or space)
9. Actual system 'flight proven' through successful mission operations

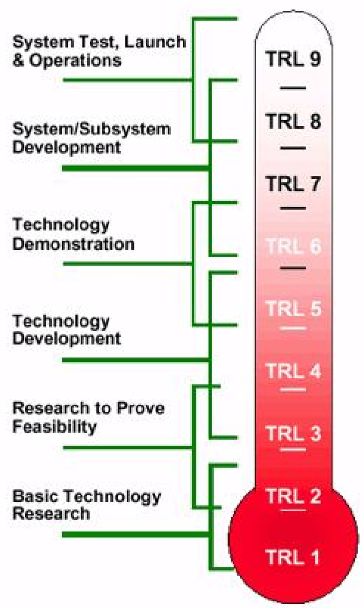


Figure 1. NASA TRL Diagram

System Readiness Levels (SRLs) ("What Are," 2009) have been developed as a project management tool to capture evidence, and assess and communicate system maturity in a consistent manner to stakeholders. In the UK, SRLs define a set of nine maturity steps from concept to in-service across a set of systems engineering disciplines. Each of the SRL steps align to key outputs from systems disciplines such as Training, Safety and Environmental, or Reliability and Maintainability. SRLs aim to take a consolidated view of the essential steps needed to properly mature and deliver a complete supportable system to the end user. SRLs are a means of analysing key outputs of an equipment acquisition project, structured in such a way as to provide an understanding of work required to mature the project. In the UK, a matrix is used to capture these key outputs and understand how they should mature over time. Projects track their maturity through the nine SRL steps across all relevant system disciplines, and a simple self assessment tool is provided (Figure 3).

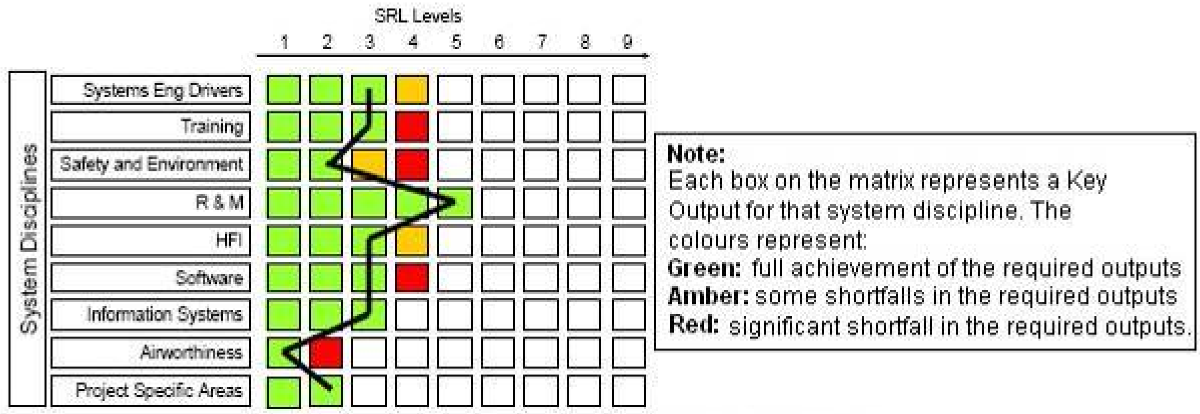


Figure 2. Outline of UK SRL Matrix with a Representative Project SRL Signature Matrix (*Applying*, n.d.)

In the generic SRL matrix, each SRL level from 1 to 9 is broken down into key outputs that need to be achieved for each of the systems disciplines, including Systems Engineering Drivers, Training, Safety and Environment, Reliability and Maintainability, Human Factors Integration, Software, Information Systems, Airworthiness, Project Specific Areas. For any project, an SRL assessment produces a "signature" rather than an absolute SRL figure. The signature records the variation of maturity that has been achieved across the systems disciplines, acknowledging that not all projects mature against the systems disciplines at a consistent rate. The signature shown in Figure 3 would be typical of a project in the Assessment phase (i.e., post Initial Gate where the target is to achieve SRL1), but indicates insufficient maturity to proceed to Main Gate (the target being SRL4).

Integration levels are the next step. When brought together with TRLs and SRLs, Integration Readiness Levels (IRLs) provide a means of progressively measuring project maturity at technology, component, sub system and whole system levels. Maturity is measured in terms of cost, schedule and risk and should also take into consideration the impact of the overall system on the systems with which it is to operate, i.e., in a "system of systems" context. IRLs are used at a prime contractors and systems integrator level, and aim to support successful transition of technologies to and between acquisition partners. IRLs are used to support strategic, business and political progression, such as funding considerations (national or private), economic offsets and inter-government partnerships.

We can consider the three (TRL, SRL, IRL) measurements as interrelated but independent sets of assessment, and use these assessments to build up a visual and numerical representation of maturity. Using the Red, Amber, Green (RAG) notation, this representation resembles a wall of bricks (Figure 4) and is, therefore, termed a wall matrix view. The lowest, and foundation levels, are the TRLs, and the number of layers relates to the number of key components. The next tranche are the SRLs that cover the nine key categories. The top, capping, level is the IRL, which can also be referred to as the System of System (SoS) integration level. Any project, of any complexity, can be evaluated using the wall matrix construct. As with any assessment, the wall matrix is linked to a specific time in the life of the project, and so represents a snapshot of maturity. Relating these "time now" wall matrix assessments to the costing lifecycle was the next step of the research.

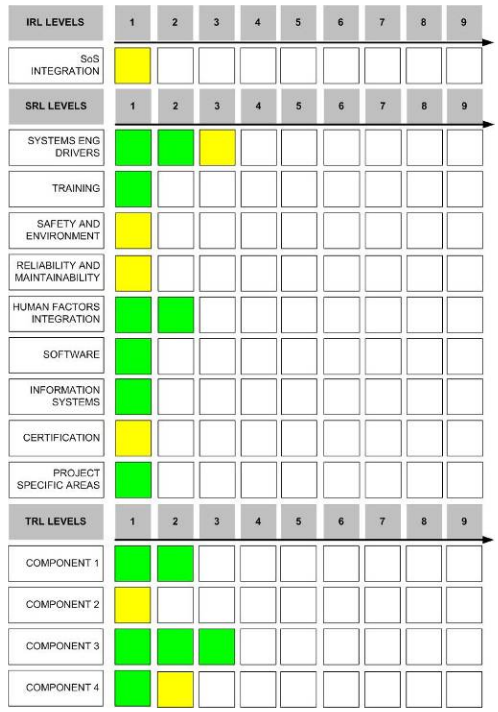


Figure 3. TRL, SRL, IRL Wall Matrix Construct

Costing Lifecycle

The costing lifecycle is a method of project representation in which all costs arising from owning, operating, maintaining and disposing of a project are considered. Project costs take into account the initial cost, including capital, investment cost, development cost, unit purchase and installation cost, and future costs, including operating cost, energy cost, maintenance cost, capital replacement cost, financing cost and any resale salvage for disposal cost over the life time of a project or technology product. Any new product or project progresses through a sequence of stages (Figure 5). Figure 5 expresses the profile against an axis of sales, but the axis could equally represent investment, effort or cost.

Using the traditional costing profile, and nesting the contribution of each of the stages of the UK Defence Acquisition CADMID[3] lifecycle, a series of contributory peaks and troughs can be mapped. Using Valerdi's results alongside similar project management costing models from Kerzner (2003), a lifecycle costing profile has been constructed (Figure 6) and then roughly aligned to the UK CADMID process. Each contributory cycle has a peak, which represents the achievement of the aim of that stage of the lifecycle.

There are a number of reports that relate to early investment, resulting in lower overall project cost. Jorgensen and Sjoberg (2001) examined a portfolio of software projects, and examined error occurrences as related to overrun costs. Their results show early investment was associated with early development of maturity, and, as a result, minimum rework and lower overall project cost (Jorgensen & Molokken-Ostovold, 2004; Jorgensen & Grimstad, 2005; Jorgensen, 2009). Valerdi (2005) and Valerdi et al. (2007) constructed a cost modeling tool that they validated against industrial projects. Using this

---

3 CADMID means Concept, Assessment, Demonstration, Manufacture, In-Service and Disposal.

evidence with the nested costing lifecycle, it can be concluded that contribution of funding prior to the peak accelerates that stage of the process; contribution after the peak ensures appropriate closure of that stage and contributes to the start up of the next stage.

The research then focused on assessing when contributory peak was reached, in relation to the maturity levels, with the premise that investment prior to the peak was constructive up to the peak point, at which point it was better to invest in the next ascending stage of the process.

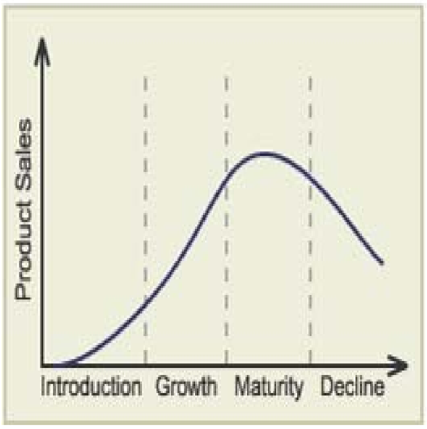


Figure 4. Product Lifecycle Diagram
(Gorhcels, 2000)

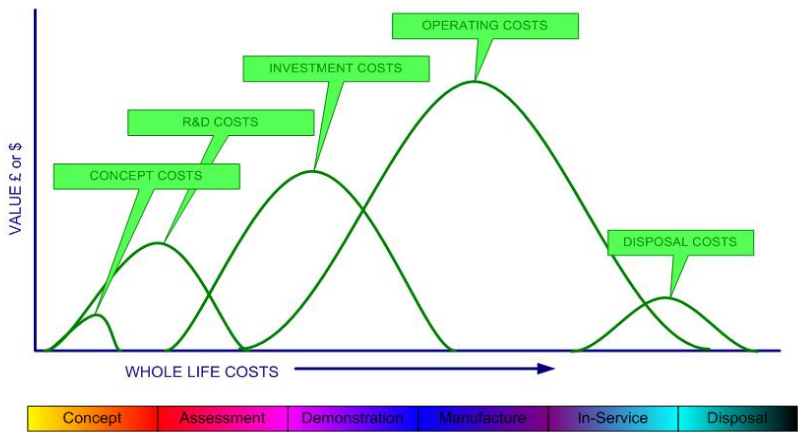


Figure 5. Lifecycle Costing with Key Contributing Stages Mapped Against CADMID

Costing Case Studies

Using historical cost and progress data, a number of projects have been examined. The cost data has been sourced from UK National Audit Office (NAO) reports (Stationery Office, 2006, November 24, p. 14; 2008, p. 5; 2006, p. 57; 2007a, p. 4; 2007b, p. 6,313; 2003) to minimize supplier interpretation, and selective accounting. The project data has also been sourced from NAO reports alongside other open source publications.

Unlike other studies, access to data was not the issue; the data was in abundance. The real issue was in consistent interpretation from the differing types of source document and in the maturity assessments, which were based on technical reports and publications. For the purposes of this openly published paper, the case studies have been deliberately censured. All the source data is available openly, but some has been interpreted in the context of information that is privileged to the UK MoD.

During the period August 2009 and March 2010, twelve projects were researched for source data. The research related to gaining published material that could be assessed against the costing and the three maturity criteria. The aim was to provide source data that could be validated by the authors and by a technical judgment panel of engineers and scientist proficient with the UK acquisition lifecycles and level assessments. The panel was sourced from colleagues with Dstl, who have familiarity with the assessment process and minimal knowledge or involvement in the selected projects. The projects were assessed against their known timeline, the theoretical costing lifecycle, published costs and associated panel TRL, SRL, IRL assessments. Each project was assessed at various points in its lifecycle. The number of assessment points varied from two to twelve. Larger, long-term projects were replete with published data and so were assessed at multiple points; for some smaller projects, data was only available at two points. For each project, a consistent selection of components was assessed for TRL. The TRLs, the nine aspects of SRL and the capping IRL were then discussed using the source data and assessed on a wall matrix by the panel.

Once a timeline position and an associated “RAG” wall matrix had been established, the average TRL, SRL, IRL score was calculated and plotted against the known cost curve of the project. Some plot points were on an ascending line, e.g., prior to peak, and some were on the declining line. In total, twenty eight wall matrix plots were constructed and associated with a costing timeline. Some of the projects were reported on for three consecutive years of NAO assessment so that a robust element of progression could be established. After ratification and review, a consolidated plot was constructed (Figure 7).

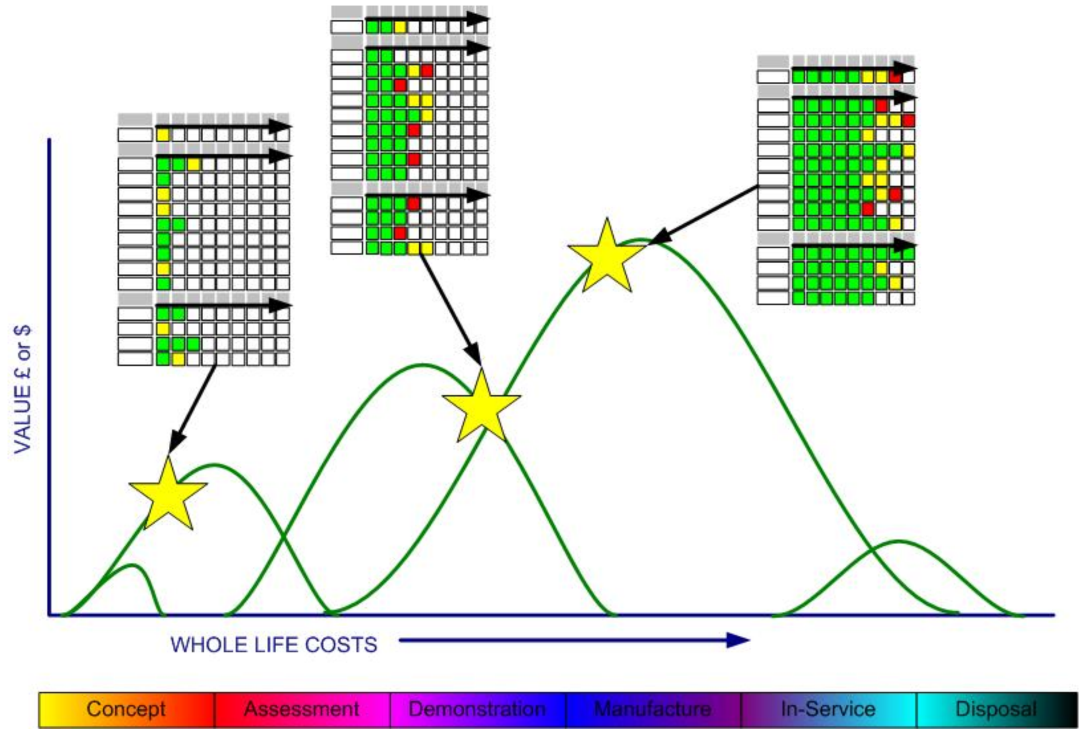


Figure 6. Consolidated Plot of Acquisition Lifecycle Stages versus Readiness Levels Matrices

Overview, Conclusions and Further Work

After reviewing and consolidating the data, a table was produced comparing the acquisition lifecycle phases of CADMID against the set of points of significance for the three readiness levels, extracting for the wall matrix (Table 2). From the data, the optimum investment date could not be established, but a limit point was found. Investments in a particular stage added benefit to a TRL, SRL, IRL limit point; investment after that point was required to ensure project progression, but did not represent the peak exchange.

Table 2. Consolidated Wall Matrix and Timeline Table of Results

	TRL point of significance	SRL point of significance	IRL point of significance
CONCEPT	< 3.2	< 2.4	N/A
ASSESSMENT	< 5.6	< 6.5	< 1.8
DEMONSTRATION	< 7.6	< 7.8	< 4.4
MANUFACTURE	< 8.1	< 8.4	< 8.2
IN-SERVICE	N/A	N/A	< 9.0

There was a large variation in the sets of TRL, SRL and IRL data that will be examined in further studies. The source of variation could be related to source data error, interpretation or factors that made the specific project different to its peer group, e.g., groundbreaking atomic physics as opposed to next generation vehicle development. Expanding the analysis to a wider pool to projects would refine the technique and increase the robustness of the “points of significance” as well as reduce the statistical effects. The use of one technical judgment panel was convenient for this stage of the research but could introduce experimental errors over time. Familiarity and prior knowledge of previous results started to bias conversations on some of the latter assessments of larger projects.

Looking at the global and national economic situation, the competition for government funding is becoming more intense, and departments such as the MoD are under increasing pressure to deliver optimum results against investment. This investment is not just what to invest in, but also when to invest. The extant UK MoD assessment criteria include TRL, SRL and IRL decision points, so this data is already available. By mapping the optimum investment point against the TRL, SRL, and IRL, a wall matrix could guide the diversion of funds into projects up to key points, which would result overall in maximizing the outcome benefit to UK Defence.

References

Acquisition operating framework (Ver. 2.0) (2009, December 19). Retrieved January 18, 2010, from http://www.aof.mod.uk/aofcontent/tactical/tlcm/content/introductiontotlcm.htm

Applying system readiness levels. (n.d.). Retrieved from http://www.aof.mod.uk/aofcontent/tactical/techman/content/srl_applying.htm

Arron, H.J., Gale, W.G., & Orszag, P.R. (2004). Meeting the revenue challenge. In A.M. Ravlin & I.V. Swahill (Eds.), *Restoring fiscal sanity: How to balance the budget* (pp. 111-127). Washington, DC: The Brookings Institution.

Britain's sharp budget choices. (2009, September 24). *The Economist*. Retrieved from http://www.economist.com

Craver, J.T., et al. (2006). *Technology program management model*. Paper presented at the NDIA Systems Engineering Conference, Army Space and Missile Defense Command Technical Center.

The defence technology plan. (2009, June). In *Proceedings of the RUSI Defence Systems Conference*.

Development, Concepts and Doctrine Centre (DCDC). (2009, July 16). Dimensions—research areas. In *DCDC Strategic Trends Programme: Global Strategic Trends* (pp. 87-158) (4th ed.). UK: Crown Copyright.

DoD. (2006, July 7). Technology readiness levels in the Department of Defense (DOD). In *Defense Acquisition Guidebook* (Ver. 1.6). Washington, DC: Author.

Economic and financial indicators. (2010, March 18). *The Economist*. Retrieved from http://222.economist.com.

European Space Agency (ESA). (n.d.) Retrieved from http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=37710

GAO. (2007, March). *Defense acquisitions: Assessments of selected weapon programs* (GAO-07-406SP). Washington, DC: Author.

Goldman Sachs Group. (2007, November). Beyond the BRICS: A look at the “next 11.” In *BRICs and Beyond* (pp. 159-164). New York: Author.

Gorhcels, L. (2000). *The product manager’s handbook: The complete e-management resource* (2nd ed.). London: McGraw-Hill.

Haskins, C., Forsberg, K., & Krueger, M.J. (2007). *System engineering handbook: A guide to systems lifecycle processes and activities*.

HM Treasury 2010-11 near cash projections. (2010, March 18). *The Economist*. Retrieved from http://economist.com
International Monetary Fund (IMF). (2008, October). *World economic outlook (WEO) 2008: Financial stress, downturns, and recoveries* (pp. 3-44). Retrieved October 16, 2008, from http://www.imf.org/external/pubs/ft/weo/2008/02/pdf/text.pdf
Jordan, G., & Dowdy, J. (2007, October). Acquisition and technology: The problem that won't go away. *RUSI Defence Systems*,*10*(2).
Jorgensen, M. (2009). How to avoid selecting bids based on overoptimistic cost estimates. *IEEE Software*, 79-84.
Jorgensen, M., & Grimstad, S. (2005). Over-optimism in software development projects: "The winner's curse." In *Proceedings of the 15th International Conference on Electronics, Communications and Computers (CONIELECOMP 2005)*.
Jorgensen, M., & Molokken-Ostovold, K. (2004). Reasons for software effort estimation error: Impact of respondent role, information collection approach, and data analysis method. *IEEE Transactions on Software Engineering*, *30*(12), 993-1007.
Jorgensen, M., & Sjoberg, D.I.K. (2001). Impact of effort estimates on software project work. *Information and Software Technology*, *43*, 939-948.
Kerzner, H.P. (2003). *Project management: A systems approach to planning, scheduling, and controlling*. Hoboken, NJ: Stevens Institute of Technology.
Mankins. (1995). *Technology readiness levels in the National Aeronautics and Space Administration (NASA): A white paper*. Washington, DC: NASA.
MoD. (2006, September). *Maximising benefit from defence research*. Working paper.
MoD. (2007, October). *Maximising defence capability through R&D*. Report.
MoD. (2008, September). *Technology partnership in defence*. Working paper.
Nolte, W.L., et al. (2003). *Technology readiness level calculator*. Paper presented at the NDIA Systems Engineering Conference, Air Force Research Laboratory.
Smartt, C., & Ferreira, S. (2010, March 17-19). Leveraging psychology and software engineering research to develop bid, proposal, and cost estimation heuristics for systems engineering (Paper #1569270565). In *Proceedings of CSER 2010, 8th Conference on Systems Engineering Research*. Hoboken, NJ: Stevens Institute of Technology.
The Stationery Office. (2003). Major Projects Report 2003 (43rd Report). HC 383, Session 2003-2004. London: National Audit Office, Comptroller and Auditor General.
The Stationery Office. (2006). *Ministry of Defence: Major projects report—project summary sheets*. HC23-1 Session 2006-2006. London: National Audit Office, Comptroller and Auditor General.
The Stationery Office. (2006, November 24). *Ministry of Defence: Major projects report 2006*. HC23-1, Session 2006-2007. London: National Audit Office, Comptroller and Auditor General.
The Stationery Office. (2007a). *Comptroller and Auditor General annual report* (Vol. 1). London: National Audit Office, Comptroller and Auditor General.
The Stationery Office. (2007b). *Comptroller and Auditor General annual report* (Vol. 2). London: National Audit Office, Comptroller and Auditor General.
The Stationery Office. (2008, July 22). *Ministry of Defence: Major projects report 2007*. HC433. London: National Audit Office, Comptroller and Auditor General.
The Stationery Office, National Audit Office (NAO). (2007). *Ministry of Defence: Major projects report 2007*. Retrieved November 30, 2007, from http://www.nao.org.uk/publications/0708/ministry_of_defence_major_pro.aspx

The Stationery Office, National Audit Office (NAO). (2008). *Ministry of Defence: Major projects report 2008*. Retrieved December 18, 2007, from http://www.nao.org.uk/publications/0809/mod_major_projects_report_2008.aspx

Valerdi, R. (2005). *The constructive systems engineering cost model (COSYSMO).* Unpublished doctoral dissertation), University of Southern California.

Valerdi, R., & Miller, C. (2007). From research to reality: Making COSYSMO a trusted estimation tool in your organization. In *Proceedings of International Council on Systems Engineering (INCOSE) 2007 Symposium.* San Diego, CA.

Valerdi, R., Rieff, J.E., Roedler, G.J., Wheaton, M.J., & Wang, G. (2007). Lessons learned from the industrial validation of COSYSMO. In *Proceedings of the International Council on Systems Engineering (INCOSE) 2007 Symposium*. San Diego, CA.

What are system readiness levels (SRLs)? (2009, December 19). *Acquisition operating framework: Technology Management*. Retrieved from http://www.aof.mod.uk/aofcontent/tactical/techman/content/srl_whatarethey.htm

THIS PAGE INTENTIONALLY LEFT BLANK

2003 - 2010 Sponsored Research Topics

Acquisition Management

- Acquiring Combat Capability via Public-Private Partnerships (PPPs)
- BCA: Contractor vs. Organic Growth
- Defense Industry Consolidation
- EU-US Defense Industrial Relationships
- Knowledge Value Added (KVA) + Real Options (RO) Applied to Shipyard Planning Processes
- Managing the Services Supply Chain
- MOSA Contracting Implications
- Portfolio Optimization via KVA + RO
- Private Military Sector
- Software Requirements for OA
- Spiral Development
- Strategy for Defense Acquisition Research
- The Software, Hardware Asset Reuse Enterprise (SHARE) repository

Contract Management

- Commodity Sourcing Strategies
- Contracting Government Procurement Functions
- Contractors in 21st-century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting, Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

Financial Management

- Acquisitions via Leasing: MPS case
- Budget Scoring
- Budgeting for Capabilities-based Planning

- Capital Budgeting for the DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-tem Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness
- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)

- Risk Analysis for Performance-based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public-Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-dimensional Imaging Technology

A complete listing and electronic copies of published research are available on our website: www.acquisitionresearch.org

THIS PAGE INTENTIONALLY LEFT BLANK

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL
555 DYER ROAD, INGERSOLL HALL
MONTEREY, CALIFORNIA 93943

www.acquisitionresearch.org