University of Southern Queensland

Faculty of Health, Engineering and Sciences

Integration Effectiveness between Engineering Teams on Complex Defence Programs

A dissertation submitted by

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Abstract

As programs grow in size and complexity, it is necessary to form sub-teams of engineers to break down the work to manageable portions. These teams, referred to in isolation as 'silos', typically focus on a specialised technical discipline (software, avionics, electrical, etc.). How well teams combine their work, or horizontally integrate (illustrated in *Figure 1 - A birds-eye view of horizontal integration*), is a huge contributor to the success of a program, in terms of meeting the customer's needs, within cost and schedule.

The integration of teams is hugely important for Defence, due to the complexity and size of programs, as well as geographic and political challenges. This drives segregation of engineering efforts, as shown in *Figure 2 - Breakdown and re-integration of a system*. To realign teams in a common direction, develop an integrated product and achieve a successful program outcome, integrating factors are applied. The identification and evaluation of these integrating factors in Complex Defence Programs emerged as a gap in identified literature, and as such is the focus of my research.

The purpose of research into engineering integration is to identify how programs can make the interactions between teams more efficient, in order to deliver the best possible product for Defence. In doing this, I've needed to define the value of integrating teams, identify what can be done to integrate teams, and evaluate the efficiency of integration efforts in aligning the direction of sub-teams on a program. This report documents these findings.

The research conducted was primarily qualitative, based upon the perspectives of subject program team members. The identification of integrating factors was achieved through a review of Systems Engineering literature, and the observations recorded in interviews. The evaluation of these factors has been subjective, but surveys have been used to quantify results and identify recurring or commonly held perspectives within the industry.

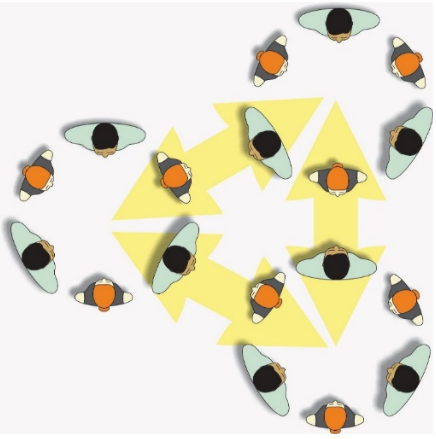

Figure 1 - A birds-eye view of horizontal integration

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Acronyms and Abbreviations

Term	Definition
IPT	Integrated Product Team
ICCPM	International Centre for Complex Project Management
NASA	National Aeronautics and Space Administration
PBS	Product Breakdown Structure
PMBOK	Project Management Bodies of Knowledge
SEIT	Systems Engineering Integration Team
WBS	Work Breakdown Structure

Table 1 - Acronyms and abbreviations

Definitions

Term	Meaning
Chief Engineer (CENG)	The CENG is the leading authority for technical decisions on the program, and provides technical guidance to program Engineers.
Engineering Integration Team	The Systems Engineering Integration Team is a team specifically created to facilitate the integration of products produced by sub teams.
Engineering Manager	The engineering manager reports to the Program Manager, and has the responsibility of managing program teams in a functional capacity.
Engineers	Engineers carry out the design work within the bounds of the Integrated Product Team area of speciality.
Integration	The term integration as used in this report refers to the interaction or collaboration of sub teams within a program.
Integration Manager	The Program Integration Manager oversees the running of program, and is responsible for cost and schedule. While the PM is "looks outwards" with their customer focus, the VPM "looks inward", overseeing the Engineering, Logistics and commercial aspects of a program.
Interface	A boundary where, or across which, two or more parts of a program (i.e. sub-teams) interact (Wheatcraft, 2010).
IPT Lead	The IPT Lead has responsibility to execute a defined portion of the scope of an engineering program.
Product Breakdown Structure (PBS)	The PBS defines the sub-products used which need to be integrated to give a final product, meeting customer and business needs.
Product team	A product team is the technical teams of engineers formed to build a sub product, as defined in the PBS. In complex programs, there are generally multiple teams.
Program	In Defence, this is considered to be the structure of people, processes, data and tools to design, build and maintain a product for Defence. A program has a larger value than a project, and due to size, are usually considered to be Complex Programs, but for the purposes of this report, program and project are used interchangeably.

Project	The same as a Program, but for a product with a lesser monetary value. Programs use smaller teams, and can be sub-programs or stand alone for lower value products. The term is used interchangeably with Program.
Project Manager	The Project Manager of Program Manager is the highest authority on a program, dealing extensively with the customer and reporting to business senior managers.
SEIT Engineers	SEIT Engineers have the role of undergoing engineering in areas not covered by the IPTs (specialty engineering), but also creating Engineering manpower for IPTs, which doubles as oversight of IPT engineering by the SEIT.
Senior Engineer	Senior Engineers will perform engineering duties, and have authority to review and approve technical decisions on the program, and to provide guidance to other Engineers.
Work Breakdown Structure (WBS)	A WBS defines the work that a program needs to complete, in order to build a product or system which meets the contract requirements. The WBS will generally replicate the PBS, but includes overhead work.

Table 2 - Glossary of terms

1. Introduction

1.1 Background

Each year the Australian Department of Defence (DoD) tenders complex programs to private organisations to build the defensive capability of the Australian Defence Force (ADF). Such programs represent significant expenditure for the Government, contributing to $31.9 billion budgeted for defence in 2015-16 (Andrews, 2015). Historically, such programs have regularly been fraught with cost and schedule overruns, and failures to meet the performance requirements sought by the DoD. The factors contributing to such shortfalls are varied, but one such factor that inevitably arises is the level of integration between teams to engineer a coherent solution.

Table 3 - Project background statement summarizes how the need for integration and associated integration methods arises, through four assumptions.

1. In complex programs, work needs to be broken down and allocated to specialised teams.	→	2. In breaking down work, “siloing” occurs.	→	3. To counteract the negative effects of “siloing”, companies employ various methods to re- “integrate” teams.	→	4. Methods of re integrating are implemented with varying levels of success.

Table 3 - Project background statement

The process of breaking down a system, developing sub products, and then integrating the sub products into an integrated product is further illustrated in *Figure 2 - Breakdown and re-integration of a system*. The figure shows how a conceptual product is broken down into sub products, with the work to develop those products allocated to sub-product teams, or simply Product Teams. Such a breakdown of teams is particularly common for Defence capability programs, given the tendency of such programs to be large, technically progressive and resultantly complex (Mazur, et al., 2014). As the direction of Product Teams differ, Integrating Factors are applied to realign the direction of sub teams, and in doing so facilitating the creation of an integrated product.

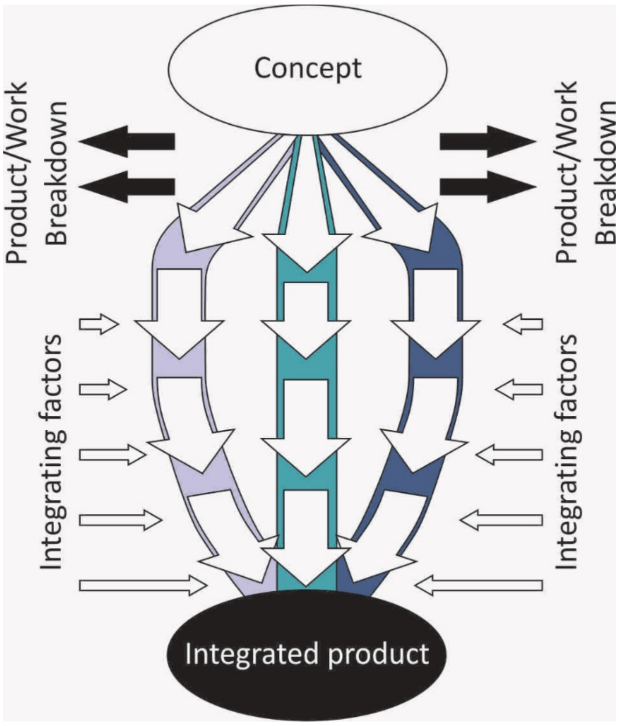


Figure 2 - Breakdown and re-integration of a system

This report seeks to evaluate firstly the role of integrating teams in developing Defence systems, and secondly the methods employed to integrate teams on Complex Defence Programs, as defined the fourth assumption on *Table 3 - Project background statement*, and illustrated in *Figure 2 - Breakdown and re-integration of a system*.

1.2 Aims

The aim of this project is to define 'integration' as it is interpreted by engineering teams working on complex Defence Programs, and to critically evaluate how programs are integrated. More specifically, this project will;

1. Identify why organisations need to integrate;
2. Identify what is done to integrate teams, in terms of organisational structure, behavioural attributes, and project governance;
3. Determine how effective attempts to integrate teams are.

The second phase will, based on the above findings;

4. Propose how engineering teams on complex programs can effectively integrate with the wider program.

These four aims will be expanded upon under *Objectives*, then addressed in the *Literature review*, as far as they are covered by identified existing research.

Methodologies will outline the how original research was carried out to fill the gaps in the existing literature, and Section *4 Findings* details the findings of this research.

1.3 Objectives

The objectives define the four project aims in more detail.

1.3.1 Define the value of integrating teams

In order to evaluate Integration efforts, it is critical to know what teams are trying to address. It is assumed that in forming 'Integrated Teams', managers are trying to overcome a particular obstacle, rather than to simply ensure that teams are working together. The first aim, to identify the need for integrated teams, will involve research into what these obstacles, or barriers, are. It will also involve research into the positive and negative effects of breaking teams up.

The second step in defining the value of integration, is to look at the negative effects of integrating teams, in addition to the benefits. It is expected that teams are broken up to gain efficiencies compared to having a single, large team, and forcing teams to work together will potentially lessen these efficiencies.

1.3.2 Define what can be done to integrate teams

This project will seek to define what programs can do to integrate teams. Integration methods are expected to be directed at encouraging collaboration within and external to teams. This list will become a basis for the evaluation of efficiency of integration methods.

The resulting list of integration techniques will be expected to correlate to the specific effects of breaking up teams, to capitalise on the positive, and to mitigate or eliminate the negative.

1.3.3 Evaluate integration efficiency

In determining how effective methods of integration are, the research will look at the perceived gains the various methods of integration can offer a team, from the perspective of engineering team members. A determination of efficiency will be based around the time spent on the interface between individuals and teams, and their perception of whether particular exchanges are value adding, and if so, then how valuable.

1.3.4 Propose optimal integration techniques

The analysis of the research presented, is intended to reveal trends of what methods work to integrate teams. The analysis will involve looking at what is perceived as value adding, and determining why this was the case. Where positively perceived interacted can be replicated by an organisation, this shall be specified, and where an interaction is perceived as non-value adding, a recommendation would be to remove that interaction from the team's workload.

1.4 Document overview

The research conducted as part of the Engineering Research Project is documented in three main sections of this report. The *Literature review* critically appraises literature on the subject of cross team integration that may be considered to inform the topic within the context of complex Defence programs, noting significant trends and shortfalls of this literature. *Methodologies* describes the manner in which original research conducted, as justified by linking to the expected outcomes. The results of the research are presented in *Findings*, in addition to an analysis of the research findings. The conclusion summarises the major findings, and proposes areas for future research.

2. Literature review

As part of the investigation of integration effectiveness on complex Defence programs, a literature review was conducted to identify, and critically assess, the value of integration in such programs, as well as the ways people have sought to integrate teams. The integrating factors are broadly grouped into organisational factors, planning factors, and tools and processes.

Much of the literature was based on engineering integration of teams in non-Defence environments, and assessed for applicability to Defence. In order to make this link to the chosen context, a review of the literature on the Australian Defence programs, and the contributors to the success of such programs was conducted.

The primary source of literature was scientific journals, but this was supplemented by a combination of websites, books and online articles. Numerous references were made to publications of the Australian Government for information about Australian Defence programs, NASA Systems Engineering Handbook (NASA, 2007) and the Project Management Bodies of Knowledge Guide (PMBOK, 2008).

2.1 Context definition - Engineering of complex Defence programs

Programs for Defence are often very complex. In order to gain a tactical advantage over potential enemies, Defence, as an industry, is hugely reliant on cutting edge technologies. In gaining this advantage, and to fill holes in Australia's defence capability, the Government has frequently tendered developmental programs, rather than purchasing Commercial-off-the-shelf (COTS) products. Even programs making use of COTS products can veer into developmental territory, when modified, or when different COTS items are merged into an integrated product. Developmental programs of substantial scale and cost are considered to be complex programs. In recent decades, such programs have experienced high cost and schedule overruns, driven by the need for contractors to propose a fixed price for the development of technologies not yet in existence.

Lawes (2006) describes the contemporary warfighting environment to be defined by complex physical, human and informational terrain and urban environments, increased threat diversity, diffusion and lethality, coupled with threats from air, land or sea (Lawes, 2006). The formalisation of Program Management as a discipline emerged from need to manage Defence programs in the 1950s (Stoshikj, et al., 2014).

Hayes, et al. (2011) noted that Complex Defence Systems are typically systems of systems. They cite Secretary of Defence Robert Gates saying that "a risk-averse culture, a litigious process, parochial interests, excessive and changing requirements, budget churn and instability, and sometimes adversarial relationships within the Department of Defence and between DoD and other parts of government" have created "unacceptable problems" in acquisition programs for the US. The authors relate this back to program complexity, and note that the problems apply to Australian Defence programs, resulting in the formation of an International Centre for Complex Project Management (ICCPM) in conjunction with the Australian Defence Material Organisation (now the Capability, Acquisition and Sustainment Group). The Centre seeks to address the frequent cost and schedule overruns experienced on complex programs, and has teamed up with the Queensland University of Technology to deliver courses in Complex Program Management. Notable challenges of Complex programs include;

- Misaligned stakeholder views of success, with a common point of conjecture being program and product success, where the value added by a product is not considered in a program's success criteria (also investigated and supported by Chang, et al. (2013)),
- Political pressure,
- Underestimating technical risk,
- Overly competitive tenders driving underbidding,
- Limitations and restrictions of traditional procurement practices,
- Limitations of traditional tools and techniques to manage cost, schedule and performance,
- Lack of experienced program managers, and
- Scope creep due to immature requirements (Hayes, et al., 2011).

Education (particularly education of Program Managers) is cited as being the key driver in overcoming these challenges, but integration is considered to assist with several issues, in particular, underestimating technical risk, scope creep and misaligned stakeholder views of success.

In addition to the isolation of engineering efforts on Defence programs, further detrimental segregation naturally occurs between Customer, Prime Contractor and Subcontractor organisations due to cultural and distance barriers. An initial investigation of the factors contributing to cost overrun on Defence Acquisition programs highlights the importance of integrating the outputs of these teams. 'Integration' emerges as a key focus area for both Defence and contracting organisations to reach the cost, schedule and quality requirements of a Program. The 2014-15 Major Projects Review (ANAO, 2015) highlights that integration issues occurred in the following areas;

- MRH-90 – Contingency funds applied for integration risks,
- E-7A faced difficulty in integrating a phased array radar and other mission critical elements into an operational system,
- Risk management not integrated with Defence processes,
- Schedule slippage often resulted from difficulties in, and underestimation of system integration, as experienced on the FFG Upgrade, Wedgetail, Air to Air Refuel, ARH Tiger Helicopters and MRH90 Helicopter,
- An integrated Program Management System was being developed at the time, and
- A need for Integration of project plans.

Furthermore, lessons learnt from previous audits propose that:

- Integrated Product Teams need to include all major stakeholders and disciplines (engineering, logistics, commercial, test and evaluation, and display development), and
- With the development of complex battle management systems, where all products can communicate with one another, there needs to be great interoperability between systems (ANAO, 2015).

The International Centre for Complex Project Management (ICCPM) webpage (ICCPM, 2016) provides a portal into a number of papers addressing issues faced by complex programs. The ICCPM partners with the Australian Government Department of Defence, QUT, CSIRO, BAE Systems and Thales, so it provides a collection to works relevant to complex Australian Defence programs. In general, however, the papers are poorly referenced and at times unprofessional, leading weight to an assumption that program management on complex programs is more an art than a science.

Experts from QUT in Brisbane have defined complex projects to be characterized by uncertainty, ambiguity, dynamic interfaces, and significant political or external influences; and/or Usually run over a period which exceeds the technology cycle time of the technologies involved; and/or Can be defined by effect, but not by solution (Hass, 2009).

Examples of programs to build the Defensive Capability of Australia include those listed in *Table 4 - Complex Defence programs,* and pictured in *Figure 3 - Air Warfare Destroyer, Hawkei Armoured Vehicle, and Wedgetail E-7A.*

Program	Contractor	Complexity driven by
Air Warfare Destroyer (SEA 4000 Ph 3)	Raytheon Australia Pty Ltd	Budgeted $8.5 billion rose to $9.3 billion. Development and production of new product, for manufacture in Australia, and heavy modification from plan. In development since 2007 (Kerr, 2014) (CASG, 2014).
Hawkei Armoured Land Vehicle (LAND 121 Ph 4)	Thales Australia	Designed and built in Australia, with several years of development and manufacture. Like AWD, pushes the bounds of Australian manufacturing. Cutting edge technology (CASG, 2016).
Airborne Early Warning and Control (E-7A) (AIR 5077 Ph 5A)	Boeing Defence Australia	A highly technical upgrade of several mission and radio systems on the E-7A Wedgetail Airborne Early warning and Control. Both scope of work and cost are large (CASG, 2015).

Table 4 - Complex Defence programs

Figure 3 - Air Warfare Destroyer (CASG, 2014), Hawkei Armoured Vehicle (CASG, 2016), and Wedgetail E-7A (RAAF, 2016)

The Defence Capability Acquisition and Sustainment Group (CASG) notes that since 2005, Australian Defence programs have been delivered on average 5% under budget, with 96% of program performance measures being met, and with a 30% schedule slippage (CASG, 2016). The variation between cost and schedule would seem to indicate that the cost associated with schedule slippage is being borne by Defence contractors, rather than the Department of Defence. Furthermore, there has been a move in recent years to the acquisition of Military off the Shelf (MOTS) products rather than developing products in country (ANAO, 2016). Examples include the Boeing P-8 Poseidon, Airbus KC-30 tanker, Boeing EA-18 Growler (Super Hornet variant) and the Lockheed Martin Joint Strike Fighter F-35 (ANAO, 2015). The move away from developmental products means that the Defence capability of Australia uses solutions designed for use by other countries, primarily the US. The remoteness and geographical challenges of Australia are not inputs to the design of these products, so they are unlikely to be a perfect fit for the Australian Defence Force.

2.2 Definition of integration

The term 'integration' is used with varying meanings in different contexts. Within Defence and the Aerospace industry, commonly spruiked terms include Integrated Product, and Integrated Team. Whether in reference to a product or team, integration refers to having subcomponents of the product (sub-products) or teams (sub-teams or individuals) working together as a whole (NASA, 2007) (Baiden & Price, 2011). It should be noted that Integration Teams can also refer to a team formed to integrate sub-products into a product.

Niemann-Struweg (2014) defined three areas of integration, being Organizational integration, Stakeholder integration and Environmental integration. While all three are very relevant to Complex programs, Organizational and Stakeholder integration will be focused on for the context of integration of engineering teams. The observation is also made that Organizational integration should be achieved before pursuing stakeholder and environmental integration (Niemann-Struweg, 2014).

For the purposes of this report, 'Integration' will refer to the extent that teams and individuals in different teams on a program share information. This is supported by the literature of Baiden & Price (2011), who consider that team integration refers to the collaborative alignment of teams with different goals, needs and cultures into a cohesive and mutually supporting unit.

2.2.1 The silo effect defined

Throughout the reviewed literature, the term 'silos' is frequently used, to refer to teams within a program working in isolation from other teams. This phenomena emerges when a team reaches a large enough head count that it becomes necessary to form teams to address these problems. To do this, those roles are grouped to form a team, based on a relationship of projects. These teams, when working in isolation of other teams, can be considered 'silos' (Legacy, et al., 2012).

In grouping individuals in a team, segregation occurs between people who would otherwise have been working together. This is a problem for the following reasons:

- Work can be misdirected to areas not in alignment with project goals
- Teams need to be able to adapt as product requirements change, otherwise sub projects can deviate from what the customer actually wants. Customer requirements are frequently adapted on complex programs, and without stakeholder input to define and accommodate these changes, a program will be ill equipped to deal with such change.

Siloing specifically refers to the 'vertical integration' of programs, where teams form their own hierarchical structure, to the exclusion of other 'silos' on the program. Information flows from the top down, or bottom up. Typically, the interface through to other teams is through the team manager, so if an engineer on one team requires input from, or requirements for, engineers on other teams, that information needs to be passed up the hierarchy, passed to the opposing manager, then down the hierarchy of the relevant team (Niemann-Struweg, 2014). Clearly, this is inefficient, and the inability for information to flow horizontally can be highly dangerous for a program.

To allow for teams to work effectively together, 'horizontal integration' is required, whereby free lines of communication across teams and departments exist, inclusive of business units, functions and regions (Niemann-Struweg, 2014). A siloed organisation structure is depicted in *Figure 4 - Example of a siloed organisation,* with the orange 'X's representing the blockers preventing horizontal integration. The investigation of these blockers represents a significant portion of this report, through literature review and interviews.

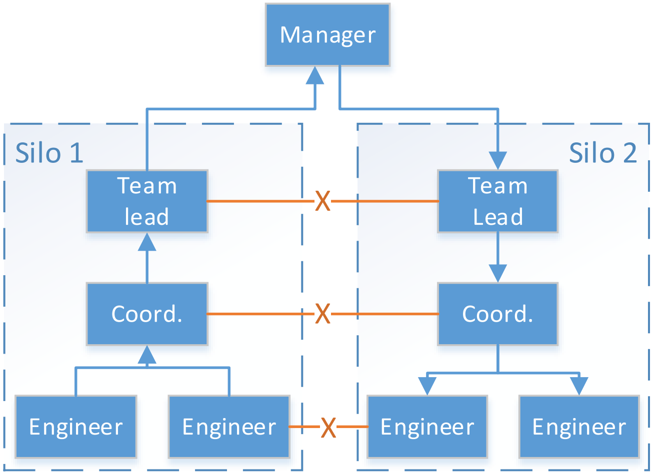


Figure 4 - Example of a siloed organisation

2.3 The value of integration

The value of integration is an integral part of the research conducted. The literature serves to identify the link between program integration and program success. This link is broken down further, and some specific benefits that integration may afford a program are identified. As a benefit, innovation as supported by integration has been heavily research, and is covered in detail. Other benefits (risk reduction and sharing of knowledge) and the disadvantages through cost are not specifically covered in the identified literature, and as such are covered in the *Findings* section on *Defining the value of integration*.

2.3.1 Integration and program success

When defining the factors contributing to program success, effectiveness and efficiency, program integration or aspects of program integration emerged as a common thread. Success, effectiveness, and efficiency do have slightly different definitions (refer to *Definitions*), but it can be assumed that effective and efficient programs have a greater prospect of success. Therefore, factors contributing to the effectiveness or efficiency of a program are assumed to also contribute to a program's success. Literature review identified that the following integration related aspects can contribute to Program success:

- Stakeholder engagement (Chang, et al., 2013),
- Internal and external stakeholder relationships (Mazur, et al., 2014), and
- Cross-functional integration (Frinsdorf, et al., 2014).

Additionally, 'The Chaos Report' (Standish Group, 1995) listed the level of user involvement to be one of the most significant factors influencing project success.

Each of these areas relate to the definition of Integration, in that they all present opportunities for teams or individuals to collaborate, or work together more easily. It clearly follows that if these factors are important for program success, then integration is equally important for program success.

Table 5- Determinants of program success/efficiency/effectiveness links the above contributors to the determinants of program success, efficiency and effectiveness.

Success determinates	**Means of Success**
Cost, Schedule, Quality, New Defence capabilities, Improved industry relationships, and Customer satisfaction.	Stakeholder engagement. Project Manager attributes (Chang, et al., 2013) (Mazur, et al., 2014)
Efficiency determinates	**Means of Efficiency**
Time, Cost, and Customer satisfaction.	Management support, Defined project goals, Cross-functional integration, Project team co location, Concurrency, and Collaborative work environment. (Frinsdorf, et al., 2014)
Effectiveness determinates	**Means of Effectiveness**
Resource availability, Project duration, PM experience, Location, Project size, Senior management visibility, and Level of technology.	Available resources, Experienced PM, Single location, Good visibility, and Manageable technology levels. (Farmer, et al., 2014)

Table 5- Determinants of program success/efficiency/effectiveness

2.3.2 Innovation as a product of integration

A common theme on managing complex programs, is that traditional program management cannot be relied upon for the program to succeed – Innovation is a necessity (Heydari & Dalili, 2015). Livens & Moenaert (2000) highlight that project communication within the team and towards stakeholders drives innovation, but note that the quality of communication processes greatly influences product development performance. While their research and cited resources are dated, there are a number of observations that remain relevant. They define communication as the passing of information from one party to another, with the intent of changing the behaviour of the opposing party, and highlight that innovation, which is interpreted as the communication driving innovation, is important in managing uncertainty on projects. They use the notion of "information requirements" to define communication lines between teams, noting that these drive information dependencies between project teams, which in turn drives the need for integration. They interpret integration as intra-project coordination, which is consistent with the definitions used in this report (Livens & Moenaert, 2000).

Ponchek (2016) reviewed research papers into drivers of innovation, and highlights the role of collaboration in the innovation process, noting (at least historically) that most innovation comes from large companies (Ponchek, 2016). Again, cited references are old, and not considered entirely applicable to innovation today, when the internet has enabled the sharing of information as a driver of innovation, without the need to physically interact. The argument can be made that the internet is a form of interaction, but for the purposes of this report, the sharing of information by being made publically available is not a considered means of integration. Modern readers are not considered to be interacting with Shakespeare himself. Ponchek (2016) notes that inter-organisational (inclusive of inter-project) collaboration is not as effective as extra-organisational collaboration (Ponchek, 2016). While not explicitly stated, this is assumed to be because innovation is often a product of two seemingly disconnected bodies of knowledge combining to come up with an "out-of-the-box" solution to an existing problem. Similarly, Chesbrough (2006) and Vanhaverbeke (2006) both reported that the vertical integration, where innovation comes only from internal Research and Development teams, is ineffective a driver of innovation, calling it the "closed model of innovation" (Chesbrough, 2005) (Vanhaverbeke, 2006).

The predominant theme from research correlating innovation and integration, is that teams need to be outwards facing in order to innovate, seeking to collaborate across teams, organisations, and industries.

2.4 Planning factors contributing to program integration

In projects, it is commonly seen that the decisions made early on have the most significant impact, especially in terms of cost, since the consequences of such decisions can influence a program for the duration. It is therefore important that early planning and strategizing the integration of teams is conducted. The findings on significant planning factors impacting cross team integration are identified below. Additionally, the flow down from management and visibility of defined goals for product teams was identified by Farmer, et al. (Farmer, et al., 2014) as being a significant enabler of aligned work activities.

2.4.1 Program Management

The Project Management Bodies of Knowledge identify Project Integration Management as the first knowledge area in Project Management (Hornstein, 2015). Turkulainen, et al. (2015) also flagged Integration as a fundamental issue in program management, due to efficiency improvements to be gained by sharing information and knowledge across an organisation. They specifically looked at project-to-project and project-to-organisation interfaces. Pitsis, et al. (2014) highlighted the importance of governance in complex projects. Chang, et al. (2013), Mazur, et al. (2014) and Frinsdorf, et al. (2014) highlighted Program Manger attributes as significant influencing factors to the level of cross team integration occurring on a program.

2.4.2 Product breakdown and work breakdown

Due to the complexity of Defence programs, it is generally necessary to form sub teams to engineer a program solution, causing segregation of engineering efforts. Integration is a critical consideration for Program Managers working in on Defence Programs, and one that has a significant impact on the efficiency and resulting success of such Programs. Typically large and complex, the size and scope of Defence Programs usually necessitates the program being managed through a series of teams, each with a clearly defined area of responsibility. The result of this segregation is a need to integrate the various areas of a program, in order to deliver a coherent and cohesive product or service.

While the importance of integrating the various facets of an Engineering plan are well recognised and promoted, how well integration occurs is an area that receives little attention in commercially available research. In a field where 'Systems Engineering' is so critical, this is a notable absence, as Systems Engineering focuses in no small part on the verification and validation of an engineered solution.

Engineers, individually and under normal time constraints, are able to design simple structures and systems. When the design becomes more complex, and coupled with a time constraint, more engineers are required to complete the task, and a need for management arises. As complexity increases further still, the numbers of engineers and other roles grow again.

Systems are broken into logical subsystems based on technical similarity, in a Product breakdown structure (PBS). A Work breakdown structure (WBS) will generally include those items on the PBS, but will include discrete activities in the areas of Management, Systems Engineering, Integration and Verification, and Integrated Logistics Support (NASA, 2007).

Program management tools or systems are cited by Stoshikj, et al., (2014) as a tool for management of the work breakdown, tracking status, allocating activities and tracking cost and resources. Included in this should be a definition of communication methods, and information distribution tools, as identified by the Project Management Body of Knowledge (PMBOK, 2008).

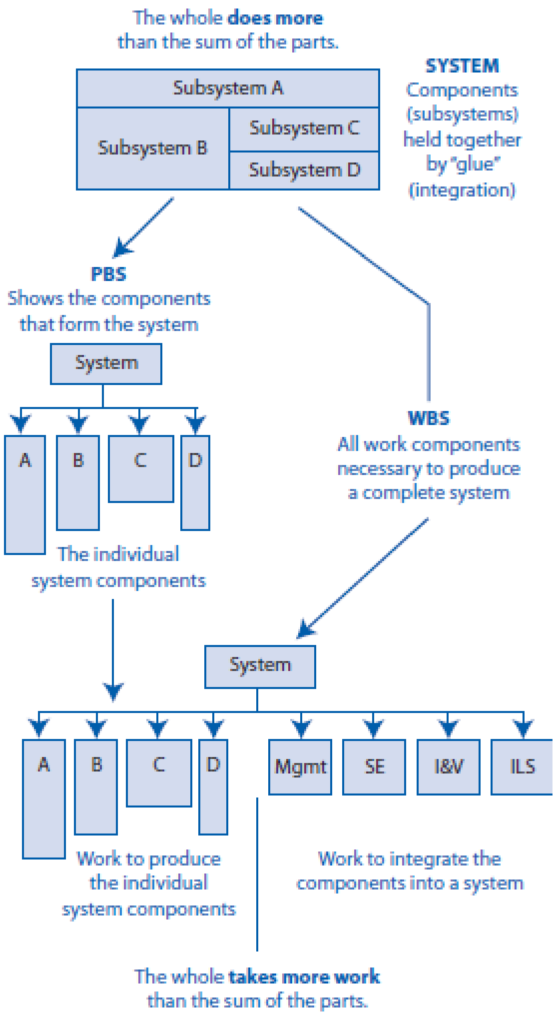


Figure 5 - Relationship between a system, a PBS and a WBS (NASA, 2007)

The NASA Systems Engineering Handbook (NASA, 2007) notably states, in reference to the difference between a Product Breakdown Structure (PBS) Work Breakdown Structure (WBS), that "the whole takes more work than the sum of the parts.

The delta, as shown in *Figure 5 - Relationship between a system, a PBS and a WBS (NASA, 2007)* is the "work to integrate the components into a system". That work fits into the functions of Management, Systems Engineering, Integration and Verification, and Integrated Logistics Support (NASA, 2007).

2.5 Organisational factors contributing to program integration

In an analysis of literature linking program success and program integration, the following integrating factors were identified, but in low levels of detail;

- Project team colocation,
- Concurrency, and
- Collaborative work environment (Frinsdorf, et al., 2014).

Additionally, the wealth of information on the merits of open plan workspaces and the optimisation of team size warranted separate sections herein.

2.5.1 Open plan workspaces

The perception of open plan offices highly varied, given the advantages and disadvantages of their use.

Kaufmann-Buhler (2016) discusses advantages and disadvantages of the use of open plan environments, with the advantages being that they;

- Promote equality between workers,
- Promote verbal communication and collaboration (driving high usage in design offices, e.g. architecture),
- Reduce cost through higher space utilisation,
- are adaptable to respond to organisational change, and
- give an image of being a progressive organisation.

The downsides of open plan environments include:

- A loss of privacy,
- Inability to personalize workspace,
- loss of status for managers,
- High noise, and
- They cater for verbal communication, not other mediums introduced through modern technologies (Kaufmann-Buhler, 2016).

Nearly all research regards open plan workspaces negatively, and note the reduction of cost to be the most common driver of their use (Kaufmann-Buhler, 2016) (Featherstone, 2015). Furthermore, Featherstone (2015) noted that only companies with a great need for innovation would benefit from open plan offices. This is, perhaps, reinforced by the move of by leading technology companies, such as Facebook, Pixar and Google, to move towards open plan offices, citing the higher potential for collaboration (Featherstone, 2015) .

2.5.2 Optimisation of team size

Staats, et al., (2012) noted that that the number of possible linkages within a team is;

$$N \times \frac{N-1}{2}$$

Using this formula for a team of 15 people, there would be 105 relationships. They proceeded to look at how team size effects the efficiency of larger teams. In a review of existing literature they noted that advantages of larger teams include;

- Labour can be subdivided across more team members, leading to a need to match workers with tasks of interest, and foster task specialization, which improves performance
- Broader base of knowledge and experience, and
- More slack resources which can be deployed if circumstances change.

Three challenges of larger teams were highlighted, being:

- A difficulty in coordinating the team, stemming from;
  - The time required to keep members informed,
  - The threat of miscommunication between team members, and
  - The need to re-integrate completed work, requiring additional time and effort, termed coordination neglect (Heath & Staudenmayer, 2000)
- A tendency towards less motivation among team members, based on:
  - Less effort being put in due to social loafing and free riding, and
  - Membership being less satisfying, and
- Conflict, due to more competition between team members.

2.6 Tools and processes contributing to program integration

In addition to planning and organisational factors, the efficient use of tools and processes are considered to be enabling factors for the integration of product teams on programs. Literature on specific tools was not identified, and the primary process identified was systems engineering.

2.6.1 Systems engineering

Systems engineering offers a framework which can significantly influence the level of integration on a program required. Locatelli, et al. (Locatelli, et al., 2014) noted that Systems Engineering may be applied to governance, including integration issues. They noted that on the International Space Station program, NASA effectively integrated 5 aerospace agencies from 15 countries, under a Systems Engineering approach. This highlights that Systems Engineering processes and principles definitely have the potential to provide a framework for gauging the effectiveness of interfaces, and resulting integration. Furthermore, they gave a general sense of how systems engineering could be applied, but in insufficient detail as to how to do it.

Systems engineering is, in itself, a methodology of balancing the inputs of different technical disciplines, or teams. As described by Michael Griffin, of NASA;

> *Systems engineering is the art and science of developing an operable system capable of meeting requirements within often opposed constraints. Systems engineering is a holistic, integrative discipline, wherein the contributions of structural engineers, electrical engineers, mechanism designers, power engineers, human factors engineers, and many more disciplines are evaluated and balanced, one against another, to produce a coherent whole that is not dominated by the perspective of a single discipline.* (NASA, 2007)

Conformance to systems engineering framework should ensure that product and work breakdown and allocation is conducted in a logical, consistent way. The specifics of the framework are already well defined in existing literature, including the NASA Systems Engineering Handbook, and will not be looked at as a method of ensuring efficient engineering integration.

Systems engineering takes a program sequentially through processes for:

1. Requirements Definition
2. Technical Solution Definition
3. Design realization
4. Evaluation
5. Product Transition

Running across these steps are processes conducted as required for Technical Planning, Technical Control, Technical Assessment and Technical Decision Analysis (NASA, 2007). These processes are applied for each sub product on a PBS, as discussed in *Product breakdown and work breakdown*. The definition processes establish an agreed set of requirements to satisfy stakeholder expectations.

Systems Engineering is commonly illustrated through the ‘Vee’ model (Locatelli, et al., 2014) shown in *Figure 6 - Systems engineering 'Vee' model (Locatelli, et al., 2014)*. Like *Figure 2 - Breakdown and re-integration of a system*, the figure illustrates how a concept is decomposed (into project teams) and defined, before being integrated and verified against a break down structure. The model identifies general tasks, which together form the methodology which is Systems Engineering.

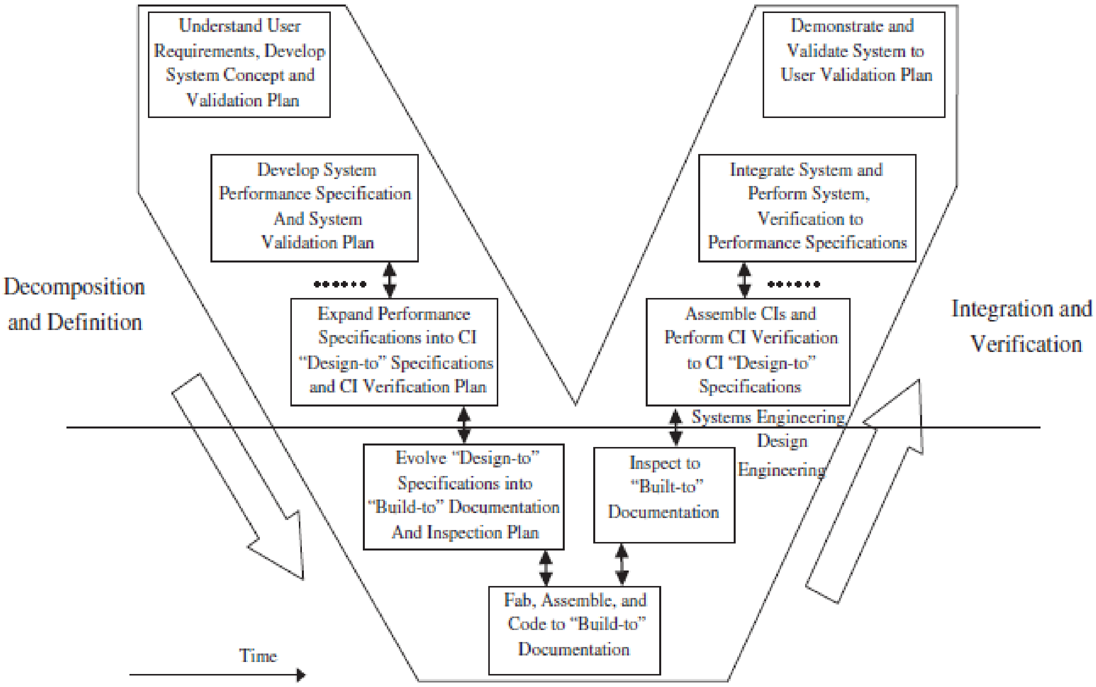


Figure 6 - Systems engineering 'Vee' model (Locatelli, et al., 2014)

The Model used by NASA (*Figure 7 – NASA's systems engineering engine (NASA, 2007)*) roughly follows the same process, but is more prescriptive in that it defines more processes, and in particular those processes for technical management, which serve to bridge decomposition and definition activities with integration and verification activities.

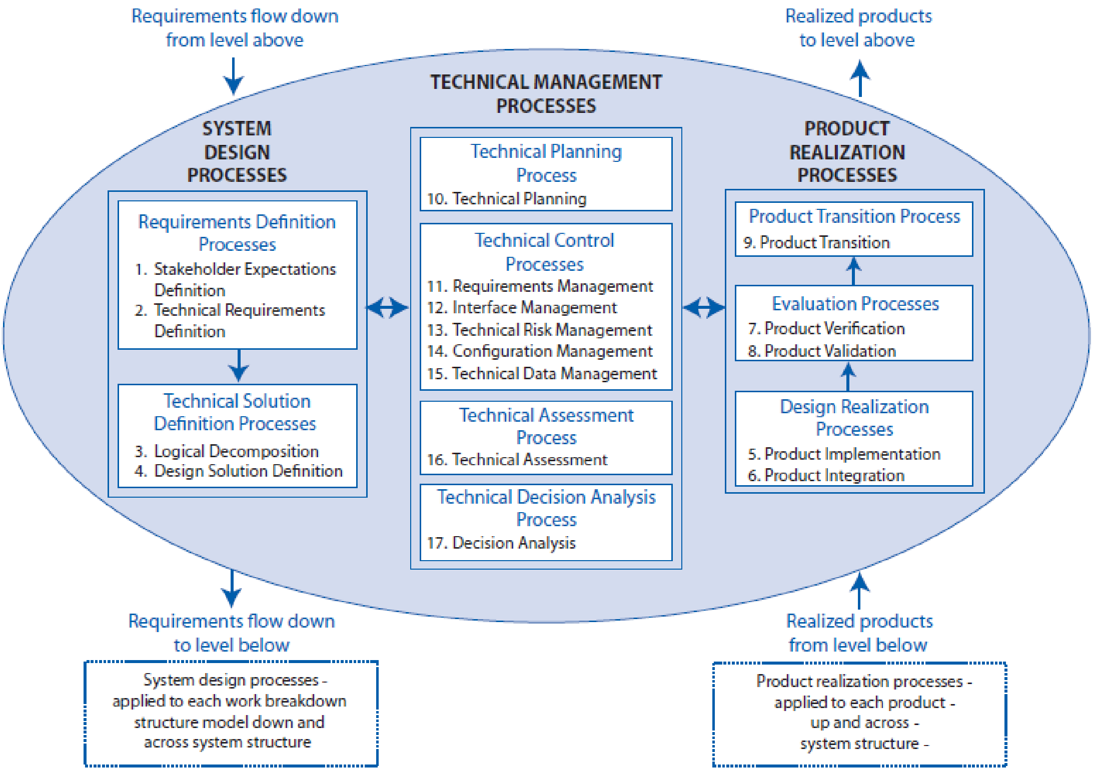


Figure 7 – NASA's systems engineering engine (NASA, 2007)

2.6.1.1 Interface definition

Interface definition is a significant component of System Engineering, in providing a framework for breaking down a system into a series of interface requirements, which can then be continuously monitored and verified through the course of a program (NASA, 2007). Furthermore, they can be a significant tool in identifying the necessary relationships between engineering teams through which the integration of teams can be optimised.

Wheatcraft (2010) recognises that Systems are part of bigger systems, are made up of subsystems and interact with other systems at the same level of architecture. A complex system generally has several layers of systems, and a large number of subsystems. Identifying the interactions, or interfaces, between systems can;

- Identify the boundary of a system,
- Help understand the system dependencies,
- Help understand the system requirements,
- Ensure compatibility between systems, and
- Expose risks to a program (Wheatcraft, 2010).

The systems of interest on this project include the various design and functional teams on a program, such as a Product Design Team. Transferring the above advantages of interface definition to a Product Team could help to;

- Identify the required scope of work for the team, while ensuring that the program has no gaps,
- Identify what help they need from other teams,
- Identify what other teams need help from them,
- Identify where a component of the design needs to be compatible with other parts (e.g. Avionics need to be compatible with airframes and mechanical systems)
- Identify areas of risk, including where systems are being developed concurrently and need to maintain compatibility.

As such, it is evident that Interface definition as a process within the systems engineering framework has the potential to aid the integration of teams.

2.7 Literature shortfalls

There are some major shortfalls in the literature identified, with regard to the topic of integration effectiveness. Notable omissions, in summary, include;

- A lack of definition of the value of integration, particularly with regard to the cost and the value of sharing knowledge to build the skill and knowledge levels of engineers,
- The identification of relatively few methods of integrating teams, except within the bounds of Project Management,
- Undue consideration for the effective level or depth of integration, but instead the prevailing assumption is that more integration of teams is always better,
- No demonstrated links between the integration of teams and the effect this has on the delivered product or system, and
- No attempts have been made to measure integration of engineering teams.

The value of integrating teams is not thoroughly defined in any of the identified literature, although individual articles do relate the integration of teams to an increase of innovation on programs, and there are many references to how teams working together can reduce risk for a program. The cost of integrating teams, and the importance of integrating teams to impart knowledge between them are considered poorly documented.

There are numerous integration factors which aren't covered in depth in the identified literature. The Project Management Bodies of Knowledge (PMBOK, 2008) and NASA

System Engineering Handbook (NASA, 2007) give thorough coverage to the factors considered part of Program Management and Systems Engineering disciplines, but outside of these bounds there are multiple omissions. Examples include the use of a System Engineering Integration Team (SEIT), use of responsibility, authority and accountability (RAA), planned interaction, and the consistent use of tools and processes across engineering teams as drivers of integration.

It is notable that the literature studied proposes how Integration may be increased (Hornstein, 2015) (Pitsis, et al., 2014) (Locatelli, et al., 2014), and therefore improved. The unstated assumption in these articles is that the more integrated a project, the better it will function. This assumption is examined through the use of interviews and surveys. This report proposes that efforts to integrate, when excessive or incorrectly targeted, can be detrimental to a program. As such, rather than to maximise integration on programs, this project will propose how to *optimise* integration.

No literature was identified which analyses the link between the integration of team, and the integration of Products. It is an unstated assumption in Systems Engineering literature that integration of teams will result in better products, but no identified study has proven this link.

No literature was identified which looks into the detail at how integration may be measured. There is potential that the concept of measuring integration may be too complex to measure, given the unique nature of complex programs. One hypothesis worthy of examination is that the level or depth of integration of a program may be indicated by the number of, frequency, and quality of interactions occurring between engineering teams over a given time period.

3. Methodologies

Research was conducted with the aim of defining;

- What Integration is and why it is important,
- The methods used to integrate programs, and
- The effectiveness of these methods.

Three different research methods were used to meet these aims;

- Literature review,
- Interviews, and
- Survey.

To define the value of integration and methods of integration, both a literature review and interviews were used, with the interviews being conducted of industry practitioners to record their observations and opinions on how integration occurs on complex Defence programs. To evaluate the effectiveness of integrating methods, a survey was employed in addition to the literature review and interviews. Specifics of these methods are contained in the sub sections below.

The interviews and surveys and associated analysis are used to either validate, disprove, clarify or expand on the existing research on why integration is important, and what is done to integrate teams.

Analysis will identify both common trends in the findings of the three research methods, as well as discrepancies between findings. Towards this end, the three research methods were not conducted sequentially. Throughout the course of research, literature was constantly referred to in order to support and validate findings from the interviews.

3.1 Literature review

The Literature review, as presented in section *2*, has been used to record relevant findings recorded in existing publications on the value, methods, and effectiveness of methods, of integration.

3.2 Interviews

The purpose of the interviews was to build on the findings of the literature review by identifying additional advantages and disadvantages to integration, integration methods, and perceptions of these methods. Eight people were interviewed, in roles including Product team lead, Integration manager, Senior Engineer and Engineer. The interviews were not recorded, but summaries of these interviews based on notes taken at the time are included at *7.4 Annex D – Interview Records*.

The interviewees were chosen very selectively. Rather than seeking to find the common perspectives across a particular program and within a particular company, the interviews seek to identify trends in perspectives of individuals who have worked across a range of Defence programs, for a range of businesses both within and external to Defence. In this way, it is considered that the findings will be more applicable to the engineering of complex Defence programs as a whole.

The structure of the interviews was loosely based around that used by Chang, et al., (2013). The interviews used a common core set of questions, with additional questions based on the known areas of expertise of an individual respondent. The approach to the interviews changed during the course of the research project, from asking many directed questions (as detailed in the interview records for Respondent 1) to asking a few broad, open-ended questions. This approach is intended to allow respondents to move the interview in the direction of the most important aspects of integration, in their view. It is considered that by doing this, any unintentional bias held by the interviewer wouldn't be reflected in the responses of the interviewee.

By comparison to the survey, the interviews ask broader, more open questions intended to extract opinions and other qualitative data from respondents. The results were used to direct and refine survey questions, and identify trends.

3.3 Surveys

The survey is used to support the findings of the interview, by asking participants to rate, and thereby quantify, some key findings from the interviews. The questions are specifically targeted to quantify the values of integration as applicable to a project, and to quantify the perceived effectiveness of integration methods. In this way, the survey extracts quantitive information from the qualitive findings of the interviews.

The survey asks more directed questions than those asked in the interviews. The specific questions are detailed in *7.5 Annex E – Survey design and records*. As with the interviews, the intent of the survey did change over the course of the research project. The initial intent was to gather information on specific interactions from a range of people on a program. The goal of this was to use the perception of specific interactions to gauge how well a product is integrated. However, this uses an assumption that was not able to be substantiated – that the level of integration on a program may be indicated through the quality and quantity of individual interactions between team members.

The survey design underwent several changes. It shifted from the primary means or rating integration effectiveness, to supporting the findings of the interviews with the addition of more empirical data.

Initially, the intent was to have individuals highlight specific interactions between teams in addition to a frequency of interaction, in order to measure integration, as indicated by frequency of interaction, and the perceived effectiveness of those individual interactions. The resulting survey was very complex, and demanding on the time of respondents. Additionally, it is considered that individual interactions as remembered by individuals are too small a component of the overall integration of teams.

The survey concept evolved from the definition of interfaces between teams, to asking respondents to rate the identified values of integration for importance to their program, and secondly to identified factors contributing to integration of teams against those four values (risk reduction, innovation, knowledge building and cost). Even a simple iteration of this survey using only 10 integration factors would require participants to give 44 ratings, and as such took a significant amount of time. Trials of this survey were ineffective, as the response rate was too low.

The final iteration of the survey is a simplification of the above whereby participants were asked to rate the outcomes of innovation in terms of importance (critical, value adding, negligible value), the barriers in terms of prevalence (often observed, observed infrequently, not observed) and the contributing factors in terms of effectiveness (highly effective, can be effective, not effective).

11 people responded to the survey out of 20 requests. While below the planned number of survey responses, this number was considered sufficient to restrict individual bias, by reflecting an average score for the group of respondents.

3.4 Analysis

Analysis has been conducted to assess the validity of findings from the literature review, interviews and surveys, but also to rate the different findings for applicability to complex Defence programs.

The identified literature review was analysed, in order to estimate the credibility of findings and hypothesis they present. The estimate of creditability is based on consistency with other literature, the justification of presented views, and the citations by other authors, both in terms of the number of citations and the review of the identified literature in referenced works. Furthermore, the findings of the identified literature were assessed for applicability to the context of complex Defence programs, and is noted throughout the literature review.

While the findings of interviews and survey reflect the views of individuals and may be subjective, analysis was conducted to reduce bias. Specifically, conflicting findings were analysed to determine (where possible) which perspective has more credibility. Literature was identified throughout the course of the interviews, and used to either verify the findings, or to in-substantiate them.

Simple statistical analysis was conducted on the results of the interviews, by counting repeated occurrences of the same observations across interviews. This was recorded in *Table 9 - Value of integration as identified through interviews*, *Table 10- Barriers to integration identified through interviews*, and *Table 12- Integration methods identified in Interviews*. These trends were presented using bar graphs created in Microsoft Excel.

The design of the survey was informed by the findings of the interviews and surveys. The most prevalent identified issues were selected for analysis through the surveys, in addition to other factors which weren't covered to a great extent by the interviews, but were considered to have more merit than the interviews would suggest.

Further statistical analysis was conducted of the surveys. As noted above, the purpose of the survey was to quantify the effectiveness of integration methods, so averages of the reported numbers could be directly plotted in Microsoft Excel, highlighting the methods of integration that are considered to be the most effective. The standard deviation was identified to determine whether ratings varied greatly.

Finally trends were analysed based on the recurrences factors by a particular role. The comparison of the ratings of engineers and managers demonstrates that the perception of integration of a program varies depending on where the person sits within an organisation structure.

3.5 Safety

Personal risk were assessed based on *Table 6 - Risk matrix*, and are listed in *Table 7 - Personal risk assessment*.

		Consequence			
		Low impact	Medium impact	High impact	Catostrophic
Likelihood of Occurrence	Very unlikely	S1		S2	
	Unlikely				
	Likely				
	Almost certain				

Table 6 - Risk matrix

Risk ID	Risk Description	Likelihood	Consequence
S1	Exposure to hazards on defence sites	Very unlikely	Low impact
S2	Risk of accident while travelling	Very unlikely	High impact

Table 7 - Personal risk assessment

The above tables illustrate that while remote risks were present, they were at an acceptable level. The risks were mitigated by identifying and following the safety procedures and precautions of Defence or the relevant contracting company.

3.6 Resource requirements

The resource requirements for this project are detailed in *7.2 Annex B – Project Specification – Resources*.

3.7 Timelines

The timeline of the planned work and milestones is detailed in *7.3 Annex C – Project Specification - Schedule*.

4. Findings

The research conducted into the effectiveness of engineering integration on Defence programs has served to identify the value, barriers to, factors facilitating, and effectiveness of factors for integrating Engineering efforts on complex Defence programs. This section of the report documents the findings in these areas, as perceived by industry practitioners, and recorded through interviews and surveys.

The interviews and surveys were not wide ranging enough to say with confidence that the findings are relevant to all contractors working on Defence capability programs, considering that the interviewees are primarily working for the same company. However, the interviewees have a work history across a range of companies on different projects, with a commonality of always being for a Defence customer, whether Army, Navy or Air Force. The interviewees were chosen selectively, based on having broad experience on Defence programs, and this provides weight towards the findings in this section being relevant to all complex Defence programs in Australia.

4.1 Defining the value of integration

In simple terms, integration is the combining of two or more parts to make a unified whole (Merriam-Webster, 2016). As a word, it can be considered a widely held focus for the defence and aerospace industries. In observed programs, engineering work is conducted under an Engineering and Integration Manager who reports to the Program Manager. The Engineering and Integration Manager directs a Systems Engineering and Integration Team (SEIT) Lead, and Integrated Product Team (IPT) leads including a Support System IPT Lead, who in turn directs an Integrated Logistics Support (ILS) Manager. Each of these teams include Systems Engineers.

The use of “Integration” in the names of teams, of organisations, and of role titles demonstrates the focus on integration that the program has, a trend which is shared throughout programs within the organisation, and also within other Defence and Aerospace programs. The focus on integration is further illustrated by the continued use of these terms in the NASA Systems Engineering Handbook (NASA, 2007). The string ‘integrat*’ is found 583 times in the Handbook, excluding front and back matter instances (NASA, 2007).

While it is clear that the word integration is commonly used, the context and how it is used is less clear. Within the Systems Engineering context as used by NASA, integration generally refers to the integration of sub product or systems into a complete product or system, as opposed to the integration of teams or people. However, *Figure 5 - Relationship* *between a system, a PBS and a WBS (NASA, 2007)* does demonstrate a link, in that the product breakdown directly drives the work breakdown to different teams. The assumption follows, that the integration of sub-systems to form a whole requires those people developing the sub systems to work together. The view that that sub products cannot efficiently be combined to a workable product without teams working together is one held by several people interviewed.

Three overarching advantages of integration were identified, and one overarching disadvantages, as listed in *Table 8 - Advantages and disadvantages of team integration*.

Advantages of Integration	**Disadvantages of Integration**
1. Reduction of risk 2. Innovation 3. Sharing of knowledge	1. Inefficiency through distraction from primary work

Table 8 - Advantages and disadvantages of team integration

These broad categories were identifying the values of integration identified through literature and interviews. A more comprehensive list is contained in Table 9 - Value of integration as identified through interviews. The table shows where a particular value has been identified through literature review ('LR'), by an interviewee ('ID'd by respondent'), and the total number of interviewees identifying a particular value ('Sum').

#	**Value of integration**	**L**	**ID'd by respondent**								**Sum**
		R	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
1.	Innovation - Sharing perspectives	Y		Y		Y			Y		4
2.	Risk – contributes to unified, consistent product		Y		Y			Y		Y	4
3.	Cost – Time spent talking to others		Y	Y				Y			3
4.	Ability to respond to change			Y							1
5.	Risk - Sharing perspectives to find a point of balance/ Goal alignment	Y	Y	Y		Y	Y	Y		Y	7
6.	Creates cross discipline expertise			Y							1
7.	Risk – Noncompliance			Y	Y						2
8.	Risk – Customer identified conflict in deliverables			Y							1
9.	Cost – duplication of effort				Y			Y			2
10.	"You don't know what you don't know"			Y	Y	Y					3
11.	Wider focus than necessary						Y				1
12.	Problems found early							Y			1

#	Value of integration	L R	ID'd by respondent 1	2	3	4	5	6	7	8	Sum
13.	Distraction due to high noise from verbal interactions	Y									1

Table 9 - Value of integration as identified through interviews

Risk mitigation through sharing of perspectives was identified in the vast majority of interviews, followed by innovation and the creation of a consistent, unified product.

4.1.1 Reduction of risk

The primary value of integrating engineering teams is the reduction of risk. Reduction of risk in some manner was identified by all interviewees as being the primary reason for integrating teams. It was noted that the higher the level of risk on a program, the greater the need for integration through cross domain input (Interviewee_2, 2016). Management of risk in on Defence programs is an area of focus, due in part to the potential catastrophic effects of product failure, and the use of firm fixed-price contracts tendered by defence. The risks mitigated by integration are multi-faceted.

The first risk is considered to be that teams will proceed in different, and potentially conflicting directions. When this occurs, the result will be wasted effort, in pursuing non value-adding initiatives (Interviewee_4, 2016), or rectifying conflict during the verification and validation (V&V) phase of a program (Interviewee_6, 2016). By way of example, Interviewee 6 (2016) referred to an instance while working on the design of a coal movement system, where one team was responsible for writing a standard for Supervisory control and data acquisition (SCADA) systems used for the remote monitoring and control of conveyor systems through programmable logic controllers (PLCs), for use by all teams programming the SCADA systems. The aim of the standard was to use coding that was easily customisable for ease of use by the operator. Other teams however, while aware of it, opted not to use the standard, instead hard wiring code for ease of input. The result was that the standard and actual coding deviated, and to regain consistency the standard needed to be rewritten to accommodate programming techniques which resulted in a reduction in customisable of the system. In another example, while working for an electronics company, three different teams were observed using their own processes for managing change, resulting in inconsistency between teams (Interviewee_4, 2016).

The second risk, and the more catastrophic, is that a system will not work when the sub-systems are integrated. This was highlighted on the Hubble space telescope program (Interviewee_3, 2016), where it wasn't know until it was in space and began sending pictures back to Earth that it did not work. In this case, a mirror was misaligned due to a faulty measuring device, and built to a wrong specification, and resulted in multiple missions to rectify the fault (Pearce, 2012). In this case, integration between design teams and manufacturing and assembly teams may have identified the fault before launch (Interviewee_6, 2016).

Thirdly, there is risk that teams will produce an end product that is not compliant with the contract or required legislation. This can occur when the priorities of teams or individuals take undue precedence over others. Interviewee 5 (2016) highlighted that by putting multiple ideas and perspectives to an open forum, it allows the group to find the middle ground through a solution that balances the priorities of all teams involves. While noncompliance isn't as catastrophic as product failure, it has the potential to be very damaging to the profit and reputation of a company

Fourthly, a risk of inconsistencies between deliverables is higher when collaboration doesn't occur between teams. Interviewee 2 (2016) noted that customer reviews frequently focus on identifying conflicting information between deliverables. Such conflicts when identified reflect poorly on a contractor organisation, and can be indicative of the second risk, that the system or product won't work when put together.

Fifthly, an ever apparent risk on Defence programs is that the contract, and associated system requirements will change. Such changes arise due to evolving technologies, optimisation of the scope of work, and the customer changing requirements. As the customer, Defence personnel frequently receive new postings (ADF Recruitment Centre, 2016), so if a capability program spans more than 5 years, then it is likely that there will be few people remaining on the program for its duration. As such, requirements are prone to change based on the preference of individual customers (Interviewee_7, 2016). Having the ability to quickly between teams through horizontal integration enables teams to respond and manage this change. It is notable that the people are adaptable, but processes are not, so people need to be involved whenever change occurs (Interviewee_2, 2016).

4.1.2 Innovation

Existing research has repeatedly demonstrated that collaboration can increase innovation, as demonstrated in *Literature review*, *Innovation as a product of integration*. Existing literature has shown that people have a much better chance of coming up with original ideas, if they are able to combine their perspectives with others. This is the same reason that many companies encourage diversity (Stevens, et al., 2008).

Innovation was not a predominant advantage of integration brought up by interviewees. Interviews 2 and 4 did note that innovation is important on complex programs that are highly developmental, but for the majority of Australian programs, the extent of complexity is integrating existing, rather than developing new technologies. It was noted that for research and development programs, the need for innovation is paramount, but for integrating Commercial-off-the-shelf (COTS) or Military-off-the-shelf (MOTS) products, the importance is negligible (Interviewee_4, 2016). However, innovation is considered useful in finding better ways of conducting engineering activities. It was noted that the prescriptive nature of the Australian Standard for Defence Contracting (ASDEFCON) suite of tendering and contracting templates dictate a need for meeting customer requirements using defined methods, rather than seeking new ways of doing things. Furthermore, a view was noted that the Defence, and the ASDEFCON templates in particular, place the development of deliverables leads design development, instead of design leading documentation (Interviewee_4, 2016) (Interviewee_5, 2016).

In contrast with the perceived lack of importance of innovation amongst interviewees, observed programs do highlight innovation as being important, through Program Charters, and as a company value (Thales Group, 2016) (Boeing, 2016). This is reflective of new ideas being more valuable to a company, as something that can be sold or reused across multiple programs, than valuable to a program, to whom the potential of an idea is primarily in more efficiently satisfying the program Scope of Work.

4.1.3 Sharing of knowledge to develop engineers

Programs rely heavily on Senior Engineers, not only to not only to develop designs based on an understanding of process, but also to conduct multiple tiers of review on deliverables, to understand what can go wrong and how to mitigate the risk, and to guide others (Engineers Australia, 2012). The required skills are developed over several years of engineering practise, in part through the conduct of engineering activities, but also by interacting with more senior engineers and practitioners, capturing their lessons learnt without having to experience failures firsthand. It is considered having engineers of varying levels of experience collaborating and imparting knowledge, is a significant outcome of the integration of engineering teams (Interviewee_6, 2016).

Sharing knowledge to develop engineers is considered more important to the business than the program. The benefits of developing senior engineers is primarily seen long term and is cumulative, whereas a program will only see short term benefits, given that the acquisition phase of a program will usually only last for a few years. The knowledge of future engineers will sustain the business in years to come (Interviewee_2, 2016).

Further to the aspect of developing the skill of engineers, the sharing of information is critical when a contract changes hands, for example between Acquisition and Support

Contracts, which are always tendered separately by Defence (Interviewee_8, 2016). An example of this is on a defence program for an upgrade of the particular RAAF aircraft, acquisition was conducted by Rockwell, while Hawker de Havilland was awarded the support contract. However, Hawker de Havilland found upon handover that the required information to support the platform was not sufficiently documented, but instead existed only in the heads of Rockwell engineers. Ultimately, Hawker de Havilland walked away from the contract. To fulfil the terms of the support contract, Hawker de Havilland needed to be firmly integrated with the cooperation of Rockwell. Problems based around a lack of documentation are compounded by attrition – when individuals leave a company, the information in their heads goes with them (Interviewee_3, 2016).

4.1.4 Cost

It is considered that many methods and integration, and the associated increase in collaboration, has a cost. The majority of interactions observed between teams under the banner of 'horizontal integration' take the form of a person asking for information or help from an individual in another team. Such interactions may, in some instances, be value adding for both parties, but in most instances there will be little value to the person accommodating the request. As such, work is duplicated, and time is spent doing work outside of the technical discipline in which an individual is paid to work (Interviewee_3, 2016).

A noted trend is that the people receiving the most requests for help are the most experienced members of the team, either managers or senior engineers. Senior engineers are depended on by a program to do much of the scope of work of a contract, so time spent imparting knowledge to others within the team can be a significant investment. *Figure 8 - Amount of time spent answering and asking questions against experience* notes this trend, showing the more experienced an engineer, the more questions they will be asked, and conversely, the less experience an engineer has, the more questions they need to ask. This emphasises that interactions need to be assessed for value, and managed accordingly.

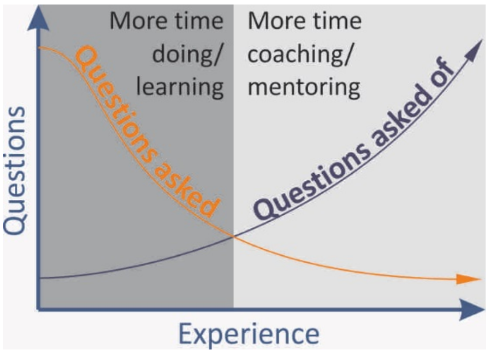


Figure 8 - Amount of time spent answering and asking questions against experience

The cost of integration should be balanced with risk. Interviewee 2 (2016) uses the analogy that "there is no point in taking to a walnut with a sledge hammer", meaning that if a particular task is low risk, one may accept the risk and proceed with the necessary actions, rather than wasting the time of several people by getting buy in from all the stakeholders (Interviewee_2, 2016). If the benefits of integrating teams are not understood, then and individual will usually adopt the view that spending money on integration initiatives is not worthwhile (Interviewee_3, 2016).

Aside from the time involved in exchanging information, frequent interaction in the workplace has the potential to be disruptive, and to prevent individuals from focusing on their work, and the priorities of the team. Deliberate isolation is sometimes practical, in scenarios where engineers shouldn't be influenced by the views of others, for example when evaluating tenders (Interviewee_5, 2016).

4.1.5 Survey results - Importance of integration values and burdens

The survey results for the rating of the values and burdens of cross team integration are represented by the graphs in *Figure 9 - Survey results for value added and burdens created by integration*, and *Figure 10 - Comparison of integration value ratings for engineers and managers*.

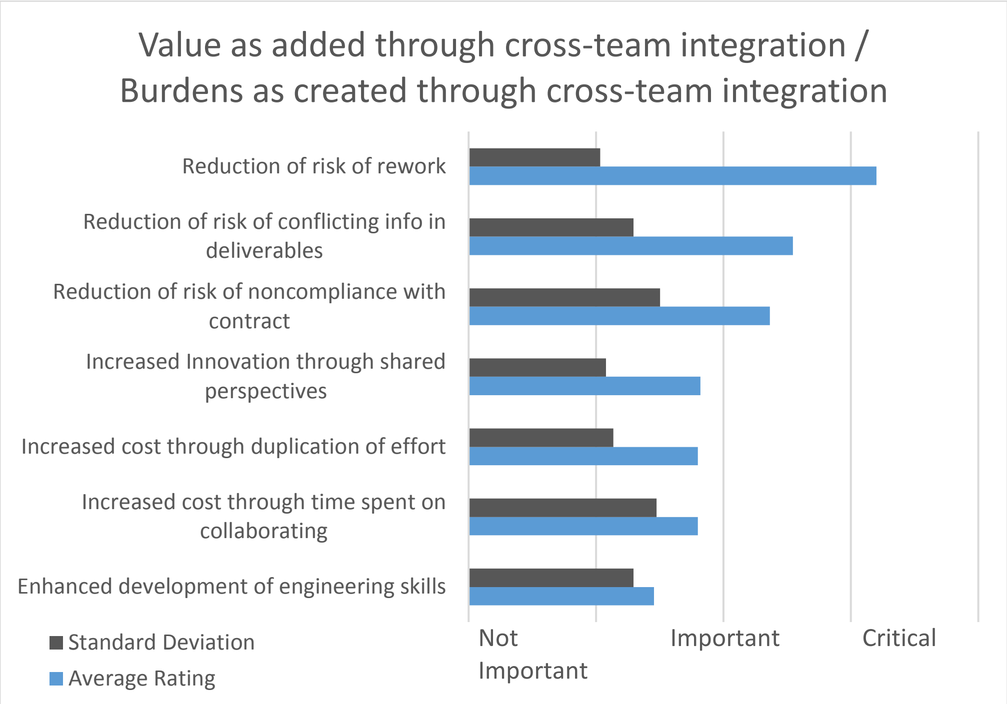


Figure 9 - Survey results for value added and burdens created by integration

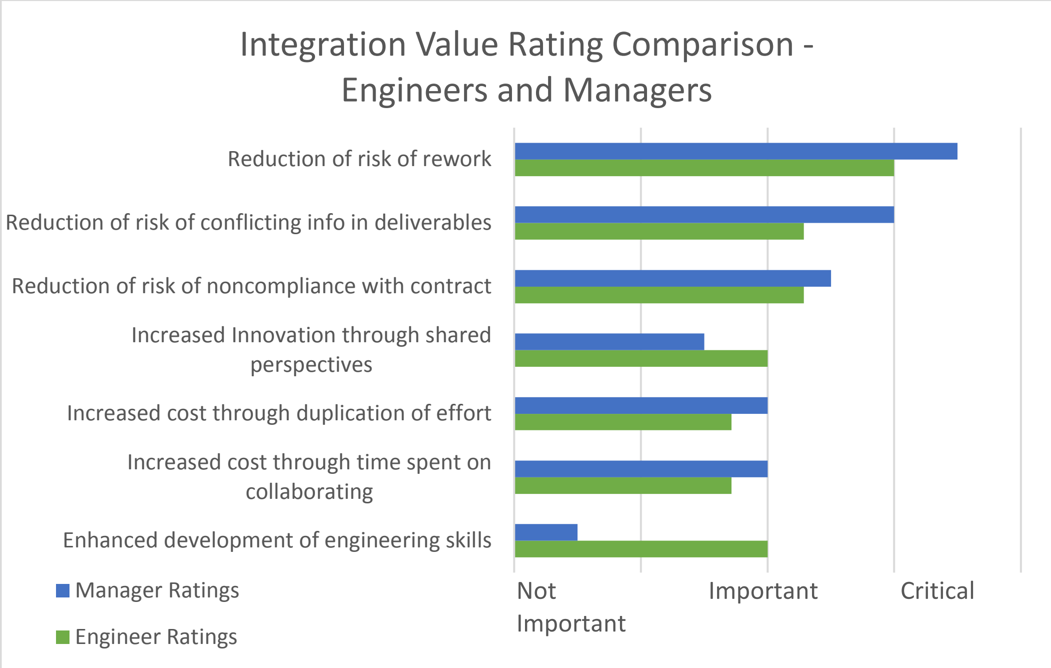


Figure 10 - Comparison of integration value ratings for engineers and managers

4.1.6 Discussion of survey results – Importance of integration values and burdens

Several notable trends were noted from *Figure 9 - Survey results for value added and burdens created by integration*, and *Figure 10 - Comparison of integration value ratings for engineers and managers*. The reduction of the risk of rework was widely held as the most valuable outcome of integration, as demonstrated by a very high average rating and low standard deviation. The three risk categories emerged as the top three values, reinforcing that risk, to the sample surveyed, is the most important reason for cross team integration. The risk of inconsistencies being identified by the customer was considered to be significantly higher in the eyes of managers, than to engineers. This highlights a discrepancy in the goals and priorities of teams, as viewed by engineers and managers.

The next highest value was innovation, which was generally perceived as being important, but not critical. This is reflective of the sample programs being based around the implementation of COTS or MOTS products, and is supported by the interview comments that innovation is more important for highly developmental products. The value of finding new and better ways of doing things are assumed to be rarely seen amongst the sample population.

The cost factors were generally perceived as being not important, but there was a significant standard deviation. As noted through the interviews, the cost is considered to be offset by the advantages that cross team collaboration can bring.

The development of engineering personnel had the lowest overall rating for importance, but the variance between the ratings given by engineers and managers was very high. This shows that engineers rate their development, as far as impacted by collaboration with engineers from the wider team, far more highly than managers do. This may be associated to the observation that the gains of personal development are seen in the long term, while the life of a program is relatively short. As such, personal development has most value to the individual and the business, ahead of value to a program.

4.2 Barriers to Integration

Barriers to integration were identified through interviews. The assumption used in that methods to overcome these barriers may also be considered integrating factors, for further analysis. *Table 10- Barriers to integration identified through interviews* provides a summary and notes recurrences of barriers. The column 'LR' highlights those barrirers which were identified through literature review, and a 'Y' under the column 'ID'd by respondent' highlights where an interview has identified a barrier. The column 'Sum' gives the total number of interviewees covering a barrier.

#	**Barrier to Integration**	**LR**	**ID'd by respondent**								**Sum**
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
1.	Location	Y	Y		Y			Y			4
2.	RAA		Y	Y							2
3.	Time – too busy		Y	Y		Y					3
4.	Lack of information flow from management	Y	Y					Y			3
5.	Prerequisite work for a task isn't completed – can't get required input			Y							1
6.	Pressure on individuals			Y							1
7.	Lack of documentation, compounded by attrition causing lost information				Y						1
8.	Earned Value Management (EVM)				Y						1
9.	Poor requirements derivation				Y						1
10.	Awareness of who does what				Y	Y	Y				3
11.	Allegiance to sub team before program					Y					1
12.	Dislike of management/other team members					Y					1
13.	Bureaucracy – excessive review chains					Y					1
14.	Psychological – Unwillingness to ask for help						Y				1
15.	Difficult customer				Y			Y			2

#	Barrier to Integration	LR	ID'd by respondent								Sum
			1	2	3	4	5	6	7	8	
16.	Individuals think they know better than everyone else							Y			1
17.	Individuals need to see personal gain to interact							Y			1
18.	Team leaders not flowing on program objectives							Y			1
19.	ASDEFCON too prescriptive					Y					1

Table 10- Barriers to integration identified through interviews

Location, time, a lack of information flow from management, and a lack of awareness of who does what were the most frequently identified barriers to integration.

4.2.1 Psychological barriers

An unwillingness to ask for help is a common psychological barrier encountered by engineers, as demonstrated by the survey results. Particularly when pressure on a program due to tight schedules is high, it can be seen as an imposition to ask for help. This perception can potentially be reinforced by the demeanour of individuals being asked for help while under pressure (Interviewee_5, 2016).

4.2.2 Perceived need for integration

For both systems engineering and integration initiatives, there is generally a cohort who does not understand the reasons for them, not having being through a full program lifecycle and seen what can go wrong (Interviewee_3, 2016). These people are likely to adopt mind frame that they know best what the objectives of a program are, and will likely present a barrier to the integration of teams (Interviewee_5, 2016).

4.2.3 Time

A frequently observed barrier to the integration of teams is people being too busy. Defence acquisition programs are planned with frequent milestones, to which specific deliverables are tied. The schedule for these deliverables can be aggressive, and as such people perceive that they only have the capacity to work on the deliverables assigned to them. In such cases, the priorities of team are placed above those of the program. The follow in impact of tight time frames, is a perception of pressure, which leads individuals to focus on their own work, to the exclusion of all other priorities (Interviewee_2, 2016).

A trend noted in the interviews is that the higher a position of an individual in a hierarchical organisation structure, the less time they are likely to have, and as such the quantity and duration of interactions needs to be controlled and restricted.

4.2.4 Earned Value Management (EVM)

Earned value management (EVM) is a key tool in the breakdown of work, and can be a barrier to the integration of engineering teams. Using EVM, work is allocated to specific individuals following manager approval. Since individuals need to charge their time back to a specific job package, for an engineer to help out another team, they need to be granted access to a charge code. This adds a layer of bureaucracy, but also can be discouraged by mangers keeping a tight hold of their 'purse-strings'. EVM works by trying to optimise every single bit, but can result in the end product being sub optimal (Interviewee_3, 2016).

4.2.5 Understanding the allocation of work

Insufficient knowledge of the knowledge, skills and attributes (KSA) of wider team was highlighted as a barrier to integration, in that team members do not know who has expertise in particular areas, and as such who they need to approach to obtain the necessary information to inform engineering and design activities. This creates a vicious cycle in that the less they know about the KSA of others, the less questions they will ask, and the less questions they ask, the less they will learn about the KSA of others (Interviewee_4, 2016).

4.2.6 Lack of awareness of concurrent engineering activities

Coupled with the Understanding the allocation of work as a barrier, the phrase 'You don't know what you don't know' was brought up in three interviews. A lack of awareness of program decisions may be a barriers, if the decisions affecting product teams aren't flowed down in a timely manner. In this case, time can be wasted doing work that isn't in accordance with modified direction. For example, if contract changes aren't flowed down to the requirements of a sub product, then the product team can't accommodate them. Similarly, different product teams may be faced with identical design problems and challenges. If teams are not aware of the challenges faced by other teams, then they cannot leverage off the work already done (Interviewee_3, 2016) (Interviewee_4, 2016) (Interviewee_5, 2016).

4.2.7 Bureaucracy

Bureaucracy has been noted as a barrier to integration, so far as it makes the request and receipt of information difficult. If the difficulty in obtaining information is high enough, then an individual is likely to not bother attempting to get it. This can be the case where Product lifecycle tools or engineering management systems enforce several layers of review and approval before information can be used in a formal capacity (Interviewee_4, 2016). Bureaucracy also hinders integration as noted in *4.2.4 Earned Value Management (EVM)*, in that if it too difficult for an individual to gain approval to do work for another team, they are less likely to try and undertake such work (Interviewee_3, 2016).

4.2.8 Location

Location was frequently noted as a barrier to integration, since face-to-face conversations aren't practical (Interviewee_6, 2016). It is assumed this stems from a common perception that face-to-face interaction is the most effective. Phone calls and email don't allow for communication through the use of body language, and the distance barrier contributes to a lack of familiarity with team members, and resultantly an unwillingness to interact. Technological advances in teleconferencing do go some way to bridging this barrier, but are not widely accepted as yet.

4.2.9 Allegiance to product team instead of to program

On large programs, it can be common for individuals to identify more as a member of a product team, than a member of a program (Interviewee_5, 2016). A sense of obligation to the team can be reinforced by familiarity and friendship, and a lack of allegiance to a program can be reinforced by a perceived disinterest from management, considering that management are perceived embodiment of the program (Interviewee_4, 2016).

4.2.10 Lack of support from management

In a general sense, there are several integrating factors which would normally be implement by management, and if these do not occur, this conveys a perception that there is no need for integration on a program. More specifically, the nature of EVM is such that people are allocated specific tasks to do, and to deviate from the specific work allocated needs the support of management, through a wiliness to allocate work packages to individuals from other teams. Additionally, if a manger doesn't promote and set an example of collaboration with other teams, team members are likely to do the same (Interviewee_3, 2016).

4.2.11 Mitigating factors to barriers

The identification of the barriers to integration is only value adding, if integrating factors to mitigate them are also identified. Table 11 - Mitigating factors to integration barriers lists the barriers identified in this section as links in the first column, and the second column contains links to the corresponding section of *4.3 Integrating factors* which details the mitigating factor/s those barriers.

Barrier to Integration	**Mitigating factors**
4.2.1 Psychological barriers	*4.3.2.4 Cross team meetings*
4.2.2 Perceived need for integration	*4.3.2.6 Education of the importance of integration*
4.2.3 Time	*4.3.2.2 Scheduling*

4.2.4 Earned Value Management (EVM)	*4.3.2.5 Attributes of managers in facilitating integration*
4.2.5 Understanding the allocation of work	*4.3.2.4 Cross team meetings* *4.3.2.7 Role rotations*
4.2.6 Lack of awareness of concurrent engineering activities	*4.3.3.1 Use of common tools and processes across teams*
4.2.7 Bureaucracy	*4.3.2.5 Attributes of managers in facilitating integration*
4.2.8 Location	*4.3.3.1 Use of common tools and processes across teams*
4.2.9 Allegiance to product team instead of to program	*4.3.2.3 Flow down of priorities from management*
4.2.10 Lack of support from management	*4.3.2.3 Flow down of priorities from management* *4.3.2.5 Attributes of managers in facilitating integration*

Table 11 - Mitigating factors to integration barriers

4.2.12 Survey results - Observed prevalence of barriers to integration

Survey participants were asked to rate the barriers to integration for frequency at which particular barriers were observed. The possible responses were ‘Frequently observed’, giving a rating of two, ‘Infrequently observed’ giving a rating of one, and ‘Not observed’ giving a rating of zero. The average score for each barrier as well as the standard deviation in the ratings for that barrier are shown in *Figure 11 - Survey results for observed frequency of barriers to integration*. A comparison of the average ratings given by engineers to the comparison of ratings given by engineering managers is shown in *Figure 12 - Comparison of integration barrier occurrence observed by engineers and managers*.

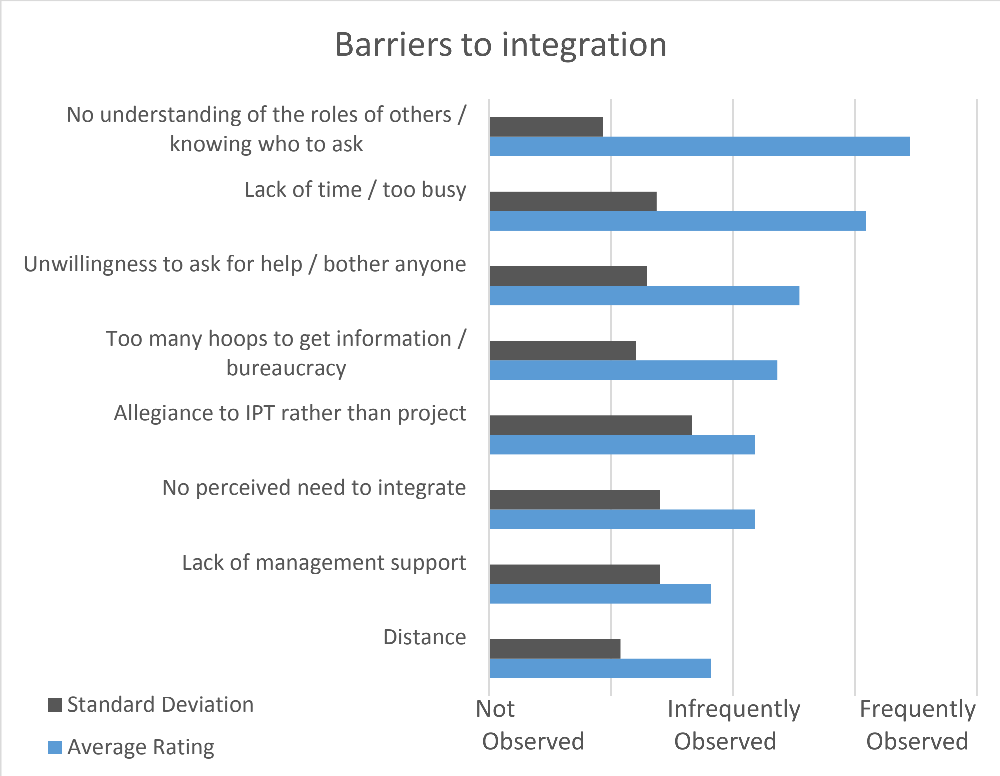


Figure 11 - Survey results for observed frequency of barriers to integration

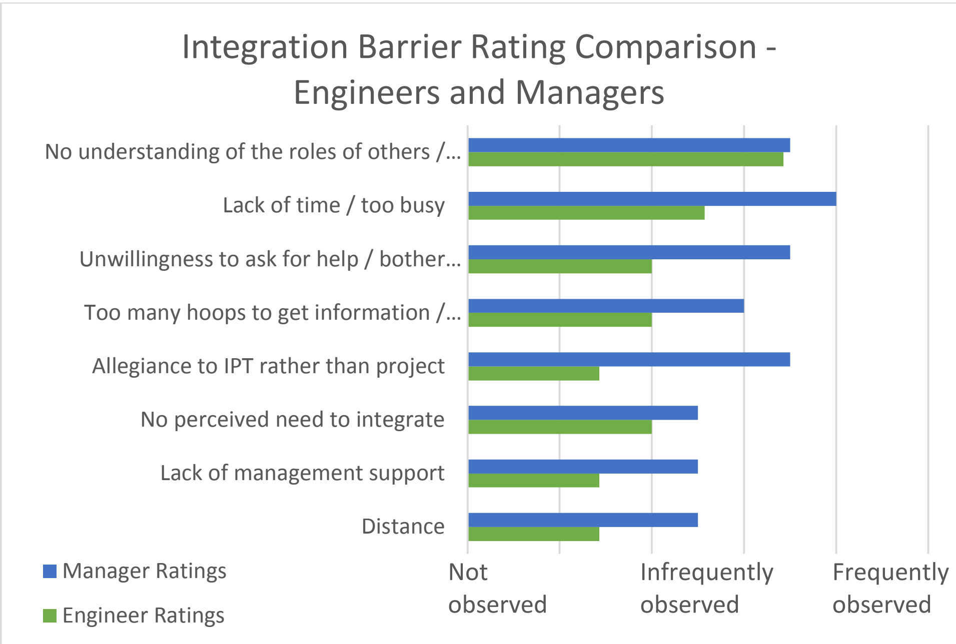


Figure 12 - Comparison of integration barrier occurrence observed by engineers and managers

4.2.13 Discussion on survey results - Observed prevalence of barriers to integration

A lack of understanding of the knowledge, skills and attributes of other people in a program emerged prominently as the most frequently observed barrier. The barrier had the highest average score, with the smallest standard deviation. This barrier was rated highly by engineers and managers alike. By contrast, distance was not perceived as a significant barrier. It is surmised that this is due to most survey participants working on, or having worked on programs in which team members are dispersed across multiple sites, and as such, have learnt to manage distance through effective use of online tools such as teleconferencing, and online work management tools such as electronic Work In Progress boards (Interviewee_6, 2016).

A lack of time, or being too busy was the second most frequently observed barrier, as supported by a prevalence in the interviews. A lack of management support was seen as the second least frequent barrier.

Significant differences in the frequency of observed barriers arose, but the barrier of an allegiance to a product team as opposed to a program showed the largest difference. This is expected to be because managers will generally interact with the managers of other teams, and as such, they have a greater to allegiance to the management 'team', and by association, the wider team. An unwillingness to ask for help was much more commonly seen by managers, in a surprising trend. It is expected that this is because the trend is easier to identify in others, and the role of management includes monitoring such barriers. Finally, managers cited a lack of time as being more of a barrier than engineers. This is supported by the observation that managers not only interact with their teams of reports, they interact with the management 'team', and as such have a much greater quantity of interfaces to manage. Staats, et al. (2012) noted this barrier.

It is notable that managers rated the barriers more highly across the board, when compared to engineers. I is expected that this is because managers will regularly monitor teams for such blockers.

4.3 Integrating factors

The identification and evaluation of integrating factors is an important part of this research project, because the findings can be directly used to advise teams on the most effective way to integrate, as discussed in *4.4 Optimisation of integration*.

The integrating factors were identified through the literature review, and interviews. The factors and where they were identified are recorded in *Table 12- Integration methods identified in Interviews*.

#	Integrating factor	LR	ID’d by respondent								Sum
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
1.	Open plan	Y	Y		Y						3
2.	Systems Engineering Integration Team (SEIT)		Y	Y	Y			Y			4
3.	RAA			Y							1
4.	Effective product and work breakdown			Y							1
5.	Consistent use of tools and processes			Y		Y		Y			2
6.	Timing of work activities	Y		Y				Y	Y		3
7.	Senior Engineers interface between IPTs			Y							1
8.	Interface definition	Y		Y							2
9.	Use both agile and lean management of interactions			Y							1
10.	Functions should be embedded in IPTs (Matrix organisation) for better goal alignment (than a functional organisation)			Y	Y						2
11.	Management flow down of priorities feed common priorities in IPTs			Y							1
12.	IPT lead to employ “Plan, do, check, act” to ensure common direction			Y				Y			2
13.	Team lead chases required info			Y							1
14.	Tool – Work In Progress (WIP) boards			Y							1
15.	Tool – Communications matrix			Y							1
16.	Cross team meetings included in “operating rhythm”			Y		Y					2
17.	Leaders promote and embody a collaborative environment	Y			Y						2
18.	Hot desking (physical rotation of desk position)				Y						1
19.	Matrix organisations exhibit better schedule performance				Y			Y			2
20.	Critical to SEIT effectiveness that team members are embedded in IPTs, and parallels development				Y						1
21.	A well-integrated team will be reflected in a well-integrated product				Y			Y			2

#	Integrating factor	L	ID'd by respondent								Sum
		R	1	2	3	4	5	6	7	8	
22.	Team members present what they're doing to the wider team on a rotational bases					Y					1
23.	Optimisation of team size	Y					Y				2
24.	Outside of work interaction					Y	Y				2
25.	Logical grouping to teams – include the team members that most frequently need to interact	Y					Y				2
26.	Set common expectations for all teams, using "Plan on a page"							Y			1
27.	Assess methods of communication used							Y			1
28.	Identify blockers on a Work In Progress (WIP) board used by all teams							Y			1
29.	Colocation	Y			Y			Y		Y	4

Table 12- Integration methods identified in Interviews

Open plan offices, the Systems Engineering Integration Team, timing of work activities, and colocation were most frequently identified in interviews.

4.3.1 Organisational factors

The broad category of organisational factors includes many factors which facilitate the collaboration of teams. Primarily these factors are implemented at program level by the Program Manager or other managers.

4.3.1.1 The Systems engineering integration team (SEIT)

The role of the SEIT is to integrate the sub products produced by the IPTs. To this end, the SEIT contains the common tools and specialists (in such areas as reliability, availability and maintainability (RAM), deployability, supportability, manufacturing, Human Factors, and System Safety) to ensure compliance to key program plans (Interviewee_2, 2016).

There have been two iterations of the SEIT used by a Defence contractor. In the first, IPTs would develop sub-products to hand off to the SEIT once complete, to integrate the sum of sub-products into a workable and integrated whole. In conducting integration post development of sub products, the SEIT ended up being just as siloed as a product team, having their own budget. The depth of integration was considered too weak for the SEIT in this iteration to be effective.

The second SEIT iteration evolved from the first. In this iteration, the SEIT is given a level of precedence and authority over the product teams, in order to ensure cooperation from the IPTs. Secondly, SEIT engineers are embedded in the IPTs, doing work within that defined technical discipline, but reporting any fundamental issues with the way that IPT operates to the SEIT Lead. In this way, inconsistencies in the developed products have a chance of being picked up early, before work progresses too far down a wrong path. It is important that SEIT Engineers have a the skills and experience to add value to a Product Team, in order to easily integrate with the team, rather than being seen as an additional layer of management oversight. It is also important that they've seen programs through to completion and understand what can go wrong, so this can be reported to the SEIT lead (Interviewee_3, 2016).

4.3.1.2 Integrated Product team

Following the breakdown of work, work is allocated to Integrated Product teams (IPTs). In siloed organisation, product teams work in isolation, leaving the integration with other teams to occur at the depth of Team Lead or above. The move by Defence contractors to append 'integrated' to the defined product teams, represents a desire to move away from this model, to one where 'horizontal integration' occurs at greater depth, such that engineers in different IPTs will frequently work together. Frequently, it is the role of Senior Engineers on IPTs to work with their peers on other teams to identify common problems, and solve them, as defined in *Responsibility, authority and accountability (RAA)* (Interviewee_2, 2016).

4.3.1.3 Open plan working environments

The literature review on *Open plan workspaces* demonstrated that there the use of open plan environments are primarily used as a cost saving initiative, and are only effective in environments where innovation is key. However it is noted that by including 'hot-desking', where people rotate seats every few weeks in order to get to know more members of the team, psychological barriers, in an unwillingness to ask people for help, are broken down. The time spent moving desks does have a cost, but is an investment in long term collaboration (Interviewee_3, 2016).

4.3.1.4 Matrix Organisations

Matrix organisations employ multiple reporting chains, where an individual will report to both a functional manager, and a program manager. Project teams in matrix organisations will be cross discipline teams, with a mix of engineering, logistics and support staff. In contrast with a functional organisation, where individuals report only to a functional manager, Matrix organisations can exhibit improved communication flows, efficient use of resources, increased flexibility and better performance due to complementary expertise among managers. Conversely, there is a possibility for morale problems, conflicting priority due to multiple reporting lines, and increased cost due to system complexity and redundancy (Britannica Academic, 2016). The organisational structure depicted in *Figure 13 - Example Organisation Structure used in Defence on acquisition program* is considered a matrix organisation, in that the individuals in the Engineering Organisation report up to the program manager rather than a functional lead, but still has functional elements shown as External Teams, which offer services to the program. In a purely matrix structured organisation, these roles would exist within the identified product teams. Conversely, in a functional organisation, the roles within the Engineering Organisation would all exist within External Teams, predominantly in an Engineering function.

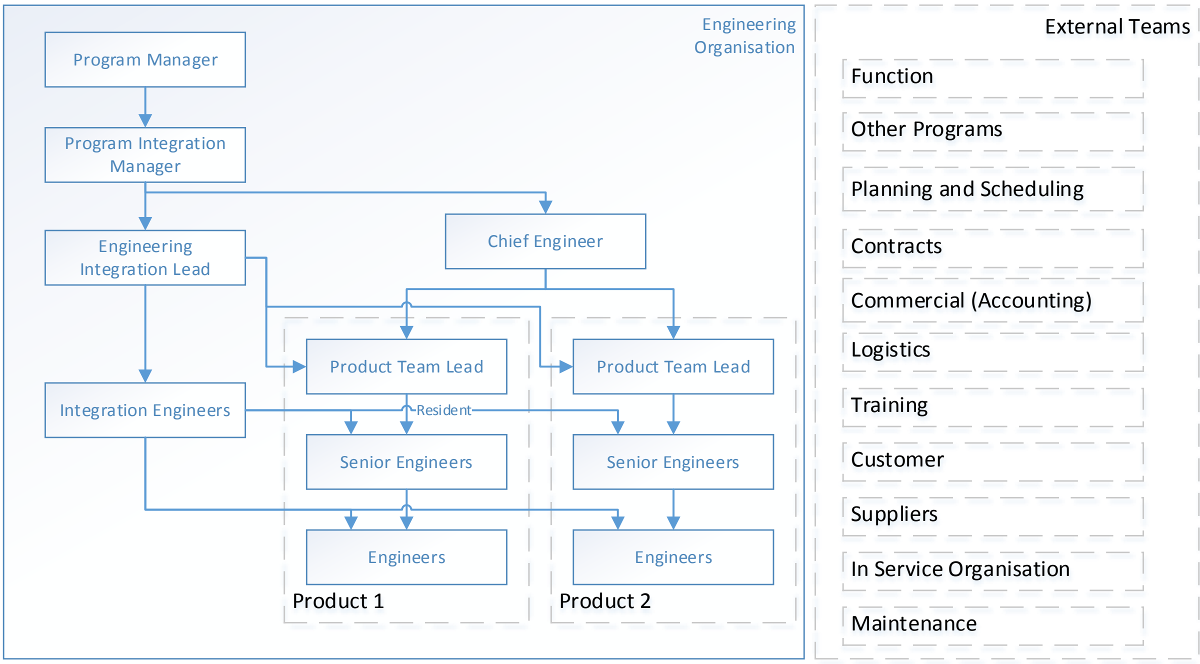


Figure 13 - Example Organisation Structure used in Defence on acquisition programs

Matrix organisations were noted as an effective method of organising teams, based on a capacity to meet schedule requirements, and having the skill sets at hand to complete the required work (Interviewee_3, 2016) (Interviewee_6, 2016). It was also noted that there is potential for further use of such structure on a particular program, whereby the Integrated Logistics Support personnel could be embedded in project teams, rather than existing as a separate team (Interviewee_2, 2016). This approach has shown to be effective on other defence programs (Interviewee_3, 2016).

It is noted that matrix organisations are expensive to set up, with projects having to find and employ people to work on a program, rather than borrowing individuals from an existing pool (Interviewee_3, 2016).

4.3.1.5 Responsibility, authority and accountability (RAA)

The notion of using responsibility, authority and accountability (RAA) as an enabler of integration arose as a mitigating factor against people being too busy to interact. The intent is that individuals are encouraged to provide assistance to related teams by mandating this through position descriptions and performance goals and appraisals. Interviewee 1 (2016) noted that clarity of responsibility is important for cross team collaboration, as individuals are more likely to help other teams if this is a defined responsibility. If individuals have a 'booking code' to charge to for time spent helping other teams, it keeps such interactions above the table, or legitimate (Interviewee_3, 2016), but there is an amount of bureaucracy involved in getting work packs signed to other teams.

4.3.2 Planning factors

Planning of integration is considered essential for effective engineering integration on complex programs. *Figure 14 - Typical cost and staffing levels across the project live cycle (PMBOK, 2008)* highlights that decisions early in the project are compounded throughout the life of a product (Interviewee_6, 2016), and as such the strategic implementation of integration factors is important to the success of a program.

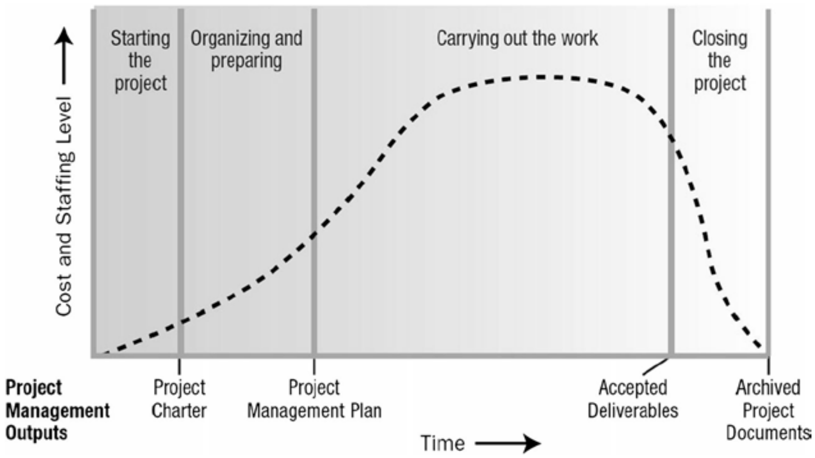


Figure 14 - Typical cost and staffing levels across the project live cycle (PMBOK, 2008)

Many of the Program Management Outputs defined in this figure and in PMBOK serve to integrate the teams on projects.

4.3.2.1 Work breakdown structure

As noted in the project *Background*, the need for integration arises as a side effect of work breakdown. Using the term ‘integrated’ in ‘integrated product team’ may be considered an oxymoron, considering that the formation is in itself a de-integrating activity (Interviewee_3, 2016). It is necessary activity however, to manage the team size (Staats, et al., 2012). This was supported by the view presented in interview that large programs exhibit lower levels of collaboration than small to mid-size teams (Interviewee_5, 2016). The Work breakdown structure (WBS) has an impact on the integration of teams that is seen for the duration of a program. The effect de-integrating should be minimised, by grouping individuals in teams consisting of the individuals that will most frequently need to interact (Interviewee_2, 2016).

In allocating work to product teams, specific requirements are derived to define the scope of work in designing a sub product. It is further noted that if work is broken down poorly, or requirements are poorly derived, then having teams working closely together to reallocate work is a necessity (Interviewee_4, 2016).

4.3.2.2 Scheduling

The integration of teams is impacted by scheduling, in that a common form of interaction between teams is a request for information. If that information is not yet documented through a prerequisite task, then it will not be possible to get that information through collaboration with other teams – it must be developed from scratch. As such tasks should be scheduled such that the work having the most flow on should be conducted first. For example, the engineering and design of a product should ideally be completed before the development of manuals to accompany those products, otherwise engineering and development will need to be conducted by technical publications personnel (Interviewee_2, 2016) (Interviewee_7, 2016).

On observed programs, design and build run almost in parallel, with design preceding by only a small margin. In such instances, consideration of the next design work conducted so that build can follow is especially important (Interviewee_2, 2016).

4.3.2.3 Flow down of priorities from management

It is important on complex programs that common priorities are flowed down from management, and used by team leads to balance work among team members (Interviewee_2, 2016). A further role of the team lead is to assess the work being conducted against the priorities of the program. Interviewee 3 (2016) notes that priorities are rarely flowed down effectively on Defence programs.

Interviewee 6 (2016) noted that the flow down of priorities will assist in setting common expectations for the team, and in doing so reducing the risk of inconsistency between sub products and deliverables.

4.3.2.4 Cross team meetings

Programs will frequently define an 'operating rhythm', which plans the meetings and routine interactions and activities for IPTs. By including regular meetings between teams in the operating rhythm, where discussion of the issues faced takes place, teams have the opportunity to collaborate to resolved on common (or similar) issues. This illustrates how integration can be a driver of innovation, in finding better ways to solve common problems. Meetings with the Program Manager as well as other teams has been proposed as an appropriate forum for discussion of issues and challenges affecting the wider team (Interviewee_4, 2016).

It is noted that meetings are commonly overused on particular programs, and planning of meetings should ensure that only those people adding value should be present at meetings, and for efficiency all attendees should have an understanding of the intent of a meeting and the input required of them (Interviewee_2, 2016).

Interaction occurring outside of the workplace between colleagues can also facilitate integration by increasing the familiarity between team members, and in doing so breaking down *Psychological barriers*.

4.3.2.5 Attributes of managers in facilitating integration

Managers at team lead level or higher have the ability to influence integration through their actions, and the examples they set. The actions of a manager are likely to be replicated by the team. For example if a manager doesn't show trust to team members, then the team will not trust a manager (Interviewee_4, 2016) (Interviewee_6, 2016), or if a manager does a lot of unpaid overtime, employees are likely to be pressured into following suit. Interviewee 2 (2016) notes that it is effective for leads to follow a 'plan, do, check, act' model, as illustrated in *Figure 15 - Plan, Do, Check, Act model for team alignment*, whereby the lead will agree to a plan work with an individual team member, they will conduct the work, then the lead will check the work and make the necessary changes to priorities. The 'check' step facilities integration, if the lead and team member seek to identify blockers in the form of information required from other teams, and accordingly plan the necessary interactions to attain this information (Interviewee_2, 2016) (Interviewee_6, 2016).

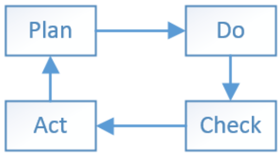


Figure 15 - Plan, Do, Check, Act model for team alignment

Managers need to believe in a collaborative approach to work, and understand the need for integration, through education where required. Generally, senior leaders have been around long enough to understand what can go wrong on a program, and as a result understand the value of integration initiatives as a mitigator of risk. By adopting a policy of open collaboration and promoting egalitarianism, leaders can create a culture of integration, where innovation in particular will flourish. It was noted during interviews that the Program Manager is the embodiment of a program to most engineers, as such the example set by the program manager sets the tone for the program (Interviewee_4, 2016). Furthermore, collaborative cultures have the potential to extend to include the customer (if the customer is amenable to such relationships), which can add significant advantages and value to a program (Interviewee_3, 2016). The importance of Program Manager attributes was further highlighted in literature by Chang, et al. (2013) and Mazur, et al. (Mazur, et al., 2014).

4.3.2.6 Education of the importance of integration

The education of the importance of integration was identified as a mitigator to the barrier of a lack of *Perceived need for integration*. The factor may be addressed by reports such as this one, where individuals may be educated and persuaded on the importance of integration, and therefore may be more likely to actively seek out collaboration opportunities with other teams.

4.3.2.7 Role rotations

Role rotations are considered to be facilitate integration for two reasons. Firstly, they provide a level of familiarity with a greater number of individuals, which breaks down the psychological barriers to integration. Secondly, they facilitate a better understanding of the priorities of other teams, and by association, the priorities of the program as a whole.

4.3.3 Tools and processes

Tools and processes can be used to facilitate integration between engineering teams in a number of ways.

4.3.3.1 Use of common tools and processes across teams

If individual teams have their own way doing things, using unique tools and processes, then there will be difficulty in sharing information, potentially leading to a breakdown in communication (Interviewee_2, 2016), as illustrated in the SCADA example the section *4.1.1 Reduction of risk* (Interviewee_6, 2016).

4.3.3.2 Communications matrix

A communications matrix defines the permissible lines of communication between teams on a programs, based on *Interface definition* activities. It defines the lines of reporting, delegations, as well as the related RAA of individuals, and as such the development of the matrix requires an understanding of the knowledge, skills and attributes required by particular roles. The plan serves to restrict allowable interactions, in order to avoid a scenario where everyone talks to everyone all the time, to the detriment of the actual work conducted. The communications matrix also defines the operating rhythm of a program. It is noted that ad-hoc interactions will occur outside of the defined interfaces in the communications matrix, but these will be assessed for necessity on a case by case basis (Interviewee_2, 2016).

4.3.4 Survey results - Efficiency of integrating factors

The efficiency of integrating factors was determined through a survey. The results of the survey are recorded in *Table 25 - Survey results*. The table records a rating for each of the integrating factors identified in *4.3 Integrating factors*, based on the average score given by respondents. The results are graphed in *Figure 16 - Survey results for effectiveness of integrating factors* and *Figure 17 - Comparison of integration factor effectiveness ratings of engineers and managers*, in order to identify trends.

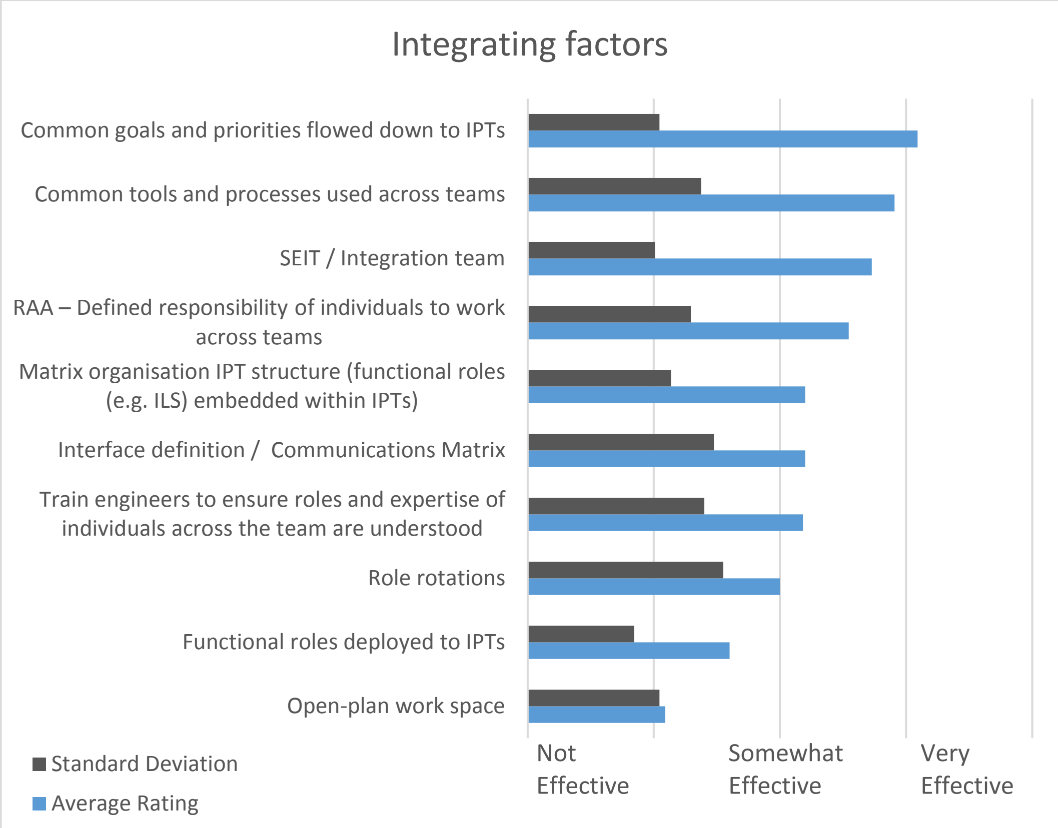


Figure 16 - Survey results for effectiveness of integrating factors

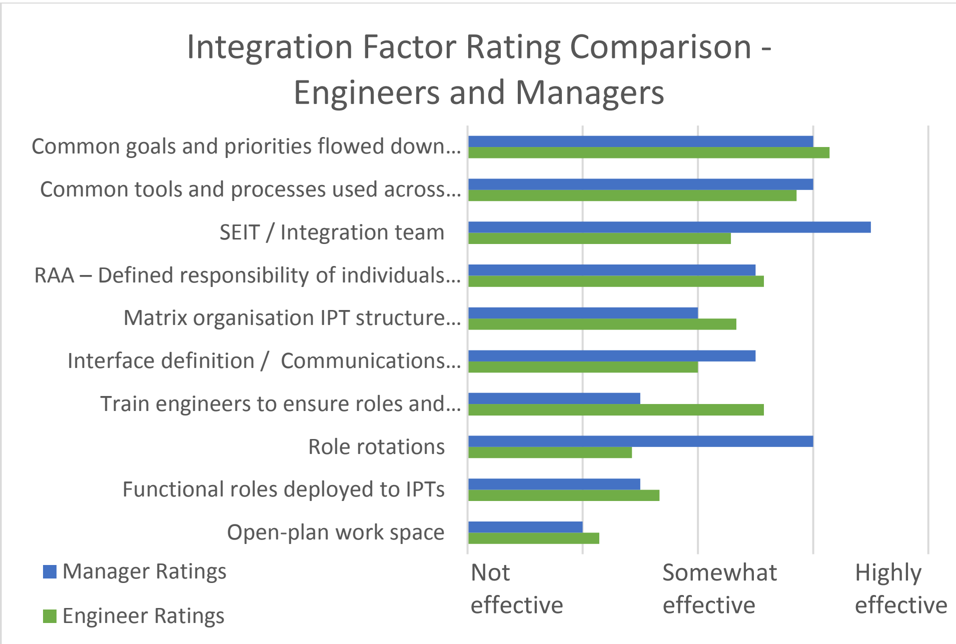


Figure 17 - Comparison of integration factor effectiveness ratings of engineers and managers

4.3.5 Discussion on survey results - Efficiency of integrating factors

The most notable arising from the survey results on integrating factors, was the order of effectiveness of such factors. The use of common goals and priorities, common tools and processes, and the SEIT or integration team were identified as the most effective, followed by RAA definition, the use of a matrix organisation, interface definition, education of the importance of integration, and role rotations. Deployment of functional roles and open-plan work spaces were considered ineffective.

The order of effectiveness directly informs the *Optimisation of integration*, by highlighting the factors that should be implemented first in order to see quick improvements in cross team integration.

The standard deviations were relatively constant, with the effectiveness of role rotations showing the widest array of answers.

There were some significant variations between the ratings of engineers and managers, for the effectiveness of the integration team, the role of training to understand the value of integration, and of role rotations. Managers considered that role rotations were more effective than engineers did. This may be because the benefits of understanding the wider business are more apparent to engineers, in a specialised technical discipline. Engineers considered that an understanding of the roles of the wider team was important, possibly because they have the least visibility of the wider organisation, and as such are the most disadvantaged by not knowing who does what. The SEIT was considered more important to managers than engineers. This may be because the benefits of product integration are more apparent to individuals who have worked on a number of programs, and the higher levels of experience of managers on such programs as opposed to engineers.

4.4 Optimisation of integration

Through the literature and interviews, a number of advantages to the integration of teams have been identified. However, there is also a cost, through the time spent collaborating with others and associated distraction from primary work. Programs need to determine the effective level of integration which provides a balance of the advantages and disadvantages.

4.4.1 Measuring integration

Programs may be considered to exhibit a level of integration. For the purposes of this report, the level of integration is a measure of the frequency of interactions between two teams. A two teams to be highly integrated, it is considered that peers in opposing teams will frequently interact. A program is considered highly integrated if each team within is highly integrated with all other teams (Interviewee_1, 2016).

It should be noted that highly integrated teams are not necessarily more efficient, and a high level of integration can be detrimental to efficiency, as discussed below.

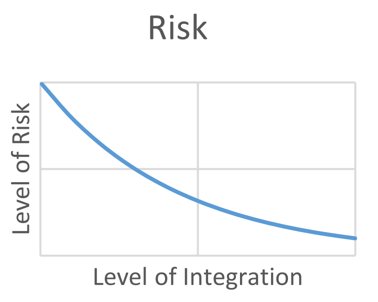
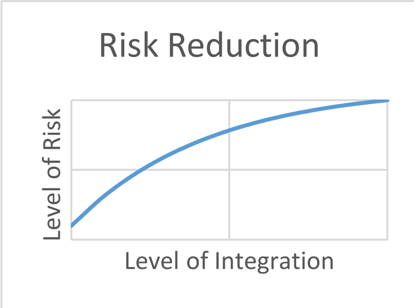
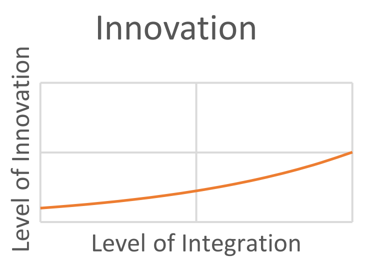
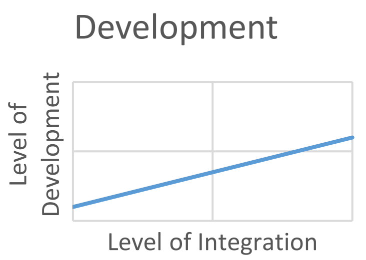
4.4.2 Level and depth of integration

A number of the interviewees reported on the notion of a level of integration or depth of integration (Interviewee_2, 2016) (Interviewee_3, 2016) (Interviewee_7, 2016). The two terms are similar in that they're both considered measures of how integration occurs, but they are not the same. The level of information is considered to be a measure of the frequency of interaction between teams, whereas the depth of integration refers to the level in a hierarchical organisation structure that cross team integration occurs down to. For example, in a siloed organisation structure, teams may be considered integrated to the depth of Team Leads, whereas in a horizontally integrated organisation, integration may occur at the depth of Senior Engineers or even at Engineer level. Despite the difference in the terms, in some instances they can be used interchangeable, since there is a linear relationship between the two, i.e. if the depth of integration is great, it follows that the level of integration is correspondingly high.

For a team of two, those team members need to only interact with one another to be considered to be highly integrated. In a team of ten however, each member needs to interact with nine other members, to the same degree as the team of two, to be considered highly integrated to the same degree. This is a simplification, as there are groupings (e.g. Org structure and reporting channels), and the definition and prioritisation of interaction channels which can negate the need for all-to-all interactions in the team for the team to still be highly integrated.

4.4.3 Effect of level of integration upon risk, innovation, skill building and cost

Table 13 - Effect of level of integration on risk, innovation, skill building and cost lists the expected trends that illustrate the effect that level of integration would likely have on the advantages and disadvantages of cost – namely risk, innovation, skill building and cost.

Integration advantage/ disadvantage	**Expected variation with Level of Integration**	**Expected general trend depiction**
Risk	It is considered that un-integrated programs will have a high level of risk. However, it is very difficult, if not impossible, to reduce all risk (Interviewee_7, 2016). Therefore, the expected trend is that the level of risk will drop exponentially, approaching a low level of risk at the greatest level of integration. The inverse curve shows the reduction in risk, as it is expected to grow exponentially with the level of integration. This curve shows the benefit of integration, so it can be compared with the other positive factors.	
Innovation	The identified literature shows that innovation can exist without integration (as detailed in the *Literature review*), but is greatly facilitated by collaborating with others (Interviewee_7, 2016).	
Development	It is expected that developing engineers will build skill by doing work, but through collaboration with senior engineers, they will be greatly increase the rate of their learning.	

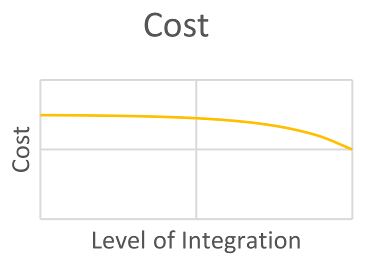
Integration advantage/ disadvantage	Expected variation with Level of Integration	Expected general trend depiction
Cost	The application of integrating factors generally has a cost, based primarily on the time it takes to interact with others. The more time engineers spend on integration initiatives, the less time they will have to develop designs (Interviewee_7, 2016). As such, cost is considered to increase exponentially with the level of integration.	

Table 13 - Effect of level of integration on risk, innovation, skill building and cost

When these values are considered cumulatively, an optimal level of integration may be identified. In *Figure 18 - Example of optimisation of level of integration*, the four factors are considered only as far as they may be influenced by integration, with positive factors shown increasing and cost decreasing according to the trends identified in *Table 13*, and weighting factors applied, as may be relevant to a fictitious program. In this example, risk reduction has had a factor of 1 applied, innovation a factor of 0.2, development a factor of 0.4, and cost a factor of 0.7.

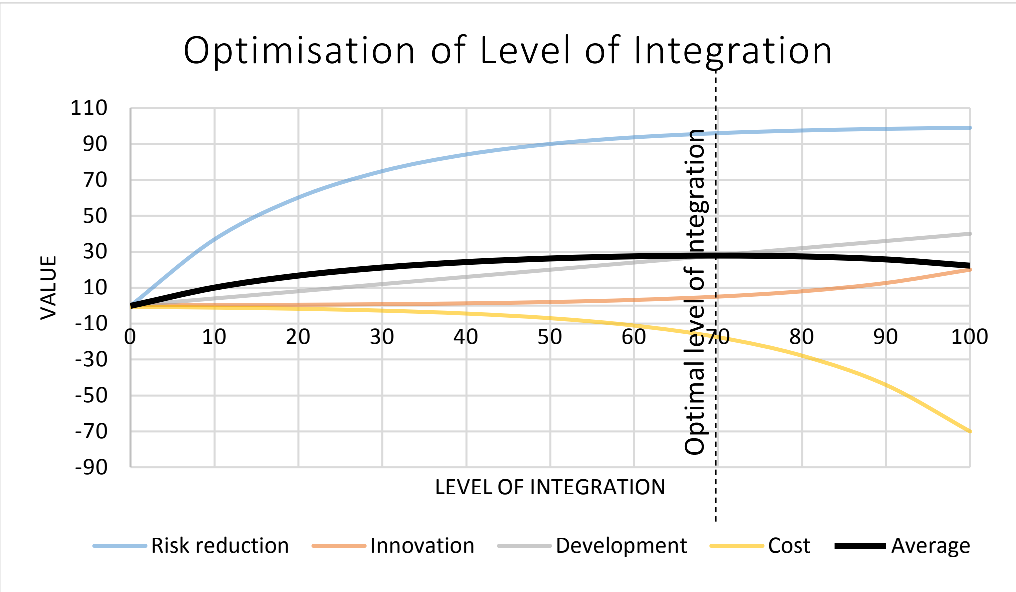


Figure 18 - Example of optimisation of level of integration

For methods to be considered worthwhile, the gains in productivity or value to a program or product through quality improvements need to justify the amount of time spent integrating teams. It is expected that gains in productivity would initially be seen with the implementation of integration measures, but after a point, the time spent integrating would outweigh the gains, an eventually productivity would diminish, as illustrated in *Figure 18 - Example of optimisation of level of integration*. If this trend is considered to be accurate, then it follows that the time and cost of integrating teams can be optimised, to give the best productivity.

4.4.4 Increasing integration to optimise level of integration

The level of integration may be increased in order to find the optimal level, such as that shown in *Figure 18 - Example of optimisation of level of integration.* In order to increase the level of integration, the factors identified in 4.3 Integrating factors may be applied in the order suggested by the survey results. Specifically, the program should attempt to;

1. Flow common goals and priorities to the team from the Program Manager, as defined in *Flow down of priorities from management*,
2. Ensure that common tools and processes are used across product teams are used, and used in the same way, as defined in *Use of common tools and processes across teams*,
3. Employ a Systems Engineering Integration Team, as detailed in *The Systems engineering integration team (SEIT)*,
4. Modify the RAA of individuals to reflect the need to work between teams, as detailed in *Responsibility, authority and accountability (RAA)*, and
5. Train engineers and managers on the importance of integration, and plan how interaction should be increased, as detailed in *Education of the importance of integration*.

Additionally, based on the prevalence of the top three barriers to integration, the lack of understanding of the roles of others, the lack of time, and an unwillingness to ask for help, that the following factors should also be implemented where necessary and possible;

6. *Cross team meetings*, and
7. Scheduling time to work with other teams, to be included in an ‘operating rhythm’ as defined in *Scheduling*.

It is considered that these seven factors may be applied to a program with relative ease, but if further results are required, then any factor identified in *4.3 Integrating factors* may be applied.

4.4.5 Restricting integration to optimise level of integration

In order to reach an optimal level of integration on programs as shown in *Figure 18 - Example of optimisation of level of integration*, it's possible that interaction will need to be restricted. A trend observed in the interviews is that senior team members receive a lot of requests for help, as explained in *4.1.4 Cost*. Based on this, there is a need to assess requested interactions, to make sure that they will be value adding. It is noted that people asking 'Have you got a second?' are imposing their priorities. Some individuals in management roles consider it necessary to insist on meeting requests detailing the nature of the interaction, in order to plan their time efficiently and to make this assessment of importance (Interviewee_2, 2016).

For an engineer needing information, it is most efficient to ask a question of the person with the most technical expertise in the area, but it is necessary to consider that:

- Priorities of the requestor will rarely match those of the requestee. If there are common priorities flowed down from management, this should inform the ranking of priorities, as noted in *4.3.2.3 Flow down of priorities from management*.
- The requestee will likely be quite experienced, and have technical in many areas, making them the target of many questions from many people, and as a result their time becomes more valuable to the program. In such instances, for example, it may be more expedient for a junior team member to spend 2 or 3 hours on a task that could be done in 1 hour by an experienced team member.
- Experienced team members may have a responsibility to coach/train less experienced members, as defined through *Responsibility, authority and accountability (RAA).*
- Timeframes are likely to result in changes to the priorities of the team, so it may be expedient to hold off on information requests in some instances.

The use of *Interface definition* and the associated *Communications matrix* can also play a role in restricting excessive interactions.

5. Conclusion

The conclusion notes significant findings from the research project, as well as recommendations for how the findings should be used, and proposes further work in the field of engineering integration on Defence programs.

5.1 Conclusions

This research has identified value adding factors of engineering integration on Defence programs, identified barriers to the integration of engineering teams, and proposed which methods are likely to be effective for integrating teams, based literature review and interviews with people working on Defence programs. Additionally, a methodology for optimising the level of integration on Defence programs.

Through a literature review, and questioning of personnel working in engineering environments on Defence programs, the research has offered insight into aspects of the effectiveness of engineering integration not available in pre-existing literature. The report provides broad coverage of the value of integration and integrating factors, but in enough detail that methods described may be implemented, at least in a basic form, by Defence contractors.

5.2 Recommendations

Through the investigation of engineering integration on Defence programs, a number of findings have arisen that are applicable to engineering teams on Defence programs. These findings are relevant to individuals working on such programs, in the capacity of either manager or engineer. The findings highlight the value of integration, the barriers to integration, the integrating factors that may be used, and additionally highlight how the level of integration may be optimised. The findings are broad, and as such provide an overview on the value of integration, and how teams may be integrated. The specific factors should be researched in more detail prior to implementation.

The information on the value of integration is recommended for use by programs in educating employees of the importance of integration, in order to convey the importance of people working together, and hopefully encourage them to do so.

Similarly, an awareness of the barriers to integration would be useful to program personnel, in order to identify when such barriers occur. The mitigating factors identified provide clear direction in overcoming such obstacles.

Awareness of the integrating factors as defined in this report will be useful to engineers and engineering managers, but the greater value is knowing how to apply them to optimise the level of integration, as I have proposed in section *4.4 Optimisation of integration*.

5.3 Further work

The effectiveness of engineering integration is considered to be not only an important topic, but a large one. In investigating the perceptions of engineering integration amongst people working on large Defence programs, this research has highlighted which areas of integration and integration factors are considered the most important. However, the data collected through interview is subjective, in that it is based on the views and observations of individuals. The interview and survey samples were sufficient to demonstrate where particular perspectives are commonly held, and therefore considered to have a good chance of validity. The findings of this report would be considered more valid where backed by an objective study of hard data.

The future study proposed is to objectively measure the level integration between teams (as proposed in *4.4.1 Measuring integration*), as well as to measure the cost of integration initiatives, risk reduction, innovation and personal development, to identify correlations between these aspect and support or disprove the expected integration trends identified in *4.4.3 Effect of level of integration upon risk, innovation, skill building and cost*. It is proposed that risk reduction can be quantified via analysis of a programs Risk, Issue and Opportunity management system where used, and innovation may be measured through numbers of patents or other documented innovation. Measurement of personal development is likely to be at least partly subjective, but may include the recorded results of learning through mentoring programs. For cost to be accurately captured, there needs to be discrete work packages to capture integration efforts. Such a study would be significant in scale, and would need the cooperation of programs. However, having tangible evidence of the effects of integration on programs would provide a basis for directed engineering integration efforts going in to the future.

An additional area of future study would be to identify the link between integrated teams, and producing an integrated product, as identified in the *Literature shortfalls*. There is a widely held assumption in the reviewed literature that integrating teams will result in an integrated product, but no identified study validates this hypothesis.

6. References

ADF Recruitment Centre, 2016. *Recruitment Centre: Postings - FAQ's - Defence Jobs Australia.* [Online]
Available at: http://www.defencejobs.gov.au/mobile/recruitment-centre/support/faqs/postings.aspx
[Accessed 10 October 2016].

ANAO, 2015. *Australian National Audit Office 2014-15 Major Projects Report.* [Online]
Available at: https://www.anao.gov.au/work/major-projects-report/2014-15-major-projects-report#12-1-costperformanceanalysis
[Accessed 20 May 2016].

ANAO, 2016. *Australian National Audit Office 2015-16 Major Projects Report.* [Online]
Available at: https://www.anao.gov.au/work/major-projects-report/major-projects-report-2015-16
[Accessed September 2016].

Andrews, K., 2015. *Budget 2015-16 - Defending Australia and it's National Interests.* [Online]
Available at: http://www.defence.gov.au/Budget/15-16/2015-16-Brochure.pdf
[Accessed 2 September 2016].

ASDEFCON, 2014. *Strategic Material Version 2.4.* [Online]
Available at: http://www.defence.gov.au/casg/Multimedia/5_SM_ILS_DID-9-4279.pdf
[Accessed 27 May 2016].

Baiden, B. K. & Price, A. D. F., 2011. The effect of integration on project delivery team effectiveness. *International Journal of Project Management,* Volume 29, pp. 129-136.

Boeing Defence Australia, 2016. *Boeing Defence Australia Jobs.* [Online]
Available at: https://jobs.boeing.com/category/boeing-defence-australia-jobs/185/2681/1
[Accessed 23 May 2016].

Boeing, 2016. *Boeing - Our vision.* [Online]
Available at: http://www.boeing.com/principles/vision.page
[Accessed 27 July 2016].

Britannica Academic, 2016. *Matrix organization.* [Online]
Available at: http://academic.eb.com.ezproxy.usq.edu.au/levels/collegiate/article/600968#
[Accessed 1 October 2016].

CASG, 2014. *Air Warfare Destroyer.* [Online]
Available at: http://www.defence.gov.au/casg/EquippingDefence/SEA4000PH3-AWD
[Accessed 2016].

CASG, 2015. *Annex C Public Australian Industry Capability Plan.* [Online]
Available at: http://www.defence.gov.au/casg/Multimedia/BOEING_Public_AIC_Plan_-_AIR_5077_Phase_5A_E-7A_Wedgetail_Interoperability_Upgrade-9-7070.pdf
[Accessed 1 August 2016].

CASG, 2016. *Australian Government Department of Defence - Capability Acquisition and Sustainment Group.* [Online]
Available at: http://www.defence.gov.au/casg/
[Accessed 2 September 2016].

CASG, 2016. *LAND 121 Phase 4 Protected Mobility Vehicle - Light.* [Online]
Available at:
http://www.army.gov.au/~/media/Files/Our%20future/LAND%20121%20Phase%204%20Fact%20Sheet%20July%202016.pdf
[Accessed 17 September 2016].

Chang, A., Chih, Y.-Y., Chew, E. & Pisarski, A., 2013. Reconceptualising mega project success in Australian Defence: Recognising the importance of value co-creation. *International Journal of Project Management,* Volume 31, pp. 1139-1153.

Chesbrough, H., 2005. *Open Innovation: A new paradigm for understanding industrial innovation,* Copenhagen: Dynamics of Industry and Innovation: Organizations, Networks and Systems.

Defence Industry Daily, 2007. *F-35 Joint Strike Fighter (JSF): Events & Contracts 2007.* [Online]
Available at: http://www.defenseindustrydaily.com/f35-joint-strike-fighter-events-contracts-2007-updated-02992/
[Accessed August 2016].

Engineers Australia, 2012. *Australian Engineering Competency Standards Stage 2 - Experienced Professional Engieer.* [Online]
Available at:
https://www.engineersaustralia.org.au/sites/default/files/professional_engineer_stage2competency_approved.pdf
[Accessed 8 October 2016].

Farmer, C. M., Mazzuchi, T. A. & Sarkani, S., 2014. Integrating Acquisition Strategy and PMO Capability: A Catalyst for Defense Systems Engineering Transformation. *Procedia Computer Science,* Volume 28, pp. 744-753.

Featherstone, T., 2015. *Is a space nook at Facebook the future of work?.* [Online]
Available at: http://www.smh.com.au/small-business/the-venture/is-a-space-nook-at-facebook-the-future-of-work-20151202-gle38e.html
[Accessed 9 September 2016].

Featherstone, T., 2015. *Sydney Morning Herald - Are open plan offices insane.* [Online]
Available at: http://www.smh.com.au/small-business/managing/the-venture/are-open-plan-offices-insane-20150520-gh68jx.html
[Accessed 1 August 2016].

Frinsdorf, O., Zuo, J. & Xia, B., 2014. Critical factors for project efficiency in a defence environment. *International Journal of Project Management,* Volume 32, pp. 803-814.

Hass, K., 2009. *Planting the Seeds to Grow a Mature Project Management Practice,* s.l.: Kathleen Hass and Associates.

Hayes, S., Kopunic:, D. & Wood, R., 2011. Program Complexity: Can We Understand It? Can We Overcome It?. *Defense AT&L,* May-June, pp. 52-54.

Heath, C. & Staudenmayer, N., 2000. Coordination neglect: How lay theories of organizing complicate coordination in organizations. *Research in Organizational Behaviour,* Volume 22, pp. 153-191.

Heydari, B. & Dalili, K., 2015. Emergence of Modularity in System of Systems:. *IEEE Systems Journal,* 9(1), pp. 223-231.

Hornstein, H. A., 2015. The integration of project managment and organizational change management is now a necessity. *International Journal of Project Managment,* Volume 33, pp. 291-298.

ICCPM, 2016. *International Centre for Complex Project Managment.* [Online]
Available at: https://iccpm.com/
[Accessed 11 September 2016].

Interviewee_1, 2016. *Integration effectiveness - Interviewee 1* [Interview] (13 May 2016).

Interviewee_2, 2016. *Integration effectiveness* [Interview] (August 2016).

Interviewee_3, 2016. *Integration effectiveness* [Interview] (September 2016).

Interviewee_4, 2016. *Integration Effectiveness* [Interview] (September 2016).

Interviewee_5, 2016. *Integration effectiveness* [Interview] (September 2016).

Interviewee_6, 2016. *Integration effectiveness* [Interview] (September 2016).

Interviewee_7, 2016. *Integration effectiveness* [Interview] (1 October 2016).

Interviewee_8, 2016. *Engineering Integration* [Interview] (5 October 2016).

Kaufmann-Buhler, J., 2016. Progressive Partitions: The Promises and Probl3ems of the American Openb Plan Office. *Design and Culture,* 8(2), pp. 205-233.

Kerr, J., 2014. AWD's $800 million blowout. *Australian Defence Magazine*, 27 October.

Lawes, I., 2006. Dealing with the Complexities of Future Warfighting. *Australian Army Journal,* 3(2), pp. 109-121.

Legacy, C., Curtis, C. & Sturup, S., 2012. Is there a good governance model for the delivery of contemporary transport policy and practice? An examination of Melbourne and Perth. *Transport Policy,* Volume 19, pp. 8-16.

Livens, A. & Moenaert, R. K., 2000. Project Team Communication in Financial Service Innovation. *Journal of Management Studies*, 37(5), pp. 733-766.

Locatelli, G., Mancini, M. & Romano, E., 2014. Systems Engineering to improve the governance in complex project environments. *International Journal of Project Management,* 32(8), pp. 1395-1410.

Mazur, A., Pisarski, A., Chang, A. & Ashkanasy, N. M., 2014. Rating defence major project success: The role of personal attributes and stakeholder relationships. *International Journal of Project Management,* Volume 32, pp. 944-957.

Merriam-Webster, 2016. *Merriam-Webster Dictionary.* [Online]
Available at: http://www.merriam-webster.com/dictionary/integrate
[Accessed 9 September 2016].

Moore, D. M. & Antill, P. D., 2001. Integrated Project Teams: the way forward for UK defence procurement. *European Journal of Purchasing & Supply Management,* Volume 7, pp. 179-185.

NASA, 2007. *NASA Systems Engineering Handbook.* NASA/SP-2007-6105 ed. s.l.:s.n.

Niemann-Struweg, I., 2014. An integrated communication implementation model for the post-2000 business environment. *Public Relations Review,* Volume 40, pp. 184-192.

Pearce, R., 2012. *What went wrong with the Hubble Space Telescope (and what managers can learn from it) (CIO from IDG).* [Online]
Available at:
http://www.cio.com.au/article/420036/what_went_wrong_hubble_space_telescope_what_managers_can_learn_from_it_/
[Accessed 1 October 2016].

Pitsis, T. S., Sankaran, S., Gudergan, S. & Clegg, S. R., 2014. Governing projects under complexity: theory and practice in project managment. *International Journal of Project Management,* Volume 32, pp. 1285-1290.

PMBOK, 2008. *A guide to the project management body of knowledge (PMBOK Guide).* 4th ed. Newton Square, PA: Project Management Institue.

Ponchek, T., 2016. To Collaborate or Not to Collaborate? A Study of the Value of Innovation from a Sectoral Perspective. *Journal of the Knowledge Economy,* 7(1), pp. 43-79.

RAAF, 2016. *E-7A Wedgetail - Royal Australian Airforce.* [Online]
Available at: https://www.airforce.gov.au/Technology/Aircraft/B737-Wedgetail/?RAAF-yFLAkgbpvuhRf7dG5J3kHi1Q4caywtso
[Accessed 30 August 2016].

Staats, B. R., Milkman, K. L. & Fox, C. R., 2012. The team scaling fallacy: Underestimating the declining efficiency of larger teams. *Organizational Behavior and Human Decision Processes*, Volume 118, pp. 132-142.

Standish Group, 1995. *The Chaos Report.* [Online]
Available at: https://www.projectsmart.co.uk/white-papers/chaos-report.pdf
[Accessed 2015 October 25].

Stevens, F. G., Plaut, V. C. & Sanchez-Burks, J., 2008. Unlocking the Benefits of Diversity - All-Inclusive Multiculturalism and Positive Organizational Change. *The Journal of Applied Behavioral Science,* 44(1), pp. 116-113.

Stoshikj, M., Kryvinska, N. & Strauss, C., 2014. Efficient Managing of Complex Programs with Project Management Services. *Global Journal of Flexible Systems Management,* 15(1), pp. 25-38.

Thales Group, 2016. *Thales - Discover Thales.* [Online]
Available at: https://www.thalesgroup.com/en/career/discover-thales#values
[Accessed 27 July 2016].

Thales, 2016. *Thales - Find the perfect job.* [Online]
Available at: https://www.thalesgroup.com/en/apply/find-perfect-job
[Accessed 9 September 2016].

Thomson, M., 2014. *The Cost of Defence - ASPI Defence Budget Brief 2014-2015.* [Online]
Available at: https://www.aspi.org.au/publications/the-cost-of-defence-aspi-defence-budget-brief-2014-2015/CostofDefence2014.pdf
[Accessed 1 October 2015].

Turkulainen, V., Ruuska, I., Brady, T. & Artto, K., 2015. Managing project-to-project and project-to-organization interfaces in programs: Organizational integration in a global operations expansion program. *International Journal of Project Management,* Volume 33, pp. 816-827.

Vanhaverbeke, W., 2006. The inter-organizational context of open innovation. In: *Open Innovation: Researching a New Paradigm.* Oxford: Oxford University Press.

Wheatcraft, L. S., 2010. *Everything you wanted to know about interfaces, but were afraid to ask.* [Online]
Available at:
http://spacese.spacegrant.org/uploads/images/UserContributedFiles/WheatcraftInterfaces110909.pdf
[Accessed 24 May 2016].

7. Annexes

7.1 Annex A - Project Specification

Project Specification

For: Sam Walker

Title: Integration Effectiveness between Engineering Teams on Complex Defence Programs

Major: Mechanical Engineering

Supervisors: Mr Bob Fulcher

Enrolment: ENG4111 – EXT S1, 2016
ENG4112 – EXT S2, 2016

Project Aim: Identify and evaluate the factors contributing to the effectiveness of Integration between engineering teams on complex Australian Defence Programs in the Acquisition phase

Programme: Issue A, 2nd April 2016

1. Research known factors affecting the integration of engineering teams on complex programs, in the areas of; organisational structure, behavioural attributes, and project governance

2. Interview team members in various roles on a Defence Acquisition Program (the subject Program) to define organisational structure, roles, and the specific interfaces between roles of different engineering teams

3. Interview members of the subject Program to determine how the factors identified at item 1 are applied to and between engineering teams

4. Conduct a survey of team members in various roles to evaluate the perceived effectiveness of the organisational structure, behavioural attributes and governance factors as applied to the subject Program

5. Analyse survey and interview data, to identify trends for successfully and unsuccessfully integrating Engineering efforts across engineering teams on complex programs

6. Document the integration methods most likely to result in an optimal level of integration between engineering teams

If time and resources permit:

7. Suggest strategies to implement these the methods identified at step 6, such that this may be replicated in an 'Integration Guide' for complex Australian Defence programs

8. For a second subject Program, repeat the interviews at items 2 and 3, survey at item 4, and analysis at item 5, and amend the documentation at item 6 accordingly

7.2 Annex B – Project Specification – Resources

Project Resources (Project Specification Annex B)

For:	Sam Walker
Title:	Integration Effectiveness between Engineering Teams on Complex Defence Programs
Major:	Mechanical Engineering
Supervisors:	Mr Bob Fulcher
Enrolment:	ENG4111 – EXT S1, 2016 ENG4112 – EXT S2, 2016
Project Aim:	Identify and evaluate the factors contributing to the effectiveness of Integration between engineering teams on complex Australian Defence Programs in the Acquisition phase

Resources: Issue A, 2nd April 2016

The critical resources to the success of this project are people. I will require the time of the following personnel:

1. Project Engineers x 6 (Organisation A, Project A)
   - Initial Interview – 30 Mins
   - Follow up Survey – 10 Mins
   - Optional – Follow up interview/survey – 20 Mins
   -
2. Senior Engineer x 3 (Organisation A, Project A)
   - Initial Interview – 30 Mins
   - Follow up Survey – 10 Mins
   - Optional – Follow up interview/survey – 20 Mins
3. Product Team Lead x 3 (Organisation A, Project A)
   - Initial Interview – 30 Mins
   - Follow up Survey – 10 Mins
   - Optional – Follow up interview/survey – 20 Mins
4. Engineering Manager/ Program Manager x 1 (Organisation A, Project A)
   - Initial Interview – 30 Mins
   - Follow up Survey – 10 Mins
   - Optional – Follow up interview/survey – 20 Mins

If time permits, a similar sampling of Engineers, Team Leads, and Project Personnel from Organisation A, Project B, will be requested to participated in the study. Depending on time and availability, this phase of investigation would use fewer personnel (2 x Engineers, 2 x Senior Engineers, 1 x Project Team Lead, 1 x Program Manager)

There are no facilities requirements identified for this project.

A free survey tool will be used, such as SurveyMonkey (https://www.surveymonkey.com/).

7.3 Annex C – Project Specification - Schedule

Project Schedule (Project Specification Annex A)

For: Sam Walker

Title: Integration Effectiveness between Engineering Teams on Complex Defence Programs

Major: Mechanical Engineering

Supervisors: Mr Bob Fulcher

Enrolment: ENG4111 – EXT S1, 2016
ENG4112 – EXT S2, 2016

Project Aim: Identify and evaluate the factors contributing to the effectiveness of Integration between engineering teams on complex Australian Defence Programs in the Acquisition phase

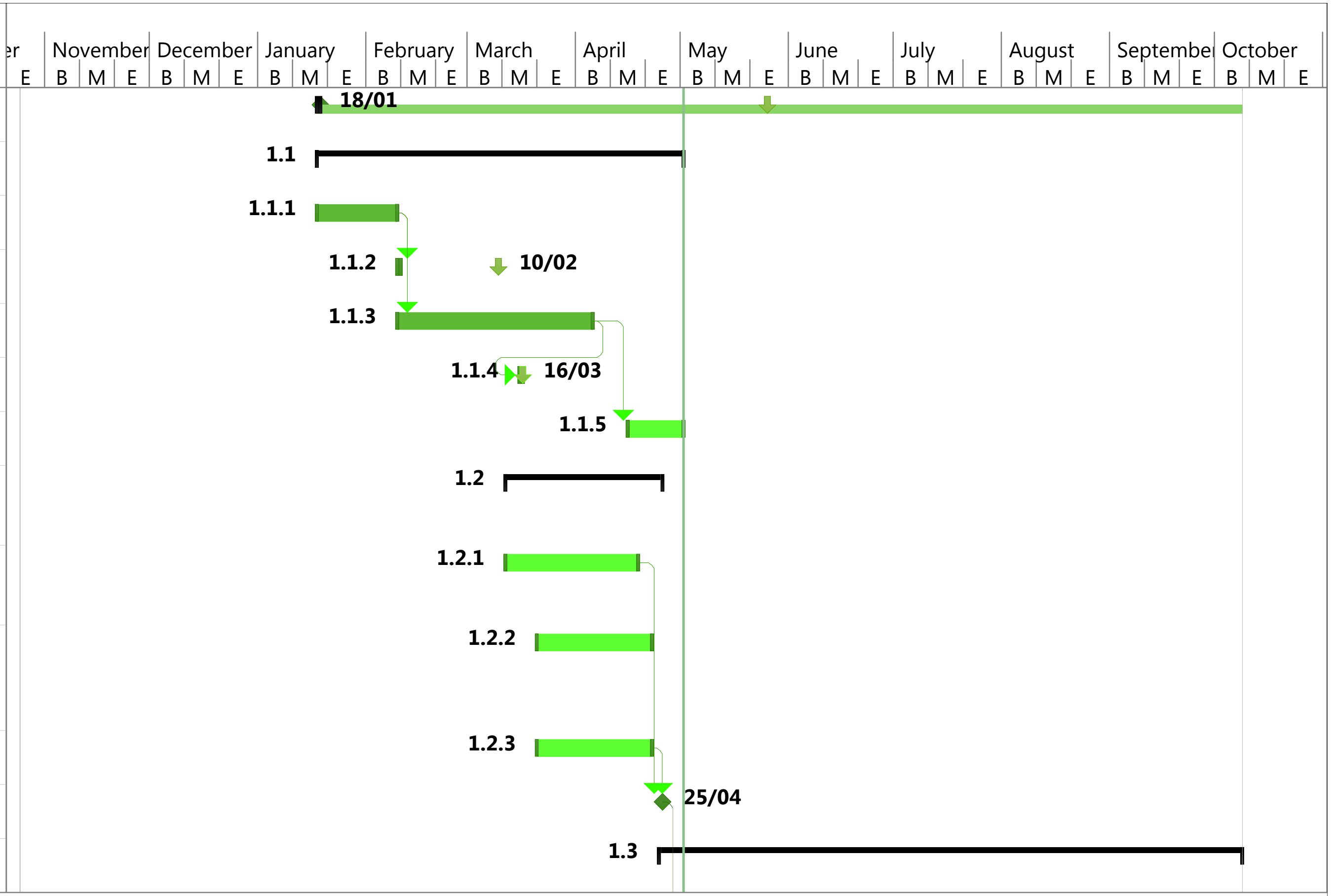
Schedule: Issue A, 2nd April 2016

WBS	Task Name	Start	Finish	Notes
1	**ENG4111 Engineering Research Project Part 1**	**Sun 25/10/15**	**Sun 25/10/15**	
1.1	**Phase 1 - Project Preparation**	**Mon 18/01/16**	**Sun 1/05/16**	
1.1.1	Refine topic	Mon 18/01/16	Tue 9/02/16	
1.1.2	Project Allocation deadline	Wed 10/02/16	Wed 10/02/16	
1.1.3	Develop Specification	Wed 10/02/16	Tue 5/04/16	
1.1.4	Project Specification Due	Wed 16/03/16	Wed 16/03/16	
1.1.5	Revise Project Specification	Sat 16/04/16	Sun 1/05/16	
1.2	**Phase 2 - Survey/Questionnaire Preparation**	**Sat 12/03/16**	**Mon 25/04/16**	
1.2.1	Conduct Systems Engineering Breakdown of a Sample Project	Sat 12/03/16	Mon 18/04/16	
1.2.2	Research Integration Practices on Complex Programs	Sun 24/04/16		Objective 1 - Research known factors affecting the integration of engineering teams on complex programs, in the areas of; organisational structure, behavioural attributes, and project governance...
1.2.3	Research Survey Techniques	Mon 21/03/16	Fri 22/04/16	
1.2.4	Identify Questions for Respondents	Mon 25/04/16	Mon 25/04/16	
1.3	**Phase 3 - Data Collection**	**Mon 25/04/16**	**Sat 8/10/16**	
1.3.1	Interview Program Representative A and B	Wed 27/04/16	Tue 3/05/16	Objective 2 - Interview team members in various roles on a Defence Acquisition Program (the subject Program) to define organisational structure, roles, and the specific interfaces between roles of different engineering teams...
1.3.2	Conduct Survey of Parties A and B	Mon 2/05/16	Fri 6/05/16	Objective 4 - Conduct a survey of team members in various roles to evaluate the perceived effectiveness of the organisational structure, behavioural attributes and governance factors as applied to the subject Program...
1.3.3	Interview Respondents, Parties A and B	Sun 8/05/16	Thu 12/05/16	Objective 2 - Interview team members in various roles on a Defence Acquisition Program (the subject Program) to define

				organisational structure, roles, and the specific interfaces between roles of different engineering teams...
1.3.4	Describe initial trends for integration effectiveness	Mon 16/05/16	Mon 23/05/16	
1.3.5	Prepare Preliminary Report	Mon 25/04/16	Wed 25/05/16	
1.3.6	Preliminary Report Due	Wed 25/05/16	Wed 25/05/16	
1.3.7	**ENG4112 Engineering Research Project Part 2**	**Thu 26/05/16**	**Sat 8/10/16**	
1.3.7.1	Interview Program Representative C and D	Mon 30/05/16	Fri 3/06/16	
1.3.7.2	Conduct Survey of Parties C and D	Mon 6/06/16	Fri 10/06/16	
1.3.7.3	Interview Respondents, Parties C and D	Mon 13/06/16	Wed 22/06/16	
1.3.7.4	**Phase 4 - Data Analysis**	**Thu 26/05/16**	**Fri 1/07/16**	
1.3.7.4.1	Analyse responses from parties A and B	Mon 13/06/16	Fri 17/06/16	Objective 5 - Analyse survey and interview data, to identify trends for successfully and unsuccessfully integrating Engineering efforts across engineering teams on complex programs...
1.3.7.4.2	Refine Survey/Questionnaire	Mon 20/06/16	Fri 1/07/16	Objective 3 - Interview members of the subject Program to determine how the factors identified at item 1 are applied to and between engineering teams...
1.3.7.4.3	Analyse Data and develp trends and document	Thu 26/05/16	Fri 24/06/16	
1.3.7.5	**Phase 5 - Develop Integration Framework**	**Mon 4/07/16**	**Sat 30/07/16**	
1.3.7.5.1	Conduct Literature Review and Develop framework	Mon 4/07/16	Sat 30/07/16	Objective 6 - Document the integration methods most likely to result in an optimal level of integration between engineering teams...
1.3.7.6	**Phase 6 - Prepare Dissertation**	**Tue 12/07/16**	**Sat 8/10/16**	
1.3.7.6.1	Prepare Draft Dissertation	Tue 12/07/16	Tue 30/08/16	
1.3.7.6.2	Draft Dissertation Due	Wed 7/09/16	Wed 7/09/16	

1.3.7.6.3	Draft Dissertation Review	Sun 4/09/16	Tue 20/09/16	
1.3.7.6.4	Presentation at PP-2	Mon 19/09/16	Fri 23/09/16	
1.3.7.6.5	Finalise Draft Dissertation	Thu 22/09/16	Sat 8/10/16	
1.3.7.6.6	Disertation Submission	Thu 6/10/16	Fri 7/10/16	

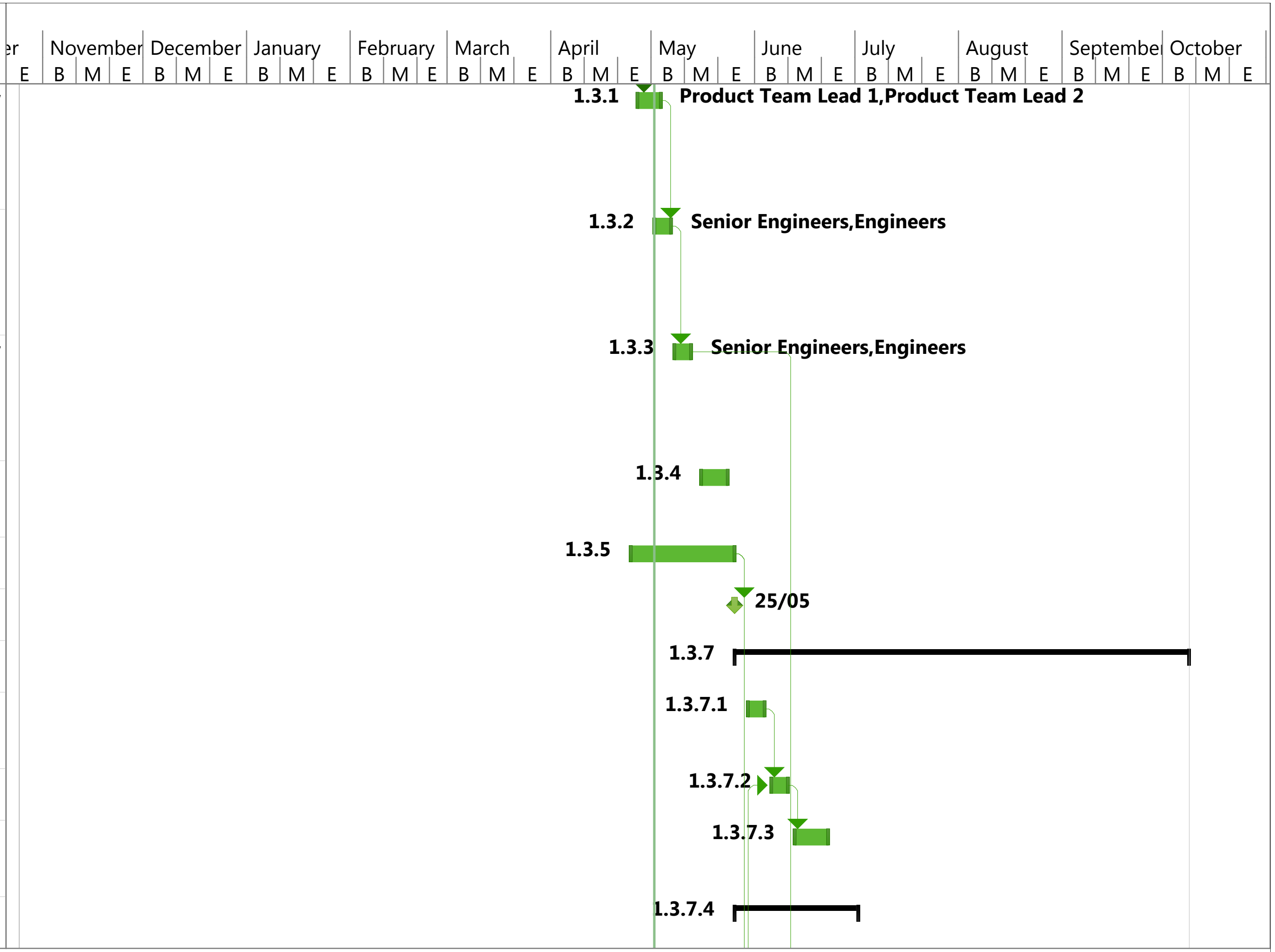
ID	Task Name	Start	Finish	Notes
1	**ENG4111 Engineering Research Project Part 1**	**Mon 18/01/16**	**Mon 18/01/16**	
2	**Phase 1 - Project Preparation**	**Mon 18/01/16**	**Sun 1/05/16**	
3	Refine topic	Mon 18/01	Tue 9/02/	
4	Project Allocation deadline	Wed 10/02/16	Wed 10/02/16	
5	Develop Specification	Wed 10/02	Tue 5/04/	
6	Project Specification Due	Wed 16/03/16	Wed 16/03/16	
7	Revise Project Specification	Sat 16/04/16	Sun 1/05/16	
8	**Phase 2 - Survey/Questionnaire Preparation**	**Sat 12/03/16**	**Mon 25/04/16**	
9	Conduct Systems Engineering Breakdown of a Sample Project	Sat 12/03/16	Mon 18/04/16	
10	Research Integration Practices on Complex Programs	Mon 21/03/16	Fri 22/04/16	Objective 1 - Research known factors affecting the integration of
11	Research Survey Techniques	Mon 21/03/16	Fri 22/04/16	
12	Identify Questions for Respondents	Mon 25/04/16	Mon 25/04/16	
13	**Phase 3 - Data Collection**	**Mon 25/04**	**Sat 8/10/**	



Project: Reseach_Project_Sched
Date: Mon 2/05/16

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

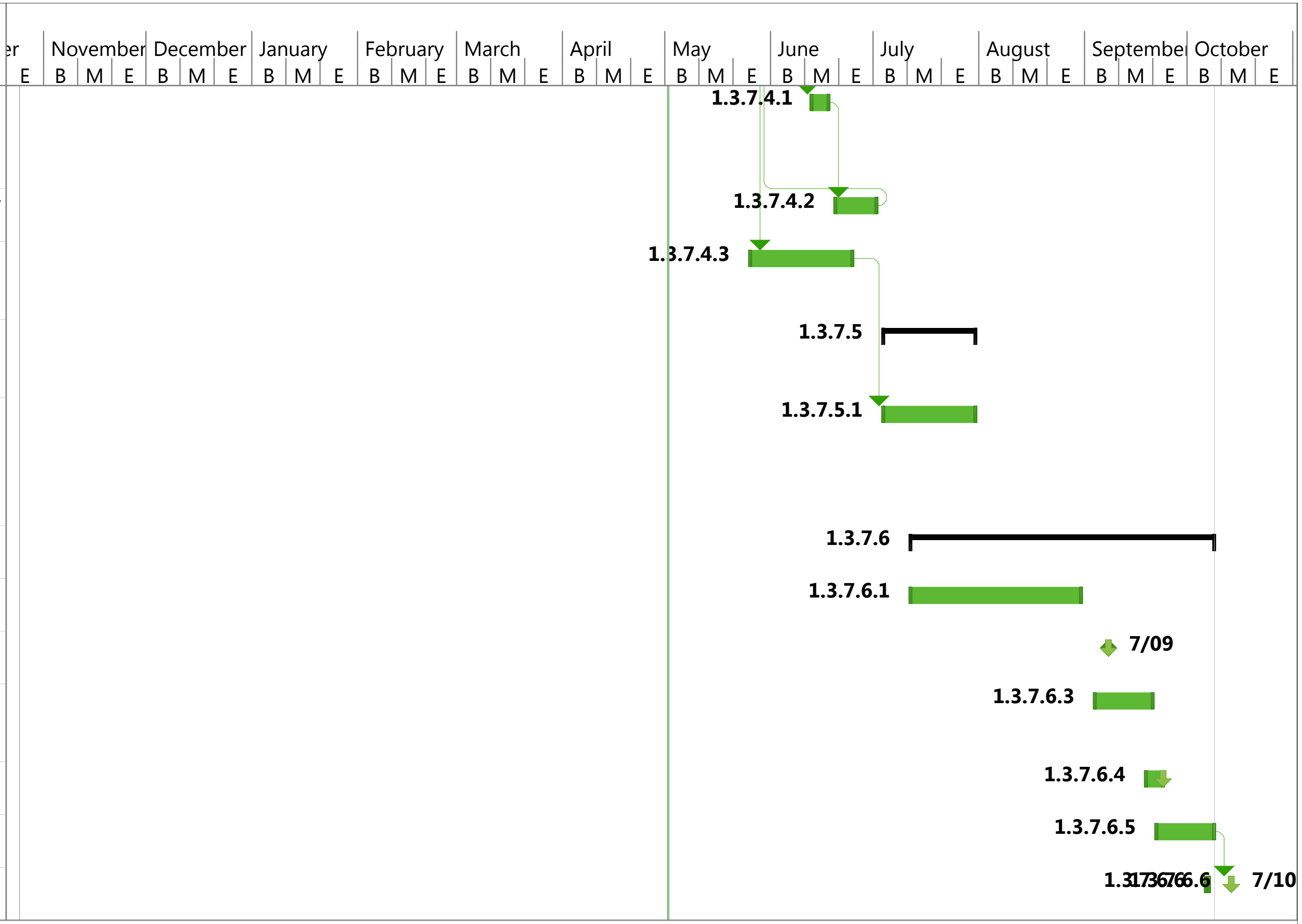
ID	Task Name	Start	Finish	Notes
14	Interview Program Representative A and B	Wed 27/04/16	Tue 3/05/16	Objective 2 - Interview team members in various roles on a Defence Acquisition Program (the subject
15	Conduct Survey of Parties A and B	Mon 2/05/16	Fri 6/05/16	Objective 4 - Conduct a survey of team members in various roles to evaluate the perceived
16	Interview Respondents, Parties A and B	Sun 8/05/16	Thu 12/05/16	Objective 2 - Interview team members in various roles on a Defence Acquisition Program (the subject
17	Describe initial trends for integration effectiveness	Mon 16/05/16	Mon 23/05/16	
18	Prepare Preliminary Report	Mon 25/04/16	Wed 25/05/16	
19	Preliminary Report Due	Wed 25/05	Wed 25/(	
20	**ENG4112 Engineering Research Project Part 2**	**Thu 26/05/16**	**Sat 8/10/16**	
21	Interview Program Representative C and D	Mon 30/05/16	Fri 3/06/16	
22	Conduct Survey of Parties C and D	Mon 6/06/16	Fri 10/06/16	
23	Interview Respondents, Parties C and D	Mon 13/06/16	Wed 22/06/16	
24	**Phase 4 - Data Analysis**	**Thu 26/05/16**	**Fri 1/07/16**	



Project: Reseach_Project_Sched
Date: Mon 2/05/16

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

ID	Task Name	Start	Finish	Notes
25	Analyse responses from parties A and B	Mon 13/06/16	Fri 17/06/16	Objective 5 - Analyse survey and interview data, to identify trends for successfully
26	Refine Survey/Questionn	Mon 20/06/16	Fri 1/07/16	Objective 3 - Interview members of the
27	Analyse Data and develp trends and	Thu 26/05/16	Fri 24/06/16	
28	**Phase 5 - Develop Integration Framework**	**Mon 4/07/16**	**Sat 30/07/16**	
29	Conduct Literature Review and Develop framework	Mon 4/07/16	Sat 30/07/16	Objective 6 - Document the integration methods most likely to result in an optimal level of
30	**Phase 6 - Prepare Dissertation**	**Tue 12/07/16**	**Sat 8/10/16**	
31	Prepare Draft Dissertation	Tue 12/07/16	Tue 30/08/16	
32	Draft Dissertation Due	Wed 7/09/16	Wed 7/09/16	
33	Draft Dissertation Review	Sun 4/09/16	Tue 20/09/16	
34	Presentation at PP-2	Mon 19/09/16	Fri 23/09/16	
35	Finalise Draft Dissertation	Thu 22/09/16	Sat 8/10/16	
36	Disertation Submission	Thu 6/10/16	Fri 7/10/16	



Project: Reseach_Project_Sched
Date: Mon 2/05/16

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

7.4 Annex D – Interview Records

7.4.1 Respondent 1

Role	Systems Engineer, IPT 1, Program 1, Company 1
Experience	Program - 1 year, Systems Engineering – 1 years, Company tenure – 11 years
Date	13 May, 2016
Introductory statement	
Explanation of: • Engineering Research project topic, • How results will be used, • Codification of names, and • Confidentiality of project data.	
Questions	
Definition of Integration	
1.	**What does 'integration' mean to you?** *That all teams, and everyone on those teams is making a concerted effort to work with one another and to ensure that a unified and consistent product is delivered.*
Integration methods and effectiveness	
2.	**What is done to integrate teams and individuals work on a programs that you've worked on?** a. *Open plan work environment, hot-desking – to encourage collaboration, and to force people to talk to one another, and get to know more people on the team, building networks.* b. *Engineering integration team – role of reporting the status and issues of all teams to a common point*
3.	**How effective is this?** a. *Open plan – It's noisy and a bit disruptive, but does force you to work with people you wouldn't work with normally. I've found that it's come in useful with the addition of other perspectives on my issues, but on the flip side – you get asked a lot of questions, which takes time.* b. *Engineering Integration team - Don't see a lot of impact, but I assume they are making sure that there are no gaps in the program deliverables. There's an engineer working in our team who reports to (Integration Team Lead). The team also provides direction*
Measuring Integration	

4.	**Can integration be measured?** *Guess you could count how many times people talk to one another, or get data from WIP boards, email or phone logging.*
Specific interfaces	
5.	**What teams or functions <u>do</u> you interact/work with?** *CM, (other IPTs), Integration team, ILS team*

Respondent 1 – Key interactions

	Person/Party/Organisation	**Type of Interface**
a.	Integration team engineers	Input, var
b.	Logistics Manager	Reporting
c.	Product team lead	Reporting
d.	Engineers in other teams	Input/output
e.	Subcontractor	Output
f.	Customer	Input/output

6.	**What teams or functions <u>should</u> you interact/work with?** *I guess the engineering function, also subcontractors and customer.*
7.	**What are the barriers to working with the other teams?** *a. Location is a big one- not as familiar with those on remote sites so less comfortable talking to/ asking help of.* *b. Clarity of responsibility – Particular people are responsible to work with other teams, you'd only take the time to offer assistance to another team if it's in your PD to do so.* *c. Time constraints – everyone is busy and you need to be cognisant of that before bugging others.*
8.	**Consider a recent time when someone asked someone for help.**
a.	**How were you asked?** *Face to face*
b.	**What were they asking for?** *Contributions*
c.	**How long did the associated work take?** *2 hrs.*
d.	**Why were you asked?** *Familiarity, area of expertise.*
e.	**What team were they from?**

	Integration team.
f.	**How did you feel about the exchange?** *A little annoyed about the time it took, when the work wasn't value adding for me.*
g.	**Who were they? (Optional)** *Withheld.*
9.	**Consider a recent time when you asked someone for help.**
a.	**How did you ask?** *Email, followed up with phone and meeting.*
b.	**What were you asking for?** *Info on how a particular system works.*
c.	**How long did the associated work take?** *8 hours*
d.	**Why did you ask that person?** *They're the most experience in that area.*
e.	**What team were they from?** *Operations.*
f.	**How did you feel about the exchange?** *Grateful!*
g.	**Who were they? (Optional)** *Withheld.*
10.	**How are you notified of project decisions, or changes to the program that effect your work?** *Often not flowed down too well, comes down chain and passed through manager. Otherwise, I find out in the tea room.*
11.	**Are you required to pass on project decisions?** *Not generally, no. Sometimes coach less experienced team members of process, that's about the extent of it.*
12.	**Are there any observations or thoughts you have on my Research topic that might be relevant?** *No.*
<End of Interview>	

Table 14 - Interview record - Respondent 1

7.4.2 Respondent 2

Role	Team Lead, IPT 1, Program 1, Company 1
Experience	Program - 3 year, Engineering – 3 years, Company tenure – 11 years
Date	13 May, 2016
Introductory statement	
Explanation of: • Engineering Research project topic, • How results will be used, • Confidentiality of project data.	
Questions	
Definition of Integration	
1.	**What is cross-discipline/cross domain program integration important?** *About differences in perspectives – different teams and individuals will see things differently, and Integration finds the common ground/point of balance.* *The Level of Integration (LoI) is more important for Major Developmental programs. Where plans are COTS based, the sub products are effectively complete, it is only the integration of sub products that requires cross-team integration.* *LoI impacts budget – it's expensive to fully integrate (no point in taking to a walnut with a sledge hammer), but conversely it adds value to the business in allowing individuals to develop cross discipline expertise that will sustain the business.*
2.	**How does planning drive integration?** *Product breakdown Structure (PBS) is equivalent to the Operational Breakdown Structure (OBS), and a Responsibility Assignment Matrix (RAM) assigns responsibilities for each sub product. The Work Breakdown Structure follows the Program Statement of Work.* *Teams have a great number of interfaces/person to person relationships possible – the allowable interfaces need to be documented as part of the Responsibility, Authority and Accountability (RAA) of individuals.* *Scalability – A consistent and systematic approach (such as Systems Engineering) can be applied to projects/programs of many sizes. A framework is useful when it*

	can be applied to a COTS based program, and equally to a fully developmental program. *At a personal level, don't start work until you're ready to. In doing work, you need to set a criteria for completion. This can be done without proper planning and continuous evaluation of progress against that plan. This is in line with Lean principles – making sure you have everything you need, but only the things you need. At the same time, in a dynamic environment, you need to be Agile (adaptable to changing priorities as they're flowed down from management)*
3.	**How does the organisation structure drive integration?** *Stovepipes (when info flows only through direct lines of reporting, i.e. up the chain, across and down through another team, i.e. vertical integration) are created because people don't talk. The intent of an Integrated Product Team (IPT) is to specialise in a technical discipline, with senior engineers primarily responsible for horizontal integration with other teams. Senior Engineers earn this role through a wider understanding of multiple disciplines.* *Having this capability to work quickly and horizontally between teams enables the wider team to respond to change (in contract, program changes) more quickly.* *On the current program, Design and Build are running in parallel, with design generally preceding/leading, but not by a big margin. In retrospect, there wasn't a need for an ILS team. With an Operations/CTE team, LTE team and CTE team with just the SEIT running across all teams would have been a more integrated approach, where ILS members are embedded in those teams. As a separate team, the direction naturally deviates to a small degree (still following a common general direction) from that of the product team. This is a problem, considering that the designers of a product are not considering how it will be supported throughout lifecycle, and vice versa – the life cycle planning isn't considering the dynamic product design as it is developed by the IPT.* *The Systems Engineering Integration Team (SEIT) contains the common tools (specialists) to ensure compliance to key program plans. Support System engineering is small enough that it could have been part of the SEIT (Note- SEIT was added later in the program), along with other specialists seeking to address the ASDEFCON notions of 'ilities (Reliability, Availability and maintainability (RAM),*

	deployability, supportability, manufacturability), Human Factors Engineering, Safety (system and operational), and environment.
4.	**How important is it for your team to interact with other Engineering Teams? Why? What happens if they don't?** *No one person can consider everything on a complex program, when you consider regulatory compliance, contract complexities, and the sheer number of technical areas.* *The higher the risk a program has, the greater the need for integration through cross domain input.* *If you don't integrate, you need a different business plan, i.e. to sell services rather than products. The sum of the whole is more than the sum of parts, and if you're not equipped to deliver a complete product, you should sub contract to deliver parts. Without integration, there's a risk of noncompliance to regulations and contract. You are invoking risk by not getting stakeholder input. You need to ask 'What level of risk can I accept?" before heading down a path without getting stakeholder input. For example, it may not worth conferring with everybody if the risk (e.g. potential financial loss) is small.*
5.	**Is your current program Siloed?** *Comparatively, yes. Other programs are structured that core processes are used across sub projects. On the current program, the processes haven't been fully developed, and this doesn't happen. Teams have their own process.* *Also, there's a lot of pressure on the current program, such that individuals think that "the world is coming down on top of me". This causes them to focus on just their key priorities, without spending the time to gather the necessary inputs, and provide outputs to other team members. Balancing priorities is key.* *Recent milestone example – Flow down occurs through flow down meetings (vertical integration), which occur several times a week, where the Engineering Manager flows down a common priority for all teams to deliver the necessary artefacts for an upcoming milestone review, and which all teams contribute to. After each team combines this with existing priorities and work, the general direction is the same, but with a slightly altered course, if the team continues on*

	that path for a length of time without horizontal integration, the result may be a significant deviation. In this case, the customer identified a number of conflicts between deliverables. *As a side note – You should manage up. Making your boss look good is key to career progression.* *The team Engineering Manager and IPT leads need to follow a circular process of Plan – Do – Check –Act, to ensure everyone is going in the same direction.*
6.	**What do you do as a Team Lead to facilitate integration?** *I manage by walking around, making sure everyone has no blockers, and confirming that the right people, processes, data and tools are being used. The people aspect is about making sure that the required lines of communication are open with a defined list of stakeholders, making sure that a plan to keep those stakeholders informed is being followed (defined in a communications plan).* *The level of reporting needs to be balanced, such that reporting up the chain is done accurately, without taking too much time of workers and managers.* *In terms of the Plan, do, check, act model, we plan on a Monday 'scrum', check how we're going against the plan at a Wednesday 'scrum', and Act to make corrections. On Friday, we reassess priorities and 'plan' for the following week. WIP boards are used to manage.*
7.	**What tools are used to facilitate integration?** *Daily, weekly and monthly communications matrix – This is used to establish an operating rhythm and tie the work that we're doing back to the stakeholder requirements. It defines the lines of reporting, delegations, allowable lines of communication, as well as the related RAA of responsibilities. Assessment of the Knowledge, Skills and Attributes (KSA) of individuals is necessary to define the required lines of communication. Teams are generally comprised of people that need to work together, and sized such that number of possible interactions is possible without spending too much time talking to others about a wider scope of work than is necessary. Managing interactions using the communications matrix prohibits the unnecessary interactions external to the IPT (i.e. the cross-discipline*

	interactions). Ad hoc interactions outside of those approved will be necessary at times, but this should be the exception. *On the current program, the communications matrix was established, but not maintained as it should be.*
8.	**How do you filter the unnecessary interactions from your day?** *I insist on people sending a meeting invite, so I can assess the value of the interaction beforehand, to check where it fits in with my priorities, and those of the program. People asking "Have you got a second?" without any pre warning are imposing their priorities on you. Planning at a personal level is as important as it is for the team, and you can't plan a work day when you're likely to get a dozen ad-hoc, unplanned meetings. Time is the most important resource we have.* *Meetings have value, but are over used. They can often be a waste of time for most people in the room. In planning a meeting, if you get the positions and input of all attendees in advance of the meeting, an hour long meeting may be reduced to 5 or 10 minutes.*

Table 15 - Interview record - Respondent 2

7.4.3 Respondent 3

Role	Team Lead, Systems Engineering Integration Team, Program 2, Company 1
Experience	Program - 2 years, Engineering – 25+ years, Company tenure – Contractor
Date	16 September, 2016

Introductory statement

The aim of my final year project is to give an overview of cross discipline integration, as applied on complex defence programs. The objectives are to:

- Define the importance of horizontal integration between teams
- List the methods programs employ to integrate teams
- Evaluate the efficiency of/value gained from the identified integration methods

The above will inform a framework for cross-domain integration best practice on complex defence programs.

In particular, I'd like to get your thoughts as to why SEIT works (or not), which aspects Systems Engineering feature most prominently.

Questions

Definition of Integration

1. **What is the importance of Product teams interacting? Any examples of not impact of under-integration?**

   Example 1 – On a program for the RAAF, design work for acquisition was contracted by Rockwell Australia to Rockwell in Anaheim, while Hawker de Havilland (HdH) had the Support contract, and were responsible for doing maintenance publications. When HdH came to get required documentation from Rockwell, late in the piece, they found that a lot of the info they needed only existed in the heads of Rockwell Engineers – it wasn't documented. HdH ended up walking away from the contract.

   *Example 2 (more info should be available in the public domain) – The Hubble Space Telescope was an example of a huge failure of product integration after joint development between the US (NASA) and European companies, and conversion between metric and imperial units caused a problem/minus sign was left out. (*It wasn't found that it didn't work until it was launched – a mirror was built to a wrong specification and was misaligned (installed backwards) due to a faulty measuring device. This wasn't picked up due to pressure to launch from Washington (Pearce, 2012)*).*

	Integration between Acquisition and Support programs can be a killer, as demonstrated in example 1 above, where the contractor will save money by saying "all that I need is written down". In reality, as Hawker de Havilland found, it often isn't. This problem is compounded by attrition – when people leave a program, the information in their heads goes with them.
2.	**How much integration is a good thing? What are the downsides?** *The value of integrating teams is commonly underestimated – the cost of integrating teams is often well spent in mitigating risk. Cross team integration necessitates a duplication of effort – people branching out of the technical discipline in which they're paid to work, which drives cost.* *The SEIT can be seen as a burden, when the first construct is used, and they integrate pre designed products of IPTs after they're "thrown over the fence". However, integration methods such as the SEIT can costly if they're not well executed. The same goes with embedding people of technical disciplines across sub teams, rather than having them in a functional sub team.* *Leaders need to believe in a collaborative approach. They should have been around long enough (at a Senior level) to understand the reasons for seemingly unnecessary work, as a mitigator of risk.*
3.	**Do you consider your current program to be siloed?** *Integrated Product Teams are anything but (integrated). Breaking down a Project team into specialised sub-teams with a specific function is deliberate dis-integration, so calling those sub teams "integrated" is an oxymoron.* *This company recognises that integrated teams still end up siloed, but does try to cater for this through the use of the Systems Engineering Integration Team.* *On a Communications upgrade program, by comparison, there wasn't an Integrated Logistics Team, rather a logistics analyst embedded in other teams.* *By comparison of last and current programs, the current program is noticeably more collaborative.* • *Hot desking (where people move their desks around to new positions/new neighbors) is used more effectively, in that it is mandated to move next to someone new every few weeks. This does waste some time, but is an investment in long term collaboration. It is cultural – leaders need to lead by example.* • *The PM stresses egalitarianism.*

	• *Pushes publicity for the program.* *Collaboration extends not only between engineering teams, but also with customer. Conversations with customer are mostly informal, and less contractual straight away. The program is a lot more open, so Contract Changes are passed much more easily. The contract is used as a tool by both customer and contractor, to get the capability that Defence, rather than as a wall.* *Organisational silos are prevalent, but physical silos also exist (Based on location of teams?)*
4.	**Are the collaborative attributes of your current program transferrable?** *They should be, but it depends on the customer as well. On other programs, the program Director (on the Customer side) will ignore the contract when it suits, and use as a whip at other times. For programs, it can come down to luck as to who you get as a customer.*
5.	**Does the use of a matrix organisation facilitate effective integration?** *In a matrix organisation, different functions (including engineering) are allocated to specific programs, whereas a functional organisation is arranged organised in functions rather than programs, with those functions farmed out to multiple programs.* *Matrix organisations can use soft or hard matrices. This company goes some way towards a matrix organisation, in that the company is highly projectised, where the Project teams are multi-discipline. By comparison, in functional organisations, engineers will all report to a single, functional engineering manager.* *A matrix organisation is expensive to set up, needing to have dedicated, costly resources, including a Program Manager/Director, as opposed to shared, functional resources. However, it is much better for meeting schedule requirements because of this.*
6.	**What is the role of the SEIT in driving integration, of product and team?** *SEIT is a construct that tries to replicate what a truly integrated approach would do. There has been two different constructs used for the SEIT.* *1. The first is where sub-teams on a program design sub-products, before handing them off to the SEIT to put together into a workable, integrated product. In this way, the SEIT ends up being just as siloed as any other team. They have their own budget, and the work it integrate occurring after sub products have been developed. This method has proved ineffective, as the SEIT needs presence during product development, to keep engineers cognisant of the need to integrate.*

	2. The second construct is where the SEIT functions in parallel to the product teams development activities, with a SEIT Engineer embedded in each product team, but reporting back any fundamental issues to the SEIT lead. In this way, inconsistencies in the development of sub products are picked up early, before too much work is directed in the wrong direction. *The second SEIT construct evolved from the first. With the first construct, the depth of integration was found to be inappropriate/weak, so the SEIT manager was elevated to a position above the IPT managers. It was found that SEIT Engineers embedded in product teams needed to be Senior Engineers, with knowledge greater than the functional team they're embedded in, in order to gain the respect of team members and to be well situated to understand when work is moving in a conflicting direction to that of other teams.* *The embedded SEIT Engineers will do work for the IPT, but have instructions to report fundamental problems with the teams direction to the SEIT. Needs to be the right person, or won't be effective (can be poorly executed). They're not just man power, they need to be people who've seen projects through to completion, the things that work, and the things that go wrong. For example, the SEIT engineer on the Aircraft team reported that Aircraft acceptance was progressing well, but not enough attention was being paid to how the Aircraft system will integrate with third party systems.* *Note, Speak to the Operations Manager. He should have a better grasp of the iteration from first to second SEIT constructs.*
7.	**Can you note any significant barriers to integration? "We know boats"?** *We know boats – this is to mean that people outside of engineering think Systems Engineering is overkill, and doesn't happen for a reason. But these people don't understand the reasons (for various Systems Engineering activities).* *Earned value management (EVM) is a barrier to the integration of teams, when managers and individuals insist on having a charge code to help out another team. EVM works by trying to optimize development for each sub-task for each sub-team, but if you try and optimise every single bit, the end product is sub-optimal. (Note: I think this is because it places the goals of sub teams above the goals of the project).*
8.	**Have you noticed any other methods for integrating teams that are particularly useful? Any other observations?** *A key question is how the product reflects the depth of integration between teams. I haven't seen much in the way of studies that analyse the hypothesis that integrated*

	teams produce better/more integrated products. There was a report from the late 90s (about Systems Engineer/Software Engineering) which emphasised the point that the less integrated teams are, the less integrated a product is. This is particularly true when product teams are designing from disparate locations. *(Note: This is a key factor towards Program risk, as mitigated by integration)*

Table 16 - Interview record - Respondent 3

7.4.4 Respondent 4

Role	Senior Engineer, Program 1, Company 1
Experience	Program – 6 months, Engineering – 10 years, Company tenure – Contractor
Date	30 September, 2016
Introductory statement	
The aim of my final year project is to give an overview of cross discipline integration, as applied on complex defence programs. The objectives are to: • Define the importance of horizontal integration between teams • List the methods programs employ to integrate teams • Evaluate the efficiency of/value gained from the identified integration methods The above will inform a framework for cross-domain integration best practice on complex defence programs.	
Questions	
Definition of Integration	
1.	**What is the importance of Product teams interacting? What are the advantages of Siloed organisations?** *I think it's most important to reduce risk before integration occurs, through good requirements analysis, work break down and Systems Engineering. Teams should get together in advance of the bulk of Engineering occurring to work out allocation of requirements to teams. If this is done poorly, the risk is that teams will go and do their own thing, not necessarily in the best interests of the program, and resulting in rework.* *(Interviewer Note: If requirements are poorly derived, then you need a human in the loop (people working together) to fix problems, and deal with change)* *For example of poor integration, while working at NEC, there were three different software teams using three different processes to update… They should have got together to integrate processes, and in this way, control consistency.* *Allows teams to align their goals.*
2.	**Are innovation and cost significant drivers?** *Innovation would be important for R&D and highly developmental programs, but we're too focused on deliverables rather than design, to worry about innovation.* *Cost isn't too significant a factor in how teams integrate, at least for horizontal integration.*
3.	**Is your current project siloed? How does it compare to other projects you've worked on?**

	Yes, it appears so, though not by design. Everyone is approachable and happy to help, but there is no formalisation of interactions. It is difficult to know who does what, who you can go to find information. <u>You don't know what you don't know.</u> *The processes to integrate programs (i.e. the systems engineering framework) are in place, but there is no evidence that they're actually being followed. The focus is on Contract deliverables (which should really be outputs of the design), rather than designing, and creating the relevant documentation to support those designs.* *Meetings with the wider team, led by the Program Manager are more for visibility of management rather than flowing down relevant Engineering information.* *Integration <u>enablers</u> from management aren't present – managers set a bad example by disassociating with engineers at lower levels. This drives cohesion of sub teams, but generally deters interest in doing the right thing by the project. To Engineers, <u>Managers are the embodiment of the Program</u>.* *The program is very professional, and managers try hard to do the right thing by people. There isn't any <u>conflict between teams</u>, which is unusual.*
4.	**What are unique aspects/challenges for Defence with regard to integrating teams?** *Defence is very focused on the delivery of documents to prove that a design is working, but this drives more work on preparing documents, than work actually designing a system. The <u>document should be the output of design work, not the primary work</u>. The Systems engineering framework drives the focus on design traceability.*
5.	**What barriers to integration have you observed?** *People only go to other teams when they need information from them, and you need to know who specialises in what to know who to go to. There is a vicious cycle in that the less integrated teams are, the less they're going to know about the specialisations of other members in the wider team, so there is less likelihood of them going to other teams to find information.* *People don't know members of other teams, so there's no way they're going to go asking for things.* *A lack of confidence in management drives loyalty to a sub-team rather than the project. Undermining of teams by getting external audits has increased this.*

6.	**Is bureaucracy a significant factor?** *In terms of Bureaucracy, the Engineering Management System has an undue level of rigor required to send letters and release documents. Being a Product Lifecycle Tool, there are a heap of reviews and promotions that need to happen to get information sent or received via official chains.*
7.	**Have you noticed any other methods for integrating teams that are particularly useful? Any other observations?** *At one stage on this project, Engineering Leads and Senior Engineers were presenting to the wider team about the work they're doing, on a rotational basis, every couple of weeks. This was pretty good tool, as it helps to get a picture of who is doing what.*

Table 17 - Interview summary - Respondent 4

7.4.5 Respondent 5

Role	Engineer, Program 1, Company 1
Experience	Program – 6 months, Engineering – 3 years, Company tenure – 6 months
Date	30 September, 2016

Introductory statement

The aim of my final year project is to give an overview of cross discipline integration, as applied on complex defence programs. The objectives are to:

- Define the importance of horizontal integration between teams
- List the methods programs employ to integrate teams
- Evaluate the efficiency of/value gained from the identified integration methods

The above will inform a framework for cross-domain integration best practice on complex defence programs.

Questions

Definition of Integration

1.	**What is the importance of Product teams interacting?** *It allows you to get <u>multiple perspectives</u>. By gaining the perspective of others you can understand the end result, and in this way reduce risk of rework. For me it helped me understand what is required for Final Acceptance (of a product).* *Proper requirements analysis provides traceability.*
2.	**What are the advantages of a Siloed organisation?** *In siloed teams, people are able to <u>better focus on the work/deliverable at hand</u>. In some cases this is necessary, on the Defence Customer side for evaluating tenders, deliberate isolation is used to prevent conflict of interest.*
3.	**Are innovation and cost significant drivers?** *ASDEFCON doesn't leave room for innovation, process is too prescribed.* *Cost isn't a big factor for horizontal integration.*
4.	**Is your current project siloed? How does it compare to other projects you've worked on?** *By comparison to the previous program I worked on, there is hardly any interaction. This could be due in part to team size – previous team was 35 people compared to current 100+. Open conversation was much more common, and outside of work socialisation more common. <u>Non work interaction facilitate work related interactions</u> through familiarity.* *On this program <u>I don't think the need to collaborate is high</u>.*
5.	**What are unique aspects/challenges for Defence with regard to integrating teams?**

	Defence is very regulated, and deliverable focused. This is primarily due to the ASDEFCON model – this is based on a US Military framework for the development of highly developmental programs, not the non-developmental and semi-developmental programs we have here, so the level of rigor is too high. It drives a great number of documents needing to be prepared to support any design.
6.	**What barriers to integration have you observed?** *Knowing who to go to, and being on speaking terms with the people you need information from. The mitigating factor would be to have more social events, or planned exposure to members of the wider team. Psychological aspects - an unwillingness to ask for help is a barrier.*
7.	**What symptoms of integration have you observed?** *There is a lot of interaction, busy workplaces.*
8.	**Have you noticed any other methods for integrating teams that are particularly useful? Any other observations?** *The organisation structure should reflect the chains of command (and associated interactions). Teams need to be logically grouped, such that a manager is positioned to get information (via vertical integration methods).* *Intentionally planned interactions, social and work related.*

Table 18 - Interview summary - Respondent 5

7.4.6 Respondent 6

Role	Engineer, Program 1, Company 1
Experience	Program – 1 year, Engineering – 10 years, Company tenure – 1 year
Date	6 October, 2016

Introductory statement

The aim of my final year project is to give an overview of cross discipline integration, as applied on complex defence programs. The objectives are to:

- Define the importance of horizontal integration between teams
- List the methods programs employ to integrate teams
- Evaluate the efficiency of/value gained from the identified integration methods

The above will inform a framework for cross-domain integration best practice on complex defence programs.

Questions

Definition of Integration

1.	**What is the value of integrated Engineering teams? Examples?** *While working on a coal movement plant (gantry, conveyors, operator interface, design of stacking patterns and mixing grades of coal), was working in a team of 3 locking down a specification for SCADA (Supervisory control and data acquisition – for remote monitoring and control of conveyor system through Programmable logic controllers (PLCs)). The aim was to create a customisable interface.* *The Customer representative was very difficult – didn't see the importance of the specification – "I'll be the specification".* *In a different team of PLC coders, (controlling breakers for application of high voltage power), a particular individual (a bit of a "cowboy") ignored the specification, hard coding as they saw fit, not at all making the design customisable. This individual had the support of the customer representative, and as a result, the Spec needed to be changed to meet an inefficient standard set by that individual at a whim.* *This highlights the value of integrating work by setting common expectations. In this case, this wasn't done, and different teams were moving in completely different directions with complete disregard for one another.* *The SEIT does try to address this (make sure all teams are on the same page/moving in the same direction). It always takes overhead to try and integrate teams, but if you can get teams working to the same standard, then integration efforts can be very worthwhile.*
2.	**What would you consider to be barriers to integration?**

	A team is likely to follow the example of the team lead, and this is a key reason for divergence of an engineering efforts. The team lead needs to make a concerted effort to flow the expectations of the program down to the product team. The Team Lead should check what the team is doing and why (Plan-do-check-act), how it ties in with Program direction. Understand why we're doing what we're doing. *The methods of communication need to be assessed for effectiveness. Email as a medium is overused – is time consuming and is easy to ignore. Should follow up with phone call.*
3.	**What integrating factors are important?** *For successful integration you need a consistent approach, and to develop this you should set standards early – problems are compounded/amplified as program goes on. Should make sure there is good clarity of scope up front. Don't start the work until you're ready.* *Define blockers on a WIP board, as a common tool used by all teams. Won't work if all teams aren't using them. Used effectively on a communications program.* *Colocation is very helpful, as well as having functional roles embedded in product teams (matrix organisation).* *A plan on a page for a project is a useful guiding tool for sub teams.*
4.	**Is your current project siloed? How does it compare to other projects you've worked on?** *Yes, there isn't a coordinated approach. No one is walking around seeing what work is being done.*
5.	**How does the integration of engineering teams affect the quality of the product?** *An integrated approach means technical risk and problems are found and resolved early, reducing work in the wrong directions. If not integrated, this will greatly increase the scope of work for Verification and Validation (V&V). More time will need to be spent cleaning up. Assess what needs to be done. Notes that interface definition has negligible value.* *The key risk is that the product or system won't work. Regardless of Key Performance Indicators, the system needs to fulfil the customer's real need, and people working together have a better chance of defining and meeting that need.*

Table 19 - Interview summary - Respondent 6

7.4.7 Respondent 7

Role	Senior Engineer, SEIT, Company 1
Experience	Program – 1 year, Engineering – 12 years, Company tenure – 3 year
Date	6 October, 2016

Introductory statement

The aim of my final year project is to give an overview of cross discipline integration, as applied on complex defence programs. The objectives are to:

- Define the importance of horizontal integration between teams
- List the methods programs employ to integrate teams
- Evaluate the efficiency of/value gained from the identified integration methods

The above will inform a framework for cross-domain integration best practice on complex defence programs.

Questions

Definition of Integration

1.	**What is the importance of people working together on product teams?** *You need people tow work together to solve any non-routine problem that a robot can't solve. You need people to work together to deal with change, especially when it's due to changes in the scope of work for a program. Having people quickly get together to work out a plan of attack for any change demonstrates a versatility that no tool, framework or process (or robot) can replicate.*
2.	**When have you seen a lack of integration as a problem?** *While working on a logistics program, I found that the logistics work was leading the engineering work, and as such we were developing Engineering documentation and handing it to the engineers. A lot of the time, this wasn't right, and a bunch of rework resulted, but I like to think we helped on the engineering side a bit.*
3.	**What effect will integration have on the risk to a program, innovation on a program, sharing of knowledge on a program, and cost of a program?** *For risk, it will be able to drastically reduce. You would never be able to eliminate all risk, but certainly teams working together to common priorities, and in an informed manner would bring it down to a manageable level.* *I think innovation would get better the more that integration occurs. By bouncing more ideas of more people, you're likely to come up with better ideas.* *Development can be accelerated by talking to more senior people, and learning the lessons they've learned. Mentoring programs are especially useful for this.*

	WRT cost, the more time you spend on innovation initiatives, the more it's going to cost. The more the senior (and highly paid) a person who is involved with interactions, the more that interaction is going to cost.

Table 20 - Interview summary - Respondent 7

7.4.8 Respondent 8

Role	Senior Engineer, IPT 2, Company 1
Experience	Program – 6 months, Engineering – 15 years, Company tenure – 1 year
Date	6 October, 2016
Introductory statement	
The aim of my final year project is to give an overview of cross discipline integration, as applied on complex defence programs. The objectives are to: • Define the importance of horizontal integration between teams • List the methods programs employ to integrate teams • Evaluate the efficiency of/value gained from the identified integration methods The above will inform a framework for cross-domain integration best practice on complex defence programs.	
Questions	
Definition of Integration	
1.	**When is it important to integrate engineering product teams?** *Integration of project teams is most important during acquisition phases. During support, the processes should be defined, and any interaction will be routine, and defined through RAA. By contrast, during acquisition, the scope of work is not understood, and the decisions made have a long term impact on the support of a program. It's therefore critical that interaction occurs, in order to make project decisions that are agreed as being in the best interest of all stakeholders.* *Also talked about Economies of scale, and project specific problems.* *Noted that as an engineer, focuses on the things in own control, rather than worrying about what management is doing.*

Table 21 - Interview summary - Respondent 8

7.5 Annex E – Survey design and records

7.5.1 Survey Iteration 1

The questions are for the first iteration of the survey design (as detailed in *Methodologies - Surveys*) in *Table 22 – First survey design iteration*.

Respondent		
Date		
Introductory statement		
The following questions will assist in my research conducted as part of my final year project for a Bachelor of Engineering at USQ, in the topic of "Integration Effectiveness between Engineering Teams on Complex Defence Programs". Your answers will be recorded anonymously on my research paper, and analysed to trends for optimising integration in Complex Defence Programs. Program data that could possibly be perceived as sensitive will not be presented in the research paper.		
Question		*Response*
1.	What is your experience (in years/months) on:	
a.	This program and role?	
b.	This type of role?	
c.	This company?	
2.	Consider the last time (or a time) you were asked to help a team member, outside of your immediate team.	
a.	Was the work required of you value adding to your team? (Yes, no)	
b.	How much time did the work required of you take? (<10mins, <30mins, <1hr, <4hrs, <8hrs, <38hrs, >38hrs)	
c.	What was the medium of the request? (Email, face to face, phone, communicator)	
d.	Was the request one that another person could have answered? (Yes, no)	
e.	Why do you think the question was asked of you, and not somebody else? (proximity, expertise, familiarity)	
f.	What function or team the person asking for help from? (Another IPT, Integration, CM, ILS, management)	

g.	Who was the person? (Optional, to cross check answers)	
3.	Consider the last time (or a time) you asked a team member outside of your immediate team for help.	
a.	What was the request for? (Work, advice, other)	
b.	How much time did the request and associated work take? (<10mins, <30mins, <1hr, <4hrs, <8hrs, <38hrs, >38hrs)	
c.	What was the medium of the request? (Email, face to face, phone, communicator)	
d.	Was the request one that another person could have answered? (Yes, no)	
e.	Why did you ask that person particularly? (proximity, expertise, familiarity)	
f.	What function or team the person asking for help from? (Another IPT, Integration, CM, ILS, management)	
g.	Who was the person? (Optional, to cross check answers)	
4.	Are there any observations you can make about your experience in integration effectiveness? (free text)	

Table 22 – First survey design iteration

7.5.2 Survey Iteration 2

The results of a small scale test of the second iteration of the survey design (as detailed in *Methodologies - Surveys*) in shown in *Table 23 – Second iteration of survey results on the effectiveness of integrating factors*.

Integrating Factors	**Perceived Benefits/Deficits**																					**Responsibility**	
	Risk reduction (0-10) Weighting (W): 6.0					**Innovation (0-10)** Weighting (W): 1.0					**Skill Building (0-10)** Weighting (W): 1.0					**Cost (-10 to 10)** Weighting (W): 2.0					**Overall Rating**	**Initiating Role**	**Receiving Role**
Key	r1	r2	r3	r4	Avg. x W	r1	r2	r3	r4	Avg.	r1	r2	r3	r4	Avg.	r1	r2	r3	r4	Avg.	/100		
	r5	r6	r7	r8		r5	r6	r7	r8		r5	r6	r7	r8		r5	r6	r7	r8				
Organisational Factors																							
Open plan office	1	0	3	1	7.5	7	5	8	6	6.5	5	5	6	3	4.8	5	1	5	3	4.8	25.8	PM/SM	IPTs/Eng
Integration team	7	9	7	8	49.5	4	5	3	3	4.0	4	6	5	5	4.8	-9	-5	-9	-4	-11.5	46.8	IM	IPTs/Eng
Comms. Matrix	5	4	4	8	31.5	3	1	3	2	2.3	3	1	4	2	2.5	0	1	2	0	1.5	37.8	PM	IPTs/Eng
Priority flow down	3	2	4	7	24.0	0	2	4	2	2.0	0	3	4	2	2.3	2	3	2	4	5.5	33.8	PM/EM	IPTs/Eng

Table 23 – Second iteration of survey results on the effectiveness of integrating factors

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7.5.3 Final survey iteration

The final survey design, including the request for participation, is shown in *Table 24 - Final survey design*.

Hi,

I'll shortly be submitting the report for my final year research project, on the topic of integration effectiveness between engineering teams on Defence programs.

Please don't feel obliged, but if you have a spare 10 mins, would you mind rating the factors identified below? For any that aren't self-explanatory or that you're unsure about, please leave blank. If you're busy, please don't feel obliged to respond at all, but if you could pick a few that are most important – that would be appreciated. I'm seeking responses by Wed (Oct 12).

Survey on Cross Team Engineering Integration

Instructions – I've listed 25 of the most significant integration values, barriers and enablers below. Please reply to this email, and mark the applicable column against each with an 'X'.

For this table, please rate the values and burdens for importance, as they are influenced by cross team integration. Skip any that aren't clear, or any that aren't impacted by integration.

	Value as added through cross-team integration / Burdens as created through cross-team integration	Critical	Important	Not important
1.	Reduction of risk of noncompliance with contract			
2.	Reduction of risk of conflicting info in deliverables			
3.	Reduction of risk of rework			
4.	Increased Innovation through shared perspectives			
5.	Enhanced development of engineering skills			

6.	Increased cost through time spent on collaborating			
7.	Increased cost through duplication of effort			

For this table, please rate the frequency of observed barriers. Skip any that aren't clear.

	Barriers to integration	Frequently observed	Infrequently observed	Not observed
8.	Lack of time / too busy			
9.	No understanding of the roles of others / knowing who to ask			
10.	Too many hoops to get information / bureaucracy			
11.	Unwillingness to ask for help / bother anyone			
12.	Distance			
13.	Lack of management support			
14.	Allegiance to IPT rather than project			
15.	No perceived need to integrate			

For this table, please rate the effectiveness of identified factors in integrating engineering teams. Skip any that aren't clear.

	Integrating factor	Very effective	Somewhat effective	Not effective
16.	SEIT / Integration team			

17.	RAA – Defined responsibility of individuals to work across teams			
18.	Open-plan work space			
19.	Interface definition / Communications Matrix			
20.	Common tools and processes used across teams			
21.	Matrix organisation IPT structure (functional roles (e.g. ILS) embedded within IPTs)			
22.	Functional roles deployed to IPTs			
23.	Common goals and priorities flowed down to IPTs			
24.	Role rotations			
25.	Train engineers to ensure roles and expertise of individuals across the team are understood			

Thank you very much for your time!

Table 24 - Final survey design

The survey results are shown in *Table 25 - Survey results*.

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Survey Questions		**Statistics**				**Responses**										
		Avg	Std dev	Eng. avg	Mgr. avg	1 Eng	2 Mgr	3 Mgr	4 Eng	5 Eng	6 Eng	7 Eng	8 Mgr	9 Eng	10 Eng	11 Mgr
Value as added through cross-team integration / Burdens as created through cross-team integration																
Critical = 2, Important = 1, Not important = 0																
1	Reduction of risk of noncompliance with contract	1.18	0.75	1.14	1.25	2	1	1	1	0	1	2	2	0	2	1
2	Reduction of risk of conflicting info in deliverables	1.27	0.65	1.14	1.50	1	2	1	1	1	2	2	1	0	1	2
3	Reduction of risk of rework	1.60	0.52	1.50	1.75	1	2	1	2	1		1	2	2	2	2
4	Increased Innovation through shared perspectives	0.91	0.54	1.00	0.75	1	0	2	1	1	1	1	1	1	1	0
5	Enhanced development of engineering skills	0.73	0.65	1.00	0.25	2	0	0	1	0	1	1	1	1	1	0
6	Increased cost through time spent on collaborating	0.90	0.74	0.86	1.00	2		1	0	2	0	1	1	1	0	1
7	Increased cost through duplication of effort	0.90	0.57	0.86	1.00	1		1	1	1	1	2	1	0	0	1
Barriers to integration																
Frequently observed = 2, Infrequently observed = 1, Not observed = 0																
8	Lack of time / too busy	1.55	0.69	1.29	2.00	2	2	2	2	2	1	1	2	1	0	2
9	No understanding of the roles of others / knowing who to ask	1.73	0.47	1.71	1.75	2	2	2	1	2	2	2	2	1	2	1
10	Too many hoops to get information / bureaucracy	1.18	0.60	1.00	1.50	1	2	1	0	1	1	1	2	2	1	1

Survey Questions		**Statistics**				**Responses**										
		Avg	Std dev	Eng. avg	Mgr. avg	1 Eng	2 Mgr	3 Mgr	4 Eng	5 Eng	6 Eng	7 Eng	8 Mgr	9 Eng	10 Eng	11 Mgr
11	Unwillingness to ask for help / bother anyone	1.27	0.65	1.00	1.75	1	1	2	0	1	1	2	2	1	1	2
12	Distance	0.91	0.54	0.71	1.25	1	1	2	0	1	1	1	1	0	1	1
13	Lack of management support	0.91	0.70	0.71	1.25	0	1	1	0	1	2	1	2	1	0	1
14	Allegiance to IPT rather than project	1.09	0.83	0.71	1.75	0	2	2	0	2	1	1	1	1	0	2
15	No perceived need to integrate	1.09	0.70	1.00	1.25	1	1	1	0	2	2	1	1	1	0	2
Integrating factors																
Very effective = 2, Somewhat effective = 1, Not effective = 0																
16	SEIT / Integration team	1.36	0.50	1.14	1.75	2	2	2	1	1	1	1	2	1	1	1
17	RAA – Defined responsibility of individuals to work across teams	1.27	0.65	1.29	1.25	1	1	2	1	2	2	1	1	0	2	1
18	Open-plan work space	0.55	0.52	0.57	0.50	0	1	1	1	1	1	1	0	0	0	0
19	Interface definition / Communications Matrix	1.10	0.74	1.00	1.25	1	2	0	0	1		1	2	1	2	1
20	Common tools and processes used across teams	1.45	0.69	1.43	1.50	2	2	0	1	1	1	2	2	1	2	2
21	Matrix organisation IPT structure (functional roles (e.g. ILS) embedded within IPTs)	1.10	0.57	1.17	1.00	2	1	1	0	1		1	1	2	1	1
22	Functional roles deployed to IPTs	0.80	0.42	0.83	0.75	1	1	0	0	1		1	1	1	1	1
23	Common goals and priorities flowed down to IPTs	1.55	0.52	1.57	1.50	2	1	2	1	2	2	1	1	1	2	2
24	Role rotations	1.00	0.77	0.71	1.50	2	2	1	1	0	1	0	2	0	1	1

Survey Questions		**Statistics**				**Responses**										
		Avg	Std dev	Eng. avg	Mgr. avg	1 Eng	2 Mgr	3 Mgr	4 Eng	5 Eng	6 Eng	7 Eng	8 Mgr	9 Eng	10 Eng	11 Mgr
25	Train engineers to ensure roles and expertise of individuals across the team are understood	1.09	0.70	1.29	0.75	1	1	0	1	2	1	1	2	1	2	0

Table 25 - Survey results

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