ACIL ALLEN CONSULTING

REPORT TO
DEFENCE SCIENCE AND TECHNOLOGY GROUP

31 AUGUST 2015

ECONOMIC IMPACT CASE STUDIES

ESTABLISHING THE BROAD ECONOMIC VALUE OF THE DEFENCE SCIENCE & TECHNOLOGY PROGRAM

ACIL ALLEN CONSULTING PTY LTD
ABN 68 102 652 148

LEVEL FIFTEEN
127 CREEK STREET
BRISBANE QLD 4000
AUSTRALIA
T+61 7 3009 8700
F+61 7 3009 8799

LEVEL TWO
33 AINSLIE PLACE
CANBERRA ACT 2600
AUSTRALIA
T+61 2 6103 8200
F+61 2 6103 8233

LEVEL NINE
60 COLLINS STREET
MELBOURNE VIC 3000
AUSTRALIA
T+61 3 8650 6000
F+61 3 9654 6363

LEVEL ONE
50 PITT STREET
SYDNEY NSW 2000
AUSTRALIA
T+61 2 8272 5100
F+61 2 9247 2455

LEVEL TWELVE, BGC CENTRE
28 THE ESPLANADE
PERTH WA 6000
AUSTRALIA
T+61 8 9449 9600
F+61 8 9322 3955

ACILALLEN.COM.AU

SUGGESTED CITATION FOR THIS REPORT

ACIL ALLEN CONSULTING (AUGUST 2015), ECONOMIC IMPACT CASE STUDIES: ESTABLISHING THE BROAD ECONOMIC VALUE OF THE DEFENCE SCIENCE & TECHNOLOGY PROGRAM.

EXECUTIVE SUMMARY

The Defence Science and Technology program is managed and largely undertaken by the Defence Science and Technology Group (DST Group). The DST Group is an applied science and technology organisation. Its role is to deliver valued scientific advice and innovative technology solutions for Defence and national security. As part of the First Principles Review implementation, DST Group commissioned ACIL Allen Consulting to undertake an independent study of the economic value of the Science and Technology program since 2003.

This report seeks to establish the likely range of the economic value of the Defence Science and Technology program. In particular, the report focusses on estimating the lower bound of this range. The assessment is based on a series of targeted case studies, all of which made significant contributions to Defence and national security and in that sense are considered to be “successful”. The case studies were selected from a larger pool of successful candidates although they were also selected to ensure that they covered the span of DST Group activities.

The economic value is assessed in terms of the economic benefits. The attributable costs are a small fraction of the benefits in the case studies. Collectively, these costs are also not representative of DST Group’s overall cost base. In our view spending a significant amount of time collating DST Group costs for the case studies would not materially change the case study findings and the report’s conclusions.

In considering economic value, DST Group is best thought of both as an applied research organisation and a facilitator of research and innovation more broadly across industry. These research efforts are ultimately focused on delivering capability for defence and national security.

Defence of Australia typically involves high levels of uncertainty in terms of future threats and response options, and must incorporate the value of possible future deterrence as well as current capability. Much of its value lies in insurance against risks that do not lend themselves to conventional actuarial assessment. While value can be delivered through increased capability it can also be increased by delivering the existing capability more efficiently. Such efforts are a core function of the DST Group and this is reflected in some of the major savings that its research and development has contributed to since 2003.

The nature of research means that some of it will always be speculative and there are inherent risks associated with research which may be managed but not necessarily avoided. Some research projects (possibly the majority) when considered in isolation will generate few benefits if at all in a classical economic benefit-cost framework. However, what they can do is provide insights into areas of research that should not be pursued further or where additional effort might be warranted where there is sufficient promise of future benefits.

Therefore, the economic value of the Defence Science and Technology program accrues to Australia in a number of ways:

— Benefits reflecting cost savings or developments of Australian specific or Australian only capabilities from tangible projects can be estimated and summed – this was the primary mechanism used in the 2003 Trenberth report (and fits with the traditional benefit-cost approach)
— Benefits attributable to the establishment of a portfolio of additional options through DST Group research and development – includes knowledge, insights and skills that provide a capacity for faster or more cost effective or more effective response to plausible future developments in technologies and threats
— Benefits attributable to capabilities and options developed through collaboration with organisations and research establishments beyond DST Group including within Australia and internationally – again providing a foundation for better responses to plausible future developments.

The case study approach encompassed within this report largely captures only the first of these three areas of benefits (at least in quantifiable terms). Quantifying the value of the options that DST Group creates and stewards on behalf of the nation is beyond the scope of this study (although we expect that these benefits would be significantly larger than those uncovered through the case study approach).

Therefore, the economic benefits identified in this report focus on benefits flowing to Australia in terms of cost savings (efficiency), capability enhancements (effectiveness) and Australian export sales. The assessment reflects the value to Australia in a world ***with and without*** DST Group. This includes all assessed benefits that would not have (or would have been unlikely to have) been achieved without DST Group. We acknowledge that other organisations (including from within Defence) may have made and usually did make major contributions to the ten projects that we considered. However, our specific focus on the economic value of the Defence Science and Technology program allows us to ignore the contribution of other parties in estimating the economic benefits for the purposes of this study.

The distinction of the Australian context in the above is important. DST Group has contributed to research and development that has in many cases had significant value to our partner nations. However, these are not benefits that flow to Australia, although undoubtedly there are *quid pro quo* benefits that flow indirectly through the sharing with Australia of other valuable research and development by our partner nations (DST Group is the “trusted” portal through which much of this research and development flows).

The period over which the economic benefits were assessed was 2003 to 2015. The choice of 2003 as the starting point for the assessment occurs naturally as it coincides with the completion of the Trenberth Review, which considered the same issue amongst other matters. The nature of many of these projects and timelines over which the benefits were delivered meant that in some cases the starting point for the assessment was slightly earlier or slightly later.

Ten case studies were assessed in some detail. ACIL Allen Consulting has conservatively assessed the tangible economic benefits of DST Group’s research and support associated with the ten case studies as being approximately **$5.1 billion**. The project by project assessment is shown in Table ES 1.

The detailed case studies set out the basis for these calculations. In general the estimates are based on the increased value, avoided costs or export revenues in 2015 dollars. However, we have not applied discounting to the estimates because of the complexity in establishing the timing of accrued benefits. As many of the benefits have already accrued, using a discounting approach would inflate those benefits in present value terms. Of course any future benefits would be discounted which to some extent would offset the inflation of historical benefits.

However, the assessment in our view is conservative. In a number of cases benefits could not be easily quantified and so they were not included as having a specified value. In other cases where benefits were calculated, the underlying assumptions in our view are conservative. In this sense the $5.1 billion is very much a lower bound on the economic benefits generated by DST Group since 2003.

The ten case studies represent a relatively small part of DST Group’s efforts over the last 12 or so years although the realised benefits are likely to represent a proportionally larger amount of the value that DST Group has created over the same period because of the bias in the selection process (projects were selected for the case studies from a larger list of "successful" projects although they were also selected to ensure that they covered the span of DST Group activities). However, the DST Group costs in undertaking these projects represent significantly less than 10 per cent of the total DST Group costs over the same period.

TABLE ES 1 – **CASE STUDY PROJECT ASSESSED BENEFITS**

Project number	Project name	Assessed Tangible benefit ($m)
1.	Collins Class Submarine Remediation	598
2.	P-3 Orion Service Life Assessment Program	432
3.	Joint Direct Attack Munition – Extended Range	853
4.	Jindalee Operational Radar Network (JORN)	1,503
5.	F/A-18 Structural Refurbishment	443
6.	E-7A Wedgetail Radar	350
7.	NULKA Anti-Ship Missile Decoy	452
8.	Advanced Short Range Air to Air Missile	110
9.	Wideband Global SATCOM System JP2008 Phase	350
10.	Force Protection Electronic Countermeasures	51
	Total	**5,142**

SOURCE: ACIL ALLEN

DST Group has undertaken and continues to undertake a large portfolio of activities to support Defence and national security. For example, since 2007, DST Group has completed 185 tasks and currently has 175 tasks that are active or approved. Undoubtedly some of these would have been small tasks with relatively small benefits and some may have generated little or no tangible benefits. On the other hand some of the projects not considered as case studies also would have likely had large benefits (e.g. the C-130J Fleet reduced maintenance costs and the savings in avoiding upgrades to the Electronic Support Measure system for the AP-3C Orion). These numbers of tasks provide insight into the level of DST Group activity.

In taking into account the conservative bias in our assessment of benefits and that the case studies represent a relatively small proportion of total DST Group effort, it may be reasonable to conclude that the extension of the case study approach across all DST Group projects would **yield 4 to 5 times the value ($20 to $25 billion)**.

As discussed above, we are of the view that the case study approach is likely to significantly undervalue the economic value of DST Group. We have included in the report a short consideration of the option values created by projects and by the whole of the Science and Technology program. We have a strong view that DST Group as an applied research organisation essentially creates and stewards options to support the tasks of defence and national security; and that this applies both currently and to the future where circumstances may change rapidly.

As is discussed in the report, these options are created and enhanced through the ability of DST Group (usually working with others) to provide increased flexibility in acquiring and utilising capability and to adapt capability as the future unfolds. In part this option value exists because of the confidence that Defence and national security organisations have in the ability of DST Group to apply its skill sets and experience when circumstances require it to do so. This in turn allows Defence and national security organisations to be less prescriptive about uncertain futures and to limit and in some cases defer investment in capability. A more prescriptive approach would likely oblige Defence and national security organisations to make more and larger pre-emptive investments or alternatively deliver less flexibility and capability for the same investment.

CONTENTS

EXECUTIVE SUMMARY I

1

Introduction *1*
1.1 Report structure 1
1.2 Report's limitations 2
1.3 Acknowledgements 2

2

Summary of findings *3*

3

Approach to estimating economic impact *5*
3.1 Generation of economic value 6

4

Case studies *10*
4.1 Collins Class Submarine Remediation 12
4.2 P-3 Orion Service Life Assessment Program 13
4.3 Joint Direct Attack Munition – Extended Range 14
4.4 Jindalee Operational Radar Network (JORN) 15
4.5 F/A-18 Structural Refurbishment 17
4.6 E-7A Wedgetail Radar 18
4.7 NULKA Anti-ship Missile Decoy 19
4.8 Advanced Short Range Air to Air Missile 20
4.9 Wideband Global SATCOM System JP2008 Phase 21
4.10 Force Protection Electronic Countermeasures 22

5

DST Group additional value *24*

A

Detailed case studies *A–1*
A.1 Collins Class Submarine Remediation A–2
A.2 P-3 Orion Service Life Assessment Program A–16
A.3 Joint Direct Attack Munition – Extended Range A–22
A.4 Jindalee Operational Radar Network (JORN) A–28
A.5 F/A-18 Structural Refurbishment (HUG3) A–37
A.6 E-7A Wedgetail Radar A–42
A.7 NULKA Anti-ship Missile Decoy A–48
A.8 Advanced Short Range Air to Air Missile A–54
A.9 Wideband Global SATCOM System JP2008 Phase A–62
A.10 Force Protection Electronic Countermeasures A–68

C O N T E N T S

B

References *B–1*

FIGURES

FIGURE 3-1 – **DST GROUP ROLES** 6
FIGURE 4-1 –**IMPACT FRAMEWORK FOR EVALUATING DST GROUP RESEARCH** 11
FIGURE 4.2 – **COLLINS SUBMARINE CASE STUDY – IMPACT FRAMEWORK DIAGRAM** 12
FIGURE 4.3 – **P-3 ORION - IMPACT FRAMEWORK DIAGRAM** 13
FIGURE 4.4 – **JDAM-ER CASE STUDY – IMPACT FRAMEWORK DIAGRAM** 14
FIGURE 4.5 – **JORN CASE STUDY– IMPACT FRAMEWORK DIAGRAM** 16
FIGURE 4.6 – **F/A 18 STRUCTURAL REFURBISHMENT – IMPACT FRAMEWORK DIAGRAM** 17
FIGURE 4.7 – **WEDGETAIL CASE STUDY – IMPACT FRAMEWORK DIAGRAM** 18
FIGURE 4.8 – **NULKA CASE STUDY – IMPACT FRAMEWORK DIAGRAM** 19
FIGURE 4.9 – **ASRAAM CASE STUDY – IMPACT FRAMEWORK DIAGRAM** 20
FIGURE 4.10 – **GWS SYSTEM CASE STUDY – IMPACT FRAMEWORK DIAGRAM** 21
FIGURE 4.11 – **FPEC CASE STUDY – IMPACT FRAMEWORK DIAGRAM** 23

FIGURE A.1 – **ADF DEATHS IN AFGHANISTAN DUE TO IMPROVISED EXPLOSIVE DEVICES** A–70

TABLES

TABLE 2.1 – **CASE STUDY PROJECT ASSESSED BENEFITS** 4
TABLE 4.1 – **CASE STUDY ORDER AND ASSESSED BENEFITS** 11
TABLE 4.2 – **JORN EVOLUTION** 15

TABLE A.1 – **CASE STUDY ORDER** A–1
TABLE A.2 – **SUMMARY OF OUTCOMES AND IMPACTS OF COLLINS SUBMARINE PROJECT** A–9
TABLE A.3 – **COLLINS CLASS SUBMARINE REMEDIATION ASSESSED BENEFITS** A–15
TABLE A.4 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE P-3 ORION PROJECT** A–18
TABLE A.5 – **SUMMARY OF OUTCOMES AND IMPACTS OF JDAM-ER PROJECT** A–24
TABLE A.6 – **JDAM-ER ASSESSED BENEFITS** A–27
TABLE A.7 – **JORN EVOLUTION** A–28
TABLE A.8 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE JORN PROJECT** A–32
TABLE A.9 – **JORN ASSESSED BENEFITS** A–36
TABLE A.10 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE HUG PHASE 3 PROJECT** A–39
TABLE A.11 – **HUGS PHASE 3 ASSESSED BENEFITS** A–41
TABLE A.12 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE WEDGETAIL PROJECT** A–44
TABLE A.13 – **SUMMARY OF OUTCOMES AND IMPACTS OF NULKA PROJECT** A–50
TABLE A.14 – **NULKA ASSESSED BENEFITS** A–53
TABLE A.15 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE ASRAAM PROJECT** A–57
TABLE A.16 – **ASRAAM ASSESSED BENEFITS** A–61
TABLE A.17 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE GWS PROJECT** A–65
TABLE A.18 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE FPEC PROJECT** A–71
TABLE A.19 – **FPEC ASSESSED BENEFITS** A–73

BOXES

BOX A.1 – **KEY FINDINGS – COLLINS CLASS REMEDIATION** A–2
BOX A.2 – **PROPELLER FATIGUE MANAGEMENT PLAN** A–6

CONTENTS

BOX A.3 – **KEY FINDINGS – P-3 ORION** A–16
BOX A.4 – **KEY FINDINGS – JDAM-ER** A–22
BOX A.5 – **KEY FINDINGS – JORN** A–28
BOX A.6 – **KEY FINDINGS – HUG3** A–37
BOX A.7 – **KEY FINDINGS – E-7A WEDGETAIL RADAR** A–42
BOX A.8 – **KEY FINDINGS – NULKA** A–48
BOX A.9 – **KEY FINDINGS – ASRAAM** A–54
BOX A.10 – **KEY FINDINGS – WIDEBAND GLOBAL SATCOM SYSTEM** A–62
BOX A.11 – **KEY FINDINGS – FPEC** A–68

1 INTRODUCTION

The Defence Science and Technology Group[1] (DST Group) engaged ACIL Allen Consulting in March 2015 to establish the broad economic value of the Defence Science and Technology program. This report seeks to establish an estimate of the likely range of the economic value of the program. The low bound of the range has been estimated through the development of case studies of ten defence projects to which DST made essential contributions. The upper bound has been estimated through conceptual application of "real options" theory to the broader scope of DST Group's science and technology activities.

DST Group is an applied science and technology organisation. Its role is as "a national leader in safeguarding Australia by delivering valued scientific advice and innovative technology solutions for Defence and national security". Core to this role is its ability and credibility in providing both expert and impartial advice to Defence in relation to current capability and force structure and for future Defence capabilities. These abilities are closely linked to DST Group's capability in knowledge and innovation integration, which in part is made possible through its partnerships (both domestically and internationally) and through its role in coordinating science and technology for national security.

DST Group is funded through the Commonwealth Defence Budget. The Defence budgeted expenses for 2015-16 is projected to be around 31.8 billion dollars. The DST Group budget within the Defence Budget for 2015-16 is projected to be around 432 million dollars.

As part of the First Principles Review implementation, DST Group commissioned an independent study of the economic value of the Science and Technology program utilising targeted case studies. This project aims to assist DST Group in articulating its value proposition by establishing the economic value of DST Group projects undertaken since 2003.

1.1 Report structure

The structure of this Report is as follows:

- Section 2 summarises our findings
- Section 3 provides a brief description the methodology that was used in establishing the broad economic value of DST Group including:
  - Estimating the minimum economic value of a specified set of DST Group projects by estimating their economic benefits attributable to DST Group's efforts
  - Establishing a stylised options approach that can be used and applied within DST Group to estimate the value of options that DST Group creates and maintains as a portfolio for Defence and National security. These may include the ability to adapt technologies to unique Australian

[1] On 1 July 2015, the Defence Science and Technology Group was established from the Defence Science and Technology Organisation (DSTO) as part of the First Principles Review implementation. As this project was commenced in March 2015 and most of the material was developed under the former name, some references to DSTO may occur throughout this report.

conditions and needs, the flexibility to adapt to uncertain future conditions and the potential for wider commercialisation and spill-overs to industry.

— Section 4 provides a short summary of each of the case studies
— Section 5 considers the value generated through options created by DST Group
— Appendix A sets out each of the ten detailed case studies.

1.2 Report's limitations

This report seeks to establish the economic value of the Defence Science and Technology program through the analysis of ten case studies and consideration of the additional option value generated by DST Group through the program. The analysis in the report is subject to the following limitations:

— The report focusses on the benefits generated by the Science and Technology program which are valued in 2015 dollars but are not adjusted for timing of occurrence (discounting). In large part the benefits were not discounted because the timing of the benefits was not certain. As most of the benefits are historical this potentially understates the benefits in present value terms
— Costs associated with the case studies are also only considered on an aggregate basis in 2015 dollars and are also not subject to discounting (again because of the uncertainty of timing). However, the aggregate benefits are able to be compared with the aggregate of DST Group's costs over the period noting that the costs attributable to the ten case studies are less than 10 per cent of DST Group's overall costs over the period.
— ACIL Allen representatives involved in developing the case studies and preparing this report operated without a security classification. This meant that where benefits associated with some of the projects related to classified capabilities, they could not be revealed to ACIL Allen.
— The work on the value of options was limited to a stylised view due to limitations of scope and resources – while it can be confidently stated that the DST Group options portfolio value is likely to have significant value, these were unable to be quantified in this report.

1.3 Acknowledgements

ACIL Allen wishes to acknowledge the assistance that it received from a broad range of DST Group staff in developing the content of the case studies and who helped us in our understanding of DST Group and the work that it undertakes.

We also wish to acknowledge the assistance of a number of other Defence staff (uniformed and civilian) who provided advice and feedback on the case studies.

In particular we wish to acknowledge the role and assistance of Dr Ken Anderson in shepherding us through the complexities of the Defence organisation and in providing guidance to us in completing this report.

2 SUMMARY OF FINDINGS

ACIL Allen's assessment of the economic value of Defence Science and Technology program is summarised in this section. The economic value is assessed in terms of the economic benefits. The attributable costs are a small fraction of the benefits and in our view have no material effect on our conclusions with respect to the economic value of the Defence Science and Technology program.

The economic benefits focus on benefits flowing to Australia in terms of cost savings (efficiency), capability enhancements (effectiveness) and Australian export sales. The assessment reflects the value to Australia in a world *with and without* DST Group. This includes all assessed benefits that in the absence of DST Group, would not have (or would have been unlikely to have) been achieved. We acknowledge that other organisations (including from within Defence) may have made and usually did make major contributions to the ten projects that we considered. However, our specific focus on the economic value of the Defence Science and Technology program allows us to ignore the contribution of other parties in estimating the economic benefits for the purposes of this study.

The period over which the economic benefits were assessed was 2003 to 2015. The choice of 2003 as the starting point for the assessment occurs naturally as it coincides with the completion of the Trenberth Review, which considered the same issue amongst other matters.

Ten case studies were assessed in some detail (refer section 4 and Appendix A). ACIL Allen Consulting has conservatively assessed the tangible economic benefits of DST Group's research and support associated with the ten case studies as being approximately **$5.1 billion**. The breakdown of the assessment by project is shown in Table 2.1.

The detailed case studies set out the basis for the calculation of the estimated benefits in each case. In general the estimates are based on the increased value, avoided costs or export revenues in 2015 dollars. However, we have not applied discounting[2] to the estimates because of the complexity in establishing the timing of accrued benefits. As many of the benefits have already accrued, using a discounting approach would inflate those benefits in present value terms. Of course future benefits would be discounted which to some extent would offset the inflation of historical benefits.

This assessment is in our view conservative. In a number of cases benefits could not be easily quantified and so they were not included as having a specified value. In other cases where benefits were calculated, the underlying assumptions in our view are conservative. In this sense the $5.1 billion is very much a lower bound on the economic benefits generated by DST Group since 2003.

The ten case studies represent a relatively small part of DST Group's efforts over the last 12 or so years although the realised benefits are likely to represent a proportionally larger amount of the value that DST Group has created over the same period because of the bias in the selection process (projects were selected from a larger list of successful projects although they were also selected to ensure that they covered the span of DST Group activities). However, the DST Group costs in

[2] Typically a discount rate of 7 per cent would be used.

undertaking these projects represent significantly less than 10 per cent of the total DST Group costs over the same period. DST Group has undertaken and continues to undertake a large portfolio of activities to support Defence and national security.

For example, since 2007, DST Group has completed 185 tasks and currently has 175 tasks that are active or approved. Undoubtedly some of these would have been small tasks with relatively small benefits and some may have generated little or no tangible benefits. On the other hand some of the projects not considered as case studies also would have likely had large benefits (e.g. the C-130J Fleet reduced maintenance costs and the savings in avoiding upgrades to the Electronic Support Measure system for the AP-3C Orion). These numbers of tasks provide insight into the level of DST Group activity.

In taking into account the conservative bias in our assessment of benefits and that the case studies represent a relatively small proportion of total DST Group effort, it may be reasonable to conclude that the extension of the case study approach across all DST Group projects would **yield 4 to 5 times the value ($20 to $25 billion)**[3].

TABLE 2.1 – **CASE STUDY PROJECT ASSESSED BENEFITS**

Project number	Project name	Assessed Tangible benefit ($m)
1.	Collins Class Submarine Remediation	598
2.	P-3 Orion Service Life Assessment Program	432
3.	Joint Direct Attack Munition – Extended Range	853
4.	Jindalee Operational Radar Network (JORN)	1,503
5.	F/A-18 Structural Refurbishment	443
6.	E-7A Wedgetail Radar	350
7.	NULKA Anti-Ship Missile Decoy	452
8.	Advanced Short Range Air to Air Missile	110
9.	Wideband Global SATCOM System JP2008	350
10.	Force Protection Electronic Countermeasures	51
	Total	**5,142**

SOURCE: ACIL ALLEN

More broadly, we are of the view that the case study approach is likely to significantly undervalue the economic value of DST Group. In section 5 we considered the option values created by projects and by the whole of the Science and Technology program. We have a strong view that DST Group as an applied research organisation essentially creates and stewards options to support the tasks of defence and national security; and that this applies both currently and to the future where circumstances may change rapidly.

As is discussed in the report, these options are created and enhanced through the ability of DST Group (usually working with others) to provide increased flexibility in acquiring and utilising capability and to adapt capability as the future unfolds. In part this option value exists because of the confidence that Defence and national security organisations have in the ability of DST Group to apply its skill sets and experience when circumstances require it to do so. This in turn allows Defence and national security organisations to be less prescriptive about uncertain futures and to limit and in some cases defer investment in capability, whereas a more prescriptive approach would likely oblige Defence and national security organisations to make more and larger pre-emptive investments.

[3] The broader estimate is based on the relatively small proportion of overall science and technology program activity embedded in the case studies (significantly less than 10 per cent) but adjusted for case study selection bias (selected only from a larger list of successful projects).

3 APPROACH TO ESTIMATING ECONOMIC IMPACT

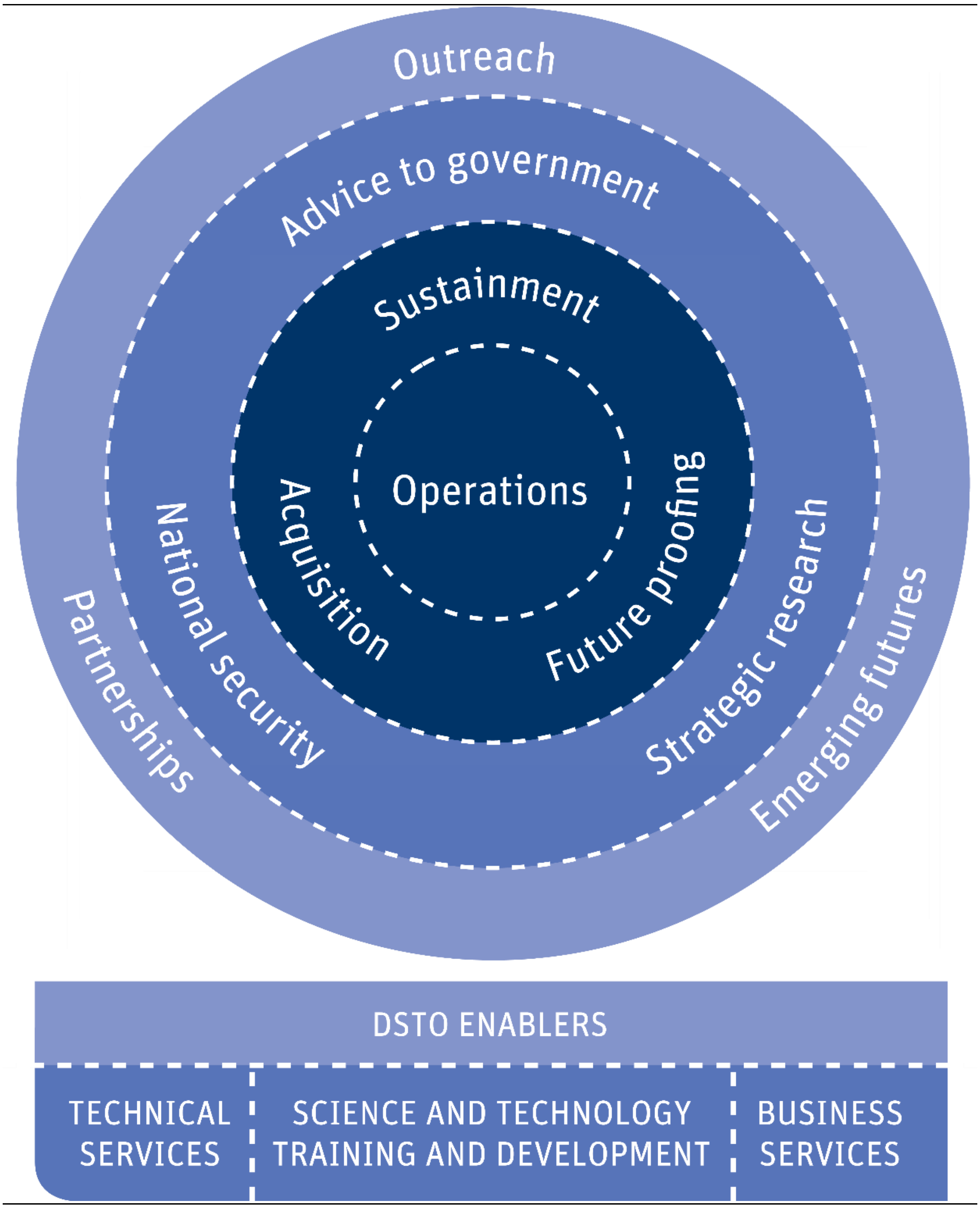
The purpose of this section of the report is to discuss the approach taken in establishing the broad economic value of the Defence Science and Technology program.

The current DST Group strategic plan emphasises the organisation's contribution to defence and national security, its role in the shaping and development of new ideas and technologies for defence and national security and the importance of knowledge integration and innovation for defence. The strategic plan also emphasises the importance of DST Group collaborating with other leading organisations both in Australia and internationally in order to foster innovation, stimulate Australian research efforts for national security and leverage applicable knowledge from external partners including industry.

In this sense DST Group provides both operational and strategic advice to Defence and more broadly is a trusted advisor across the Commonwealth Government on relevant Defence, National Security and related matters. The value that DST Group provides is magnified through its various partnerships and relationships within research institutions and the broader Australian defence industry and globally with other governments, research institutions and defence industries. In addition DST Group's long track record in developing and adapting defence technologies specifically suitable for Australia's conditions and force structure provides Defence and the Commonwealth Government with greater flexibility when considering the acquisition of capabilities.

The role of DST Group is succinctly captured in Figure 3-1 which is taken from the current DST Group Strategic Plan (2013-2018). While supporting Defence operations and the acquisition of new capability are core functions, the broader trusted advisor and relationship leveraging functions become possible through the credibility that DST Group delivers in providing these core functions.

FIGURE 3-1 – **DST GROUP ROLES**



SOURCE: (DSTO, 2014)

3.1 Generation of economic value

In considering its economic value, DST Group is best thought of both as an applied research organisation and a facilitator of research and innovation more broadly across industry. These research efforts are ultimately focused on delivering capability for defence and national security. However, in the decade since the last review of DST Group there have been some significant changes to the environment in which DST Group operates. These include:

— a blurring of the types of threats (state and non-state) faced by Australia (and other nation states)
— greater access to off-the-shelf technologies
— a growing threat from knowledge economy type capabilities, including cyber and other disruptive technologies.

These changes to the operating environment mean that DST Group is required to spread its efforts more broadly than before.

In the classical economic benefit-cost sense DST Group's research efforts are beneficial, in the first instance, where the value to society of its research exceeds the cost of undertaking that research. However, assessing this value is complex and difficult because it is not specifically priced, is subject to rapid shifts in geopolitics and in technology that then affects and also shapes capability and because failure is often costly and may be catastrophic. In a defence context, the very term "value" needs to be interpreted carefully.

Defence of Australia typically involves high levels of uncertainty in terms of future threats and response options, and must incorporate the value of possible future deterrence as well as current capability. Much of its value lies in insurance against risks that do not lend themselves to conventional actuarial assessment. In addition it includes the value for Australia in supporting global defence and humanitarian efforts that fall well beyond direct threats to Australia[4].

While value can be delivered through increased capability it can also be increased by delivering the existing capability more efficiently. Such efforts are a core function of DST Group and this is reflected in some of the major savings that DST Group research and development has contributed to since 2003.

This should not be taken to mean that an efficient research and development mechanism will have no 'wastage'; the nature of research means that some of it will always be speculative and there are inherent risks associated with research which may be managed but not necessarily avoided. Inevitably many research projects (possibly the majority) when considered in isolation will generate few benefits if at all in a classical economic benefit-cost framework. However, what they can do is provide insights into areas of research that should not be pursued (at least for the time being) or where additional effort might be warranted where there is sufficient promise in one or more particular lines of research.

This leads us to conclude that the economic value of the Defence Science and Technology program accrues to the nation in a number of ways:

— Benefits reflecting cost savings or developments of Australian specific or Australian only capabilities from tangible projects can be estimated and summed – this was the primary mechanism used in the 2003 Trenberth report
— Benefits attributable to the establishment of a portfolio of additional options through DST Group research and development – includes knowledge, insights and skills that provide a capacity for faster or more cost effective or more effective response to plausible future developments in technologies and threats
— Benefits attributable to capabilities and options developed through collaboration with organisations and research establishments beyond DST Group including within Australia and internationally – again providing a foundation for better responses to plausible future developments.

Estimating the benefits of the first of the above is amenable to standard benefit-cost analysis, although we consider that any such assessment should reflect the flexibility inherent in the way the new capability feeds into overall defence capability. It should also be recognised that the development of new capabilities may also add options that are relevant to the second and third ways. Estimating the benefits of the latter two requires additional analysis to assess the potential future benefits from a portfolio of options where the priorities for research and development can be adjusted and optimised as the future unfolds (becomes more certain).

In practice, projects rarely fall into just one of these categories. Almost any project that delivers a specific capability will also very likely deliver the flexibility to respond differently to emerging threats to overall defence capabilities and will underscore options for further future innovation. For any such project, it is feasible to look at benefits in terms of the specified capability, while also taking into account the value of any broader flexibility and options.

In this project we attempted to capture both the tangible benefits and the increased flexibility/options associated with DST Group's efforts as follows:

[4] Benefits in terms of relationships and projected influence but also in terms of benefiting the lives saved or improved.

- Benefit-cost analysis techniques were used to estimate the tangible benefits attributable to DST Group efforts (for ten specified projects) – these establish the lower bound economic value attributable to Defence's Science and Technology program.
  - This recognises the extent to which the planned project outcomes have supported wider flexibility options.
- A stylised options approach was developed using a small sample of DST Group research and development to indicate how the portfolio of options that DST Group creates and maintains could be valued.
  - This looked at the valuation of the above flexibility options built into the planned project outcomes, recognising that part of the flexibility is likely to lie in skills that defence personnel acquire in using the planned project outcomes
  - It also looked at illustrating how the wider innovation options might be assessed and factored into investment decisions – options for innovation in future Defence strategy and responses, specifically in relation to its access to R&D and innovation capabilities through DST Group, industry and wider networks.

These two approaches are discussed in more detail below.

3.1.1 Tangible economic benefits

Consistent with the project scope of works, we reviewed ten DST Group projects as case studies chosen from the thirteen set out in the DSTO Submission to the First Principles Review (DSTO Submission). The primary purpose of the case studies was to establish the tangible economic benefits associated with each project that can be attributed to DST Group research and development efforts. The results of this assessment was used to establish a lower bound for the economic value that DST Group has contributed over the period considered.

We sought to focus on benefits from 2003 onwards; i.e. benefits that have accrued since the previous study, the Trenberth Review, was written. However, there was a need to find natural project or phase of project start points and end points to be able to usefully estimate benefits and so, depending on the project, 2003 was not a hard start point.

In assessing benefits we focussed on benefits flowing to Australia (we ignored benefits flowing to other nations). Sales of product were limited to Australian sales where they could be credibly estimated (i.e. export income). In this sense the assessment of benefits reflects the value to Australia in a world *with* and *without* DST Group. While other organisations (including from within Defence) may (and usually did) make major contributions to the ten projects that we considered, we included all assessed benefits, that in the absence of DST Group, would not have not been achieved. This approach is consistent with the benefit-cost approach.

In assessing benefits, we determined

- Identifiable cost savings from DST Group efforts in supporting current capabilities (including delivering lower cost capability than would be provided by alternative solutions, extending the life of existing capability or efficiency gains in capability solutions that are in service or are in the process of being developed)
- Identifiable benefits in DST Group efforts in delivering capability that would otherwise not be available (could have included the potential impact on force structure/size/cost to achieve the same level of overall capability or level of security in the absence of the capability)
- Benefits attributable to sales of capability to third parties
- Benefits attributable to savings or delivery of capability that were derived through in-kind or quid pro quo inputs that came about through DST Group efforts in collaborating with other parties.

This classical assessment of benefits did not reflect the value of the options that the DST Group contributions would have created in terms of future flexibility. In this sense we expect that the tangible economic benefit assessment more than likely understates the value of the DST Group contribution, especially when considered on a portfolio basis.

3.1.2 DST Group options value

Achieving optimal investment in defence capability faces a number of hurdles including:

- delivering the desired capability at the right time (not too early nor too late) and at the lowest cost
- ensuring that the desired capability is able to be adapted to meet uncertain future threats on both a time and cost basis
- minimising or avoiding investment in capability that will quickly become obsolete.

Defence capability is heavily built around investment that involves high fixed costs (in acquisition and support of equipment and in training of people) to deliver the capacity to respond to threats that commonly do not materialise across the life of a given fleet of equipment. These capabilities primarily deliver substantial insurance, but can often be deployed for tasks that were not central to the reason for acquiring the capability in the first place. However, almost inevitably a high level of investment occurs for reasons of 'insurance'. It primarily delivers risk reduction and risk mitigation services, rather than hard production of tradeable goods and services.

Decisions to invest in defence capability (especially with respect to large equipment and training programs) are mostly irreversible; the cost in both dollars and time cannot usually be recouped should the circumstances and external environment for which they were intended, quickly change. The future defence and national security environment is uncertain and is constantly changing. This implies that there are potential futures where particular investment decisions by Defence may later be regretted; i.e. decisions to acquire capability that, as it turns out, is not needed and decisions not to acquire a capability for which a real need does emerge. And because of investment irreversibility Defence cannot adjust its capability without cost (time and dollars) should one of those futures materialise. This places a strong emphasis on flexibility in Defence capability.

In the context of the Defence Science and Technology program, research and development undertaken through the program, including innovation fostered through collaboration, is likely to create various real options for Defence. Some of these options may have little apparent known value at the current point in time under current threat outlooks and technologies, but may yet have considerable value especially in an environment in which both the nature and extent of threats to defence and national security may change rapidly. Once established, options can be maintained where the cost in doing so is modest, developed where circumstances dictate and abandoned or mothballed where the cost of maintenance is considered to exceed the plausible known and unknown benefits.

This project did not allow for a full assessment of the portfolio of options that exists under the Science and Technology program. However, we consider the benefits that likely flow from the science and technology activities undertaken by DST Group which broadly reflects the types of optional capabilities that DST Group has established and that currently exist. These options would also capture the option value inherent in some of the systems where DST Group work has been instrumental in the delivery of Defence capability.

This range of optional capabilities that would be expected to be captured would include:

- the ability to adapt technologies unique to Australian conditions and needs
- the flexibility to adapt to uncertain future conditions
- the ability to respond to surges in demand for capability
- the potential for wider commercialisation and spill-overs to industry
- the additional options that may flow back to defence capability as a result of spill-overs to industry.

4 CASE STUDIES

This section of the report provides a summary of the case study findings including the assessed benefits for each case study. Unlike more traditional benefit-cost analyses, we focussed primarily on the economic benefits generated by DST Group's involvement in each of the projects consistent with the project scope.

In most cases DST Group's involvement involved knowledge/expertise that was used to research options, guide the testing of and in some cases test options, leverage commercial and international knowledge sharing relationships and recommend solutions or one or more paths forward. As knowledge workers and applied research scientists, DST Group's costs attributable to each project were usually only a small fraction of the benefits involved[5]. Collectively, these costs are also not representative of DST Group's overall cost base. In our view spending a significant amount of time collating DST Group costs for the case studies would not materially change the case study findings and the report's conclusions.

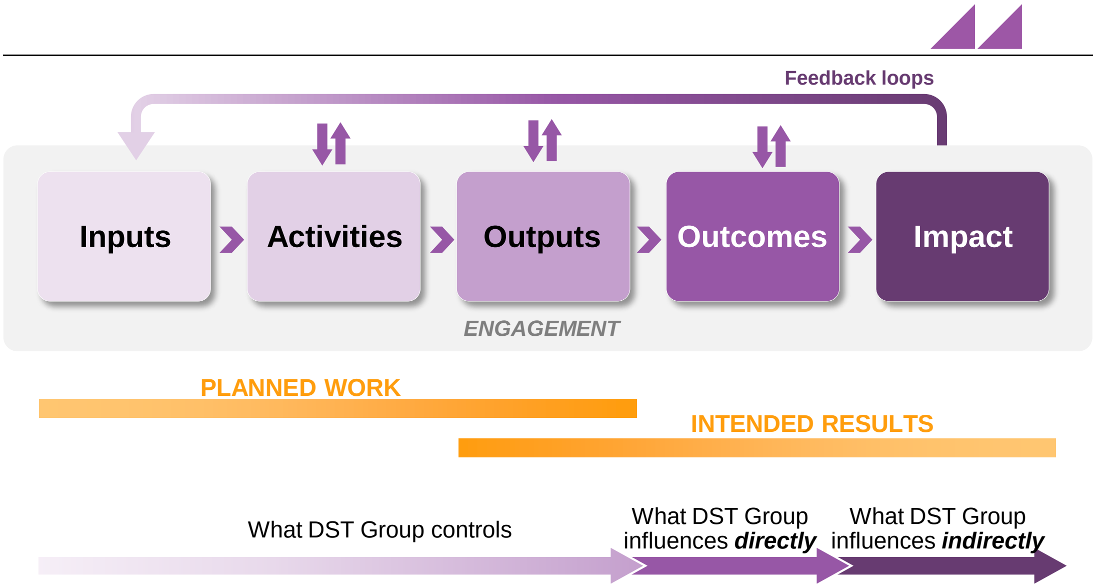
The broad approach to assessing tangible economic benefits from the case studies was set out in section 3.1.1. For each selected case study we used the impact framework illustrated in Figure 4-1 to assess the benefits. The impact framework that we utilised has been applied previously by ACIL Allen to assess the benefits of R&D in other contexts and includes collecting and collating information for each of the following elements:

- Inputs – who provided what inputs (financial and in kind) in order to carry out the project?
- Activities – who did what R&D?
- Outputs – what were the results of the R&D?
- Outcomes – what did the outputs mean 'on the ground'?
- Impact – what were the impacts of the outcomes – e.g. costs avoided or reduced, lives saved, savings made, technology transferred to industry, etc.?

As discussed previously, this report follows the approach used in the Trenberth Review and in many ways is an update of the case study assessment undertaken in 2003. Therefore the case study reviews reflect activities in which DST Group has been involved since the 2003 Trenberth Review.

[5] The exceptions are the P-3 Orion Service Life Assessment Program and JORN but even in those cases, DSTO's costs represent only about 10 per cent of the assessed benefits.

FIGURE 4-1 –**IMPACT FRAMEWORK FOR EVALUATING DST GROUP RESEARCH**



SOURCE: ACIL ALLEN

The order in which the case studies are covered and the assessed economic benefits is given in Table 4.1 below. The tangible economic benefits between 2003 and 2015 is assessed to be around $5.1 billion. While only a small fraction of DST Group resources were utilised on these projects it is useful to consider them in the context of all DST Group's costs over that period. If the 2015/16 budget of $432 million is used as a normalised cost for the 12 years in question, the total costs sum to around $5.2 billion, which is the same as the assessed economic benefits from the ten case studies over the same period.

Therefore the economic benefits from these ten case studies alone in effect covered the cost of DST Group over the twelve year period. This lower bound by definition does not factor in value for the components not quantified or which were undervalued by the conservative approach used. Therefore strong conclusions can be drawn to the effect that DST Group offers value for money to Australia's defence investment and defence capability. It does not follow from this that there is no room for improvement – areas where costs may not be fully justified by benefits, or areas where even greater or refocused investment could be more cost effective – but a strong conclusion as to benefits in excess of costs can be drawn.

TABLE 4.1 – **CASE STUDY ORDER AND ASSESSED BENEFITS**

Number	Case study	Assessed Tangible benefit ($m)
1.	Collins class submarine remediation	598
2.	P-3 Orion Service Life Assessment Program	432
3.	Joint Direct Attack Munition – Extended Range	853
4.	Jindalee Operational Radar Network (JORN)	1,503
5.	F/A-18 Structural Refurbishment	443
6.	E-7A Wedgetail Radar	350
7.	NULKA anti-ship missile decoy	452
8.	Advanced Short Range Air to Air Missile	110
9.	Wideband Global SATCOM System JP2008 Phase	350
10.	Force Protection Electronic Countermeasures	51
	Total	**5,142**

The case studies summaries are set out below.

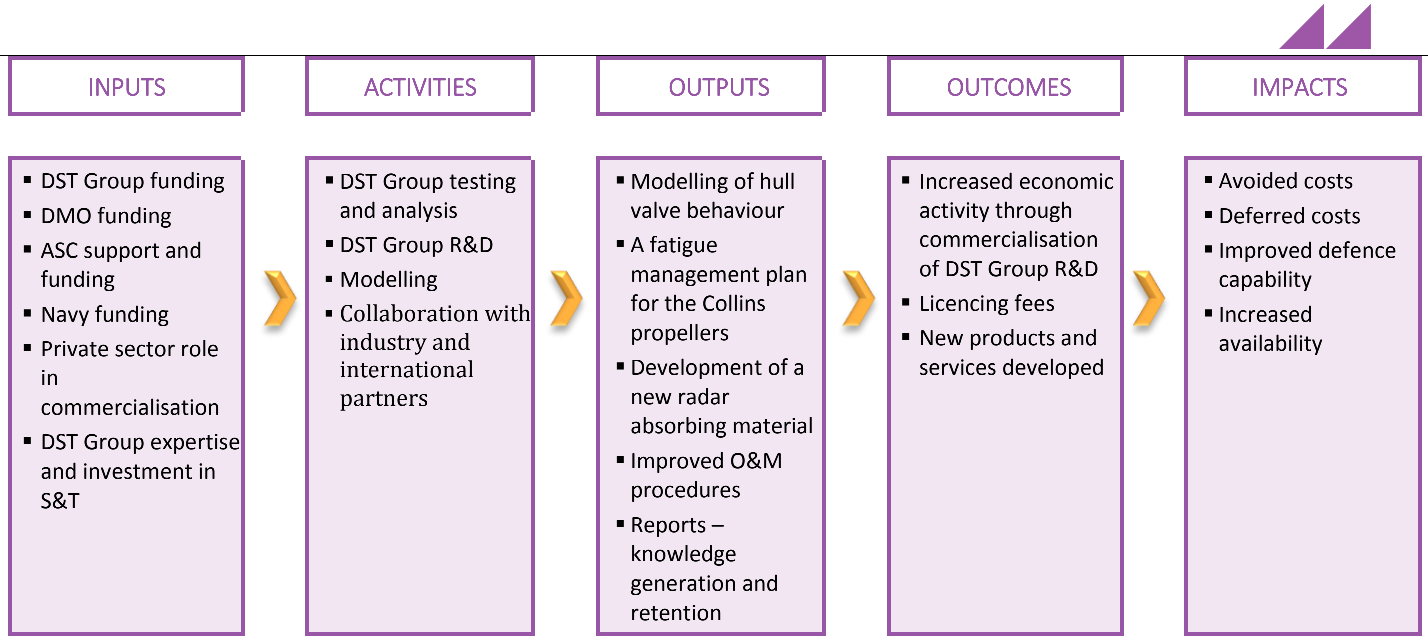
4.1 Collins Class Submarine Remediation

This case study considered DST Group's role in supporting six areas of the Collins submarine[6]:

— Hull valve tests and management program
— Fatigue testing and management of propellers
— Hull Structural assurance and safety
— Replacement of Radar Absorbing Materials (RAM) on the masts
— In-situ replacement of main propulsion motor armature bands
— Urgent remediation of combat system issues.

The impact framework evaluation for the Collins Submarine case study is shown in Figure 4.2. Benefits included avoided costs, deferred costs, improved capability and increased fleet availability.

FIGURE 4.2 – **COLLINS SUBMARINE CASE STUDY – IMPACT FRAMEWORK DIAGRAM**



SOURCE: ACIL ALLEN

ACIL Allen determined that DST Group's research in relation to these activities has been critical in ensuring that Australia had access to a submarine fleet that was more capable and had much higher availability than would otherwise have been the case. It is arguable that in the absence of DST Group's work Australia may not have been able to deploy its submarine fleet for extended periods of time or perhaps at all. Without the work done by DST Group it is possible that the contract for the submarines could have ended in the courts and the delivery of the vessels could have been delayed for years.

ACIL Allen estimated the total benefits that can be attributed to DST Group arising from just six DST Group tasks conducted as part of the Collins project to be **$598 million**. Almost half this amount (approximately **$285 million**) was derived as a result of DST Group's work to test the integrity of hull valves and develop a management program.

The detailed case study is set out in section A.1 of Appendix A.

[6] The ongoing benefits in relation to DST Group's efforts with respect to hydrodynamics and anechoic tiles are not captured here.

4.2 P-3 Orion Service Life Assessment Program

This project involved a significant life extension to the P-3 Orion aircraft. By extending the structural life, via an inspection program, the structural refurbishment program involving the replacement of wings and tailplanes undertaken by a number of other nations was not required to be undertaken by Australia.

DST Group's contribution to this project consisted of the full scale test and teardown of a P-3 empennage, a contribution to the flight loads test program, the analysis and interpretation of all test results for Australia, the development of a set of inspection instructions and structural life limits specific to the RAAF P-3 operations and the development of an individual aircraft tracking (IAT) system.

Aerospace Division undertook the activities using the experience, facilities, knowledge and client relationships built from 40 years of engagement with the RAAF in the field of airworthiness and structural integrity.

The program drew upon DST Group's understanding of RAAF operations, DST Group's skills in the areas of aircraft loads, stress, full scale testing, fatigue, forensic analysis and airworthiness regulation coupled with DST Group's ability to conceive and deliver outputs that anticipate RAAF needs.

The impact framework evaluation for the P-3 Orion case study is shown in Figure 4.3. Benefits included the avoided costs of wing replacements, increased aircraft availability and the ability to better plan an eventual aircraft replacement program.

FIGURE 4.3 – **P-3 ORION - IMPACT FRAMEWORK DIAGRAM**

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
▪ DST Group investment in S&T ▪ Support by US, Canada and the Netherlands ▪ Private sector support	▪ DST Group research into defects ▪ DST Group fatigue modelling ▪ DST Group conducting flight test loads.	▪ Development of the Safety by Inspection program ▪ Development of a Fatigue Monitoring plan ▪ Reports – knowledge generation and retention	▪ A life extension for the P-3 Orion aircraft until 2019 ▪ An optimised program of inspection and testing to ensure ongoing airworthiness ▪ Avoiding the risk and cost premiums normally associated with an accelerated replacement program	▪ Avoided costs of wing replacements ▪ Increased aircraft availability ▪ Ability to better plan an eventual aircraft replacement program

SOURCE: ACIL ALLEN

DST Group's research enabled Defence to extend the planned withdrawal date of the P-3 Orion fleet out to 2019 without the need to make costly major structural modifications to the aircraft. It also enabled an optimised monitoring and maintenance program to be developed that provides ongoing confidence in its continuing airworthiness. The work also had a significant benefit in terms of increased aircraft availability.

ACIL Allen has identified benefits arising from the P-3 Orion project that can be attributed to DST Group to be $432 million, consisting of the avoided cost of replacing the wings on each of the 18 aircraft in Australia's fleet. By being able to avoid taking each aircraft out of service for around a year to replace the wings the aircraft availability was significantly increased. ACIL Allen has not estimated the monetary value of this increase in aircraft availability.

4.3 Joint Direct Attack Munition – Extended Range

The Joint Direct Attack Munition – Extended Range (JDAM-ER) is the culmination of a long-running partnership between scientists of DST Group and Boeing. The JDAM-ER consists of a set of deployable wings strapped to a standard Joint Direct Attack Munition (JDAM) which convert the JDAM into a long range precision glide bomb.

In 2001 DST Group and Boeing agreed to a joint Capability and Technology Demonstrator (CTD) Project in order to combine the Boeing JDAM with the DST Group developed wing-kit to create a long range, precision glide munition. The first flight tests were completed in 2006, followed by a second round of tests in 2008 using a new high-wing configuration. The project was a resounding success.

At that point the then DMO (now part of Capability Acquisition and Sustainment Group, CASG) joined the partnership and an acquisition project commenced with the RAAF as the first customer. Successful tests of separation and glide of the munition were carried out at Woomera in late 2013.

During the CTD phase the work effort was joint between DST Group and Boeing. During the acquisition phase the effort associated with the project largely shifted towards Boeing and DMO. However, DST Group continued to provide specialist science and technology support to DMO.

The impact framework evaluation for the JDAM-ER case study is shown in Figure 4.4. Benefits included avoided costs, improved defence capability, increased exports.

FIGURE 4.4 – **JDAM-ER CASE STUDY – IMPACT FRAMEWORK DIAGRAM**

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
▪ DST Group investment in R&D ▪ DST Group investment in Concept Technology Demonstrator ▪ DMO support for acquisition ▪ RAAF support for testing ▪ Boeing support for commercialisation ▪ Ferra Engineering support for commercialisation	▪ DST Group research ▪ Testing ▪ Commercialisation ▪ Collaboration with industry	▪ Improved operational capability and flexibility for the RAAF ▪ An affordable, stand-off weapon system. ▪ Licencing of IP to Boeing. ▪ A partnership between Ferra Engineering and Boeing to produce JDAM-ER wing kits.	▪ Take up by defence ▪ Increased economic activity through commercialisation ▪ Export sales ▪ Improved capability ▪ Avoided acquisition costs ▪ Licencing fees ▪ Improved survivability of RAAF planes	▪ Avoided costs ▪ Improved defence capability ▪ Fewer deaths or injuries ▪ Increased international trade ▪ Employment, contribution to GDP

SOURCE: ACIL ALLEN

DST Group's research has extended the distance from which the Joint Direct Attack Munition-Extended Range (JDAM-ER) can be launched to three times further away from the target than the standard JDAM munition.

ACIL Allen has estimated the total benefits arising from the JDAM-ER project that can be attributed to DST Group to be $853 million, consisting of $42 million as a result of avoided acquisition costs, $576 million from exports and $235 million due to increased capability. While the ability to launch the munition from a point that is much further from the target will also reduce the risk to both the plane and pilot from anti-aircraft defences, we have not sought to value this benefit due to the uncertainty around the timing and scale of any such benefit.

4.4 Jindalee Operational Radar Network (JORN)

JORN (Jindalee Operational Radar Network) consists of three sky-wave over-the-horizon radars (OTHRs), located in Queensland, Western Australia and the Northern Territory, the JORN Coordination Centre in South Australia and a series of sounders and transponders around the country.

JORN provides layered surveillance of Australia's northern and western approaches. The radars operate by refracting high frequency (HF) radio waves off the ionosphere, enabling detection ranges of between 1000 and 3000 kilometres, well beyond that of conventional microwave radars constrained by the visual horizon. The key features of OTHR technology that make it a highly attractive for surveillance are its very long range detection capability, ability to detect targets at all altitudes, insensitivity to atmospheric weather and comparatively low cost per unit area under surveillance.

DST Group began investigations into the feasibility of OTHR in the 1950s. The evolution of JORN from that time and the current development plan is summarised in the table below:

TABLE 4.2 – **JORN EVOLUTION**

Timing	Phase
1950s-1972	DST Group research into the feasibility of over the horizon radar
1972-2003	Design, construction and ongoing development of the Jindalee Facility Alice Springs (JFAS)
1987-2003	JORN acquisition (JP 2025 Phases 3 & 4)
2004-2014	JORN enhancement (JP 2025 Phase 5). Included integration of JFAS into JORN.
2014-2017	JORN PIC Support Program (JPSP - Air Force Sustainment activity).
2017-2027	JORN major mid-life upgrade (AIR-2025 Phase 6 – in planning)

SOURCE: DST Group correspondence, 2015

DST Group has played a central and evolving role throughout the development of OTHR in Australia. For example, from 1972 until 1987, DST Group was responsible not only for all R&D, but also for design, construction, sustainment and enhancements of JFAS. Transition of JFAS to an operational radar began around 1987 and was formalised in 1993 when it became 50% RAAF operational radar and 50% DST Group experimental test-bed.

Today, the DST Group retains R&D authority for JORN, but works in close and effective partnership with its two major partners in the Australian OTHR community:

— OTHR Systems Program Office (OTHRSPO) of Capability Acquisition and Sustainment Group (CASG) – responsible for JORN maintenance and support
— No1 Remote Sensor Unit (1RSU) of the RAAF – responsible for JORN operations.

The Trenberth Review considered JORN in detail. The assessment in this report focusses on benefits since 2003.

The impact framework evaluation for the JORN case study is shown in Figure 4.5. Benefits since the 2003 Trenberth Review included the increased capability at reduced cost, reduced operating/upgrade costs, export/IP revenue, improved Defence self-reliance, increased Defence mutual reliance with allies, particularly the US and ability to evolve capability quickly to meet emerging Defence threats and opportunities.

FIGURE 4.5 – **JORN CASE STUDY– IMPACT FRAMEWORK DIAGRAM**

INPUTS

- Expertise and effort of DST Group staff in HF radar R&D
- Investment in radar hardware and software development, experimentation and trials
- Funding to support collaboration with domestic and international partners

ACTIVITIES

- Ongoing support to extant JORN systems operations and sustainment
- Support to JORN acquisition (Phase 5, JPSP, Phase 6):
  - Needs analysis, development of detailed technical solutions and options
  - Technical risk assessment and reduction
  - Operational demonstrator development
  - Test and evaluation
  - Transition support and advice throughout acquisition
- Next Generation OTHR Program:
  - Development of new concepts and architectures
  - Prototyping
  - Experimentation and trials
- Collaboration with industry, universities and international partners

OUTPUTS

- Support to extant JORN systems
  - Ongoing S&T advice for JORN operations
  - Radar performance assessment tools and reports
  - Sustainment advice and solutions
- JORN Phase 5 work packages transitioned to JORN, including:
  - Algorithm for doubling coverage and sensitivity
  - High capacity COTS-based signal processing computing architecture
  - Electronic warfare algorithm
  - Ship detection and tracking systems
  - Airfield Surveillance and Altitude Estimation
- JPSP/JORN Phase 6:
  - Acquisition strategy and documentation for JORN Phase 6 first pass approval
- Expertise, capabilities and facilities in HF radar that are unique to Australia and of value to allies
- Published research in HF radar

OUTCOMES

- Quadrupling the surveillance capacity of JORN
- Major enhancements to JORN detection and tracking performance and robustness for both aircraft and ships
- Acquisition risk reduction through early-transition/operational demonstrator model
- Stronger, more capable and more efficient Australian industrial/research base supporting JORN, including export sales.
- Stronger Defence cooperation with allies, particularly the US

IMPACTS

- Increased capability at reduced cost
- Reduced operating/upgrade costs
- Export/IP revenue
- Improved Defence self-reliance
- Increased Defence mutual reliance with allies, particularly the US
- Ability to evolve capability quickly to meet emerging Defence threats and opportunities

SOURCE: ACIL ALLEN CONSULTING

DST Group's research enabled Defence to effectively quadruple the capacity of its OTHR systems without needing the acquisition of additional facilities. It has also enabled the streamlining of the program staging through replacing a traditional 'waterfall' methodology with an incremental 'rapid prototyping' approach, resulting in reduced operating/upgrade costs. The capability developed by this research is considered world leading and has led to export revenue potential and strong research collaboration with the US. It has also led to a strengthening of efficiencies in the Australian industry supply chain.

ACIL Allen has identified benefits arising from the JORN Phase 5 project that can be attributed to DST Group to be $1,503 million, predominantly the reduced costs in quadrupling the capacity of the existing JORN assets together with some export sales of DST Group-designed equipment.

4.5 F/A-18 Structural Refurbishment

The replacement F-35A JSF (Joint Strike Fighter) aircraft are not expected to enter Full-Rate Production until 2019, by which time the oldest RAAF F/A-18 would have been in service for 34 years. In order to ensure that Australia continued to have the capability outlined in the 2009 Defence White Paper, the service life of the F/A-18A/B fleet was required to be extended until 2020. The initial structural substantiation program for the F/A-18 Hornet aircraft determined that a major structural refurbishment program was required for the airframe to reach the planned withdrawal date (PWD).

In August 2007, DMO tasked DST Group to reassess the extant safe life limits of specific centre barrel locations in order to see if there existed any scope for life extension. This would have the potential of offering greater flexibility in the structural refurbishment schedule and potentially eliminate the need for some centre barrel replacements altogether.

DST Group scientists devised a structural test program in which retired centre barrels from US Navy, Canadian and Australian aircraft were tested to destruction in order to enable fatigue damage to be better characterised and modelled, thereby allowing more accurate determination of the aircraft's true safe life without compromising airworthiness.

The impact framework evaluation for the F/A 18 Structural Refurbishment case study is shown in Figure 4.6. Benefits included avoided expenditure and improved defence capability and availability.

FIGURE 4.6 – **F/A 18 STRUCTURAL REFURBISHMENT – IMPACT FRAMEWORK DIAGRAM**

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
▪ DST Group investment R&D, modelling and testing ▪ QinetiQ Aerostructures support for R&D ▪ DMO funding ▪ Centre barrels for testing were provided by the US ▪ Fortburn provided support for instrumentation	▪ R&D ▪ Testing ▪ Modelling	▪ Safe life increase of 10 per cent of the aircraft ▪ Publications ▪ Defence Science Award in October 2010	▪ Avoided cost of doing 39 CBRs ▪ Increased the availability of the aircraft ▪ Revenue from testing overseas aircraft	▪ Avoided expenditure ▪ Improved defence capability and availability

SOURCE: ACIL ALLEN

DST Group's work justified an overall safe-life increase of 10% whilst retaining existing levels of safety, and allowing the aircraft to achieve its revised planned withdrawal date.

The number of Centre Barrel Replacements (CBRs) required was reduced from the planned 49 to just 10.

ACIL Allen has estimated the total benefits arising from the project that can be attributed to DST Group are about $443 million, consisting of $52 million as a result of increased availability of aircraft, $1 million from overseas contracts and $390 million in avoided costs.

4.6 E-7A Wedgetail Radar

The DST Group activities in support of the Wedgetail AEW&C project were borne out of the need to understand the detailed technical challenges with the development of an airborne early warning radar capability. While the specific topic was new for Australia, it was built on a substantial background capability in airborne microwave radar systems. The project supported a programme of risk focused research into those areas where DST Group believed there were technical challenges and where there may be alternative solutions to the ones that were being pursued by the suppliers.

The delivery of an AEW&C System was the subject of a tender process from DMO and had three bid teams short-listed to meet the requirement. Most of the early research executed by DST Group was addressing common risks to all of the proposed solutions although with differing details.

The project activities were largely undertaken by DST Group, with some data obtained from a joint trial with the US Jet Propulsion Lab and some contractor assistance with radar performance model development.

DST Group made use of a collaborative arrangement that was developed with the US Air Force Research Laboratory (AFRL). This gave Australia access to a high fidelity radar system model and the US access to the DST Group research outputs. This government to government collaboration was based on equitable sharing in which AFRL gained access to the wider DST Group AEW&C related research and DST Group gained access to the model.

The impact framework evaluation for the Wedgetail case study is shown in Figure 4.7. Benefits included avoided additional costs, improved aircraft capability, possible royalty payments and export sales.

FIGURE 4.7 – **WEDGETAIL CASE STUDY – IMPACT FRAMEWORK DIAGRAM**

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
▪ DST Group R&D and S&T skills ▪ DMO funding support ▪ US Air Force Research Laboratory (AFRL)	▪ DST Group research on radar resource management, radar signal processing for detection and electronic protection ▪ Etc.	▪ A knowledge base used to identify serious capability failures in the system ▪ Ability to identify significant shortcomings in compliance tests ▪ Ways to improve radar signal processing ▪ Publications	▪ Avoided costly and lengthy litigation ▪ Negotiated outcome that addressed identified capability shortfalls ▪ Possible future royalty payments	▪ Avoided additional costs to obtain specified capability ▪ Improved aircraft capability ▪ Possible royalty payments ▪ Employment, contribution to GDP?

SOURCE: ACIL ALLEN

DST Group's research has helped to ensure that a lengthy and costly period of litigation with the supplier was avoided and that the Wedgetail AEW&C aircraft was delivered with close to the required capability without any additional costs having to be incurred.

ACIL Allen has conservatively estimated that the lower bound for the benefits arising from the Wedgetail project that can be attributed to DST Group is $350 million. Given that there are a number of benefits which have not been quantified, and the potential for future benefits, this amount is likely to be substantially below the true net value delivered as a result of DST Group's work.

4.7 NULKA Anti-ship Missile Decoy

Nulka is an electronic decoy system capable of defending a ship against advanced sea-skimming anti-ship missiles. When an approaching anti-ship missile is detected Nulka is launched. It flies a pre-programmed path, hovering near the targeted ship and its on-board active electronic warfare payload lures the incoming missile away from the intended target.

While United States Naval Research Laboratory (NRL) had done some of the early work that led to this project, for most of the 1970s and much of the 1980s the US and most NATO countries failed to appreciate the need to counter advanced western sea skimming anti-ship missiles such as the Exocet. Consequently, for most of this period Australia largely worked alone on the project. However, the scale of the threat posed by sea skimming missiles was recognised after the dramatic sinking of HMS Sheffield during the Falklands war. In 1986 Australia and the United States formed a joint project, called Nulka. The project name subsequently was adopted as the name of the decoy.

DST Group leads all Australian Government based and tasked R&D on Nulka. This specifically includes but is not limited to:

— Support for joint Australia US Initiatives
— Support for National (Australian) Nulka activities.

The impact framework evaluation for the NULKA case study is shown in Figure 4.8. Benefits included avoided costs, improved defence capability and export sales.

FIGURE 4.8 – **NULKA CASE STUDY – IMPACT FRAMEWORK DIAGRAM**

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
▪ DST Group S&T and R&D skills ▪ DMO financial support ▪ ANZAC Combat System Integration Laboratory ▪ RF Technologies Laboratories ▪ Weapon System Laboratories ▪ Rocket motor Test Facility ▪ Explosives Ordinance Precinct ▪ Missile Simulation Centre ▪ Industry (commercialisation)	▪ S&T to support the sustainment and life extension and development of Nulka capability ▪ Development, testing and evaluation ▪ Collaboration with industry and international allies	▪ Improved decoy cartridge performance ▪ Service life extension of rocket motor ▪ Improved deployment tactics for Nulka	▪ Savings due to service life extension ▪ Significantly improved capability of Nulka ▪ Improved decoy deployment techniques ▪ Export sales in excess of $500 million ▪ New products and services?	▪ Avoided costs ▪ Improved defence capability ▪ Increased international trade ▪ Employment, contribution to GDP

SOURCE: ACIL ALLEN

DST Group's research has increased the capability of the Nulka and demonstrated that a life extension of five years is justified.

ACIL Allen has estimated the total benefits arising from the Nulka project that can be attributed to DST Group to be $452 million, made up of $40 million as a result of estimated efficiency improvements, $12 million from deferred expenditure and $400 million in export earnings.

4.8 Advanced Short Range Air to Air Missile

The Advanced Short Range Air-to-Air Missile (ASRAAM) is an imaging infrared air-to-air missile carried by the Australian Classic Hornet (F/A-18A/B) and UK Typhoon and Tornado aircraft.

ASRAAM gave a vastly superior capability over the previous AIM-9M weapon system. However, it was appreciated during the capability requirement phase that a software-based weapon in the early stages of development would likely enter service with a base-line capability. Science and technology support would be necessary to enhance capability through incremental software updates, improving performance in complex environments and against new threats with evolving countermeasures.

Science and technology support has also been required to aid extension of the service life of energetic components and sustain other subcomponents which are currently out of production.

The objectives of the DST Group R&D were two-fold: to improve the capability and tactical use of the existing ASRAAM hardware through software updates; and to aid life extension through energetics studies and assistance to the UK in development of replacement subsystems.

The impact framework evaluation for the ASRAAM case study is shown in Figure 4.9. Benefits included avoided costs through ASRAAM life extension and sustainability and export sales.

FIGURE 4.9 – **ASRAAM CASE STUDY – IMPACT FRAMEWORK DIAGRAM**

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
▪ DST Group S&T and R&D support ▪ DMO investment ▪ UK Ministry of Defence, UK Defence Science and Technology Laboratory and UK Defence Equipment and Support ▪ RAAF and RAAF ▪ MBDA UK and BAE Systems Australia	▪ Software development and testing ▪ Work to verify life extension ▪ Field and laboratory testing	▪ Three software upgrades ▪ Development of an new seeker ▪ Better understanding of missile component lifetimes	▪ Roll out of three sets of software improvements ▪ Improved missile performance ▪ Extension of ASRAAM service life ▪ World leading trial and testing capability in DST Group ▪ Depth of knowledge of missile operation ▪ Exports of ASRAAM software	▪ Avoided cost of replacing ASRAAM ▪ Improved defence capability and sustainability ▪ Increased international trade

SOURCE: ACIL ALLEN

DST Group's research on the ASRAAM project was critical to enabling Australia to maintain the capability provided by the ASRAAM missile until the planned retirement date of the F/A 18. I also helped to ensure that the capability of the missile was maintained over the life of the missile. It also ensured that the operation of the missile was tailored to meet Australia's needs.

ACIL Allen has conservatively estimated that the total benefits arising from DST Group's work on ASRAAM are around $110 million ($100 million in avoided costs to replace the ASRAAM missile and $10 million in savings associated with the improved software for the missile). This is likely to be a conservative estimate of total benefits as there are a number of benefits which, while likely to be substantial, ACIL Allen is not able to quantify.

4.9 Wideband Global SATCOM System JP2008 Phase

The Wideband Global Satellite Communications Systems (WGS) is the ADF's primary long range communications system. When the system is completely operational in 2018 it will consist of nine satellites.

DST Group recognised that WGS (then called Wideband Gapfiller Satellite) represented an important technology innovation and used its links with the US DoD research community to establish contact with the US subject matter experts on WGS in 2004.

In 2005 DST Group started to develop its capability to model satellite communications systems. From 2006, DST Group started developing a database that captured the then existing SATCOM system as well as the plans for its future expansion. That database also captured the ADF's then existing use of satellite communications services and the potential future demand for such services. This was developed to support a high fidelity model, being built by industry for DST Group, in the anticipation that Defence would need an independent ability to evaluate future ADF wideband satellite communications proposals.

Following the invitation to consider joining WGS, DST Group finalised the industry work program and continued the development of the modelling suite internally, focussed on WGS, under extreme time pressure due to the commercially generated deadline. This proved essential to the successful MoU negotiation as the business case to Government for approval to participate relied on the analysis provided by DST Group using the WGS system model.

The impact framework evaluation for the Global SATCOM System case study is shown in Figure 4.10. Benefits included avoided acquisition costs, increased defence capability and increased availability

FIGURE 4.10 – **GWS SYSTEM CASE STUDY – IMPACT FRAMEWORK DIAGRAM**

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
▪ DST Group staff time and expertise ▪ DMO (leader of negotiation team) ▪ Technical information from the US DoD	▪ Developing a data base of Australia's use and future needs for SATCOM system ▪ WGS modelling ▪ Support for negotiations with US	▪ Database of satellite terminals ▪ Detailed information exchange requirements ▪ Vignettes for operational requirements under different scenarios ▪ A model with an interface to the database to allow the extraction of linked information based on different scenarios	▪ demonstrated that the initial US offer was unfair to Australia ▪ Enabled Australia to negotiate a more favourable access regime to WGS System ▪ Demonstrated that the new access regime was also advantageous to the US	▪ Avoided acquisition costs ▪ Increased defence capability ▪ Increased availability

SOURCE: ACIL ALLEN

DST Group's research was critical to enabling Australia to negotiate a much more favourable access arrangement to the Wideband Global SATCOM System. The MOU that was able to be negotiated based on the evidence provided as a result of DST Group's analysis extended the time during which capacity on the system would be available to Australia by several years. It also provided Australia with a more favourable access regime to a higher percentage of satellite beam resources.

ACIL Allen has conservatively estimated that the total benefits arising from the improved access to the SATCOM system that can be attributed to DST Group are around $350 million.

4.10 Force Protection Electronic Countermeasures

ADF troops and the land vehicle platforms operating in current areas of conflict face extremely high level threats from Improvised Explosive Devices (IEDs). In the period from 2007 to 2013 fourteen ADF personnel were killed by IEDs. This was over a third of all casualties in Afghanistan over that period. The Defence department does not provide details about wounded personnel, however, if we assume that the proportion of soldiers wounded by IEDs is on average the same as proportion who are killed by IEDs then this would imply that 78 soldiers may have been injured by IEDs over the same period (out of a total of 229 wounded ADF personnel between 2007 and 2012).

In 2009, DST Group was tasked with developing Counter-IED systems to reduce ADF personnel vulnerability to these life endangering devices. In response the Communications Electronic Warfare Group in DST Group's Cyber and Electronic Warfare Division began a design and development program for a force protection electronic counter measure (FP ECM) system to protect against IEDs.

In 2012/13 the ADF again sought an urgent DST Group solution to an emerging new IED threat against which there was no existing effective countermeasure capability within the ADF or Australia's coalition partner. DST Group responded by rapidly developing and testing a countermeasure technique against this threat suitable for integration with existing ADF systems.

Finally, DST Group developed a family of low-cost, robust Force Protection units under the REDWING program, which have been mass produced and sold to the Afghanistan Security Forces. Two systems have been developed: GREENGUM, a small personal unit; and GREYGUM, designed for use on light vehicles.

The first element of the project led to the development of the AN/PLT-2000 V2 personal IED countermeasures system. The technology was successfully tested, then transferred to, and commercialised by, a number of Australian companies. It was introduced into operational service with the ADF in mid-2011, where it has continued to operate as a successful IED countermeasure until the present day.

The IP and capability developed as a result of this project is regarded as world leading. Australia was the first coalition partner to have the capability to protect their personnel in this way. The same technology was also used in equipment supplied by Australian firms to the US.

The second element of the project was carried out in response to an urgent need to respond to a new IED threat to ADF personnel. The ADF's existing countermeasures were ineffective against this emerging threat and Australia's coalition partner was unable to provide a solution.

One option for the ADF would have been a multi-million dollar rapid acquisition of new equipment to address the threat facing ADF troops. However, DST Group were able to rapidly develop and successfully test an enhanced countermeasure technique against this threat suitable for integration in one of the existing ADF systems.

This DST Group countermeasure enhancement has now been introduced into the operational theatre as a fully integrated element of the ADF's suite of IED countermeasures.

The output of the third element of the project was a family of low-cost, mass produced, robust device to protect Afghan forces. Two systems were developed: GREENGUM, a small personal protection unit; and GREYGUM, designed to protect light vehicles. This technology has been sold to the Afghan security and defence forces to protect their personnel from IEDs.

As part of this FPEC process DST Group has, and will continue to develop, new countermeasure techniques for use in existing operational ADF systems to counter new and emerging IED threats.

The impact framework evaluation for the FPEC case study is shown in Figure 4.11. Benefits included avoided acquisition costs, reduced acquisition costs, reduced number of deaths and injuries from IEDs and export sales.

FIGURE 4.11 – **FPEC CASE STUDY – IMPACT FRAMEWORK DIAGRAM**

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
▪ DST Group investment of $4.1 million in R&D ▪ DMO investment $4.9 million (based on the net cost of equipment in terms of dead weight losses) ▪ In kind support from BAE, Ultra-Avalon and Micreo	▪ R&D into the characterisation of IEDs and countermeasure techniques ▪ Construction of prototype IED countermeasure devices ▪ Laboratory and field testing of prototypes ▪ Preproduction design ▪ Provision of engineering services ▪ Licensing of the IP generated by the project to various Australian firms ▪ Provision of pre-production and production support ▪ Supporting the delivery into service of the finished products ▪ Providing operational support	▪ The development of a personal IED countermeasures system ▪ An urgent response to a new IED threat to ADF personnel ▪ Low-cost IED countermeasure devices to protect Afghan personnel and vehicles	▪ Use of IED countermeasure devices by Australian, US and Afghan personnel ▪ Increased economic activity through the commercialisation and export of IED countermeasure technologies ▪ Licensing of DST Group developed technology to Australian firms	▪ Avoided acquisition costs ▪ Reduced acquisition costs ▪ Improved defence capability ▪ Reduced number of deaths and injuries from IEDs ▪ Export sales of IED countermeasures technology ▪ Royalty payments to Australian government

SOURCE: ACIL ALLEN

DST Group's research is likely to have already saved the lives of and prevented serious injuries to a number of Australian and US and Afghan defence personnel serving in Afghanistan, as well as preventing damage to operational equipment. It is also likely to have helped save future lives and significant future damage to operational equipment.

ACIL Allen has estimated the total benefits arising from the FPEC project that can be attributed to DST Group to be $51 million, consisting $46 million from exports and $5 million in avoided acquisition and vehicle integration costs. These benefits do not include any estimates in relation to past and future prevention of loss of life and injury (including rehabilitation / dealing with permanent physical and psychological disability) and damage to operational equipment, which apart from the direct cost could further endanger lives.

5 DST GROUP ADDITIONAL VALUE

The Defence Science and Technology program is inherently about creating new options to support Defence capability and to aid Defence in future decision making. These options are in essence opportunities to do things differently and possibly better, with a decision on whether to take up the opportunity being based on whether the pay-off from exercising the option is likely to be maximised, based on what is known at the time.

As discussed in section 3, the potential value in the options created by DST Group flow from the science and technology activities that they undertake. This includes the range of critical expertise within DST Group, the range of technologies that its research and development could make available (including ability to modify third party or partner technologies), the ability to understand and counter or render harmless future hostile technologies and the ability to enhance knowledge and technologies through collaboration with partners and friendly third parties. It also would include the types of option value inherent in some of the systems where DST Group work has been instrumental in the delivery of Defence capability.

The discussion and analysis in section 4 and set out in more detail in Appendix A reflects the brief for this assessment, focused largely on value 'delivered' from the 10 case studies and, indeed, has sought to be conservative in that assessment. The project economic benefits considered in detail are, in most cases, highly tangible; i.e. costs avoided, capability enhanced, sales revenues, etc., as a result of delivered improvements in sourcing and maintenance of defence capabilities, and direct sales/leasing of products or intellectual property.

While inevitably, there is some uncertainty as to the scale of these benefits relative to the alternative or counterfactual version of how the challenges and Defence needs would have been met without DST Group's role, the nature of the benefits delivered is generally fairly clear and provides a solid basis for developing at least a lower bound assessment of DST Group value from the 10 case studies.

Of course, such value derived from these case studies is likely to be very much less than the true value delivered by DST Group for a range of reasons:

— The 10 case studies, while chosen in part because they were known to have delivered tangible value, only scratch the surface of the whole portfolio of DST Group activities.
  - Other potential case studies were considered for inclusion in the set of those to be examined in this study; These were also known to have delivered high value based on the experience of past assessments – the emphasis has been on demonstrating new values, not already considered in detail in past studies, and it was necessary to work with only a sample of prospective case studies, given the size and scope of the study.
  - Inevitably, some projects were excluded from the case studies where there prospects for demonstrating high value appeared at least comparable to that offered by some of the case studies actually done

  - Realistically, a more comprehensive trawling across the entire portfolio of recent DST Group project activity, using the same methods used in the 10 case studies, would have demonstrated much greater value than can be inferred from the 10 case studies alone.
- As is discussed in section 3.1.1 even within the chosen cases studies, the approach used was deliberately designed to err, if anything, on the side of under- rather than over-estimation of the tangible benefits of the projects, to allow confident (and correspondingly less controversial) conclusions to be drawn regarding a sound lower bound estimate of value.
  - Not all of even the tangible benefits of the individual case studies were factored into the quantified assessment. For example, in the case of the JORN case study (refer Appendix A.4) benefits were limited to phase 5 only.
  - Where uncertainty was high, judgments as to parameter assumptions and implied levels of impact were made conservatively, leaning towards under-estimation of benefits
  - The choice of counterfactual tended also to be made in a somewhat optimistic manner – the true counterfactual in the absence of the DST Group input, in most cases would have been more expensive or less effective than has been assumed and would imply greater value from DST Group's involvement
- The assessment largely excluded consideration, and especially quantification, of a range of broader options delivered as a result of the DST Group involvement, building capabilities with potentially high value future application to Australia's defence and to Australian industry
  - These options are the focus of this chapter; while not a central consideration in the brief for the assessment, they are of sufficient importance to any balanced assessment of overall DST Group value to require some consideration here.

Therefore, we consider that it would be misleading to focus on this conservative assessment of the tangible benefits from a small selection of DST Group activities as capturing the whole economic value story. For example the case study approach provides very limited insights in to questions such as:

- How much value does DST Group deliver? The analysis in Appendix A indicates that the quantified benefits from the case studies might be only a fraction of total benefits delivered – but how small a fraction?
- Which of the areas considered in the case studies offers the greatest returns – in aggregate and on marginal investment. This type of information is crucial to sound management of DST Group investment strategy through time, yet the case study approach yields little information with respect to this. For example, an area that appears to be underperforming based on the tangible benefits may well support disproportionately high options values that make it the best overall performer.
- What broader lessons can be drawn as to the factors that distinguish better performing DST Group activities from other activities that might provide useful guidance in working out where best to direct resources?

While detailed coverage of these issues lies well beyond the scope of the present assessment, it is important that this wider context not be lost when using the results, and especially the quantitative results, of the assessments.

A

DETAILED CASE STUDIES

This section provides the detailed analysis undertaken for each of the ten case studies in estimating the economic value generated by DST Group through its involvement with each case study. The case studies were assessed using the impact framework for DST Group research set out in Figure 4-1.

The case studies are covered in the following order:

TABLE A.1 – **CASE STUDY ORDER**

Number	Case study
1.	Collins Class Submarine Remediation
2.	P-3 Orion Service Life Assessment Program
3.	Joint Direct Attack Munition – Extended Range
4.	Jindalee Operational Radar Network (JORN)
5.	F/A-18 Structural Refurbishment
6.	E-7A Wedgetail Radar
7.	NULKA Anti-ship Missile Decoy
8.	Advanced Short Range Air to Air Missile
9.	Wideband Global SATCOM System JP2008 Phase
10.	Force Protection Electronic Countermeasures

A.1 Collins Class Submarine Remediation

BOX A.1 – **KEY FINDINGS – COLLINS CLASS REMEDIATION**

Key finding 1 – DST Group's research has been critical in ensuring that Australia had access to a submarine fleet that was more capable and had much higher availability than would otherwise have been the case.

Key finding 2 - ACIL Allen has estimated the total benefits that can be attributed to DST Group arising from just six DST Group tasks conducted as part of the Collins project to be $598 million. Almost half this amount (approximately $285 million) was derived as a result of DST Group's work to test the integrity of hull valves and develop a management program.

A.1.1 Project origins and inputs

Planning for the construction of the Collins Class submarines began in 1978, some fifteen years before the launch of the first boat, HMAS Collins, in 1993. Navy required a replacement for its six UK built Oberon Class submarines. In the early 1980s the decision was taken to build a unique submarine that matched Australia's special requirements[7] rather than buying an off-the-shelf submarine from an overseas supplier. Having an Australian built vessel was also seen as essential to ensuring the strategic goal of being able to have an industry with the ability to fully support the submarine capability in country.

The six Collins class submarines were launched between 1993 and 2001.[8] Each was commissioned two to three years after it was launched. The total cost of the acquisition was around $5 billion.

As occurs with almost all 'first of a kind' builds, there were various problems associated with the constructions of the Collins class. There were early issues around the quality of the welding of some sections of the hull. In 1999 a report identified problems with the diesel engines, noise propagation, and the performance of propellers, periscopes, masts and the combat system.[9] The report found that that Australia's strategic circumstances would have had to have been extremely serious to risk the submarines being 'sent into danger' given their operational state at the time.

DST Group's role in supporting the acquisition, sustainment and operations of the Collins class submarine began in the 1990s. Since then, DST Group has been instrumental in resolving the problems mentioned above. DST Group's capabilities and skills have also evolved to the stage where they could address emerging challenges associated with the Collins as well as activities needed to help support the next generation of submarines.

For example, anechoic tiles required for the reduction of acoustic target strength were not made available to Australia. DST Group's research was instrumental in developing effective anechoic tiles that met Australia's requirements and greatly increased the capability of the submarine fleet. The Trenberth report valued the anechoic tiles program at around $1.7 billion in 2003.[10] As the DST Group activity related to the anechoic tiles largely occurred prior to 2003 and consistent with the conservative approach to estimating benefits, none of the anechoic tile benefits have been included in this case study.

Throughout the lifetime of Collins, DST Group has had a vital role in the remediation of issues, insertion of region leading capabilities and creation of scientific partnerships providing privileged access to allied partners technology in submarine warfare systems such as sonar, periscopes, communications, and the joint development of the Mk48 torpedo and AN/BYG-1 tactical command and control system with the US Navy.

This case study does not revisit the benefits identified by Trenberth. Rather we look at how the skills and experience built up over the period covered by the Trenberth Review have continued to be used

---

[7] Australia's geographic and strategic circumstances were seen as requiring a higher speed conventional submarine capable of longer journeys and longer endurance compared with existing European submarines at the time.
[8] HMAS Collins, HMAS Farncomb, HMAS Waller, HMAS Dechaineux, HMAS Sheean and HMAS Rankin.
[9] M.K. McIntosh, J.B. Prescott: *Report to the Minister for Defence on the Collins Class Submarine and Related Matters*, June 1999
[10] Robert J Trenberth and ACIL Tasman, *Review of DSTO's External Engagement and Contribution to Australia's Wealth*, September 2003.

to maintain and enhance the capability of the Collins class, support the greater availability of the vessel for at sea deployment and reduce O&M costs.

For the purposes of this case study we have selected six elements of DST Group's ongoing support for the Collins submarine, namely:

— Hull valve tests and management program
— Fatigue testing and management of propellers
— Hull Structural assurance and safety
— Replacement of Radar Absorbing Materials (RAM) on the masts
— In-situ replacement of main propulsion motor armature bands
— Urgent remediation of combat system issues.

Hull valve tests and management program

The shock integrity of safety critical hull valves within the Collins class submarine fleet was raised with DST Group due to significant Navy concerns over the effects of selective-phase corrosion, in part due to a lack of information on the extent and structural effect of the corrosion. Corrosion of similar valves had been found to be an issue for the submarine fleets of other countries.

In order to reduce the risk of a valve failure, a plan for the mandatory replacement for critical seawater valves every four years was developed, coupled with possible operational restrictions until the integrity of valves could be established. However this mitigation strategy increased maintenance times and costs. The cost for replacing the valves on each submarine are around $1.3 million in material terms, plus the maintenance time. Consequently DST Group was tasked by Navy to assess the level of in-service corrosion in valves and determine the effect on valve shock integrity, to inform a review of the hull valve maintenance plan.

Project Inputs

DST Group put in seven person years of effort over three years between end of 2008 and 2011.

Fatigue testing and management of propellers

In 1998 cracking was discovered in the propeller of HMAS COLLINS when it was in dry dock. The operation of the Collins fleet was halted pending a DST Group investigation into the cracking. An interdisciplinary DST Group team was tasked with determining the extent of cracking in the propellers (including underwater inspections), measures to halt the cracking and to develop a fatigue-life management scheme which would prevent further cracking in the other fleet propellers enabling the Collins class submarines to continue operations.

The propellers were manufactured by a company called Stone Manganese Marine. Importantly, neither the Swedish designer of the propellers, SSPA, nor the manufacturer placed any operational constraints on the submarine. Some aspects of the full spectrum of submarine operations resulted in more onerous fatigue conditions than SSPA had designed for (i.e. their analysis did not predict the actual fatigue loading that the propeller would encounter during some operations). DST Group knew this because they measured the fatigue loads.

None of our allies operates submarines which use propellers made from the alloy which we used. In addition, each propeller is designed to provide the power requirements for that particular submarine design given the hydrodynamic flow which is particular to the specific submarine hull shape. Predictions of the stresses and fatigue life are made using the design data and the predicted design loads. In order to achieve what DST Group achieved they had to make actual measurements on propellers in service on our submarines and had to undertake full scale fatigue testing of the propeller under the conditions they experienced. One important thing to note is that the fleet was tied up alongside until DST Group was able to provide advice on what to do, which they were able to do in a matter of days. If that advice could not have been provided the submarines would have been out of operation for months.

The initial advice was relatively conservative but as DST Group gained more information it was possible to relax the operational restrictions on the submarine.

The majority of work on this project took place from July 1998 until 2001. The results of DST Group's research were transitioned to the Australian Submarine Corporation (ASC) from 2001 to 2005. The fatigue life management plan for the propellers is still in use today. ASC continues to seek DST Group advice if they wish to deviate from the management plan.

Project inputs

DST Group put in around 18 person years of effort over four years between 1998 and 2001

Hull Structural Assurance and Safety

The Collins Class Submarine is constructed from a unique high strength steel, not used by any other submarine in the world. When weld cracking and other defects were found in the hull of HMAS COLLINS, a DST Group staff member was appointed to a Weld Review Team which investigated the cracking issues and their implications for structural safety for HMAS COLLINS and for the rest of the fleet. After the review, DST Group provided technical knowledge into the Integrated Project Team that developed the Collins class Weld Management Plan - steering the philosophy behind the plan into alignment with contemporary risk management practices. This management plan forms an integral part of the continued structural assurance of the Collins class submarine fleet through the ASC Structural Validation Program.

Project inputs

DST Group contributed around 8 person years of effort over the 4 year research project.

Replacement of Radar Absorbing Materials (RAM) on the periscopes

Radar Absorbing Materials (RAM) is attached to the periscopes on the Collins Class Submarines to reduce the periscope up radar signature of the vessel. The original RAM was originally provided by an overseas supplier. The original RAM rusted, delaminated and detached from the periscopes requiring the periscopes to be frequently removed from the submarine and the RAM reapplied. In addition, the material was also not optimised for Australian requirements for radar protection. Work to investigate the problem and provide a solution commenced in earnest in 2003, although a low level of activity began as far back as 1994.

Project inputs

DST Group contributed around 1.5 person years per annum to the project over the period from 2003 to 2007 plus non-salary financial input of around $30,000 per annum over 13 years from 1994.

In-situ replacement of main propulsion motor armature bands

In the mid 2000's the armature bands on the main propulsion motor on some submarines were found to be degrading sufficiently to compromise the safe operation of the motor. In December 2008 DST Group was tasked with investigating technical issues and safety implications associated with the degradation of the armature bands. In June 2009 it was decided that the ASC, with the support of DST Group, would test to confirm new retained tension predictions and develop a qualified procedure for replacing armature bands on the MPMs of the Collins Class submarines. The Main Motor Banding Integrated Product Team (IPT) was established in July 2009.

Project inputs

The project was a collaborative one between ASC, DMO and DST Group. The duration of the project was initially fixed at two years. Some additional resources were required and approved due to technical challenges encountered, though there was minimal slippage in time as this was constrained by the Full Cycle Docking activity plan for the target submarine. DST Group contributed around 0.8 person years in 2009/10, 1.8 person years in 2009/10, 0.9 person years in 2010/11 and 0.6 person years in 2011/2012. Also in-kind support was provided through the use of DST Group's research infrastructure.

Urgent remediation of combat system issues

In 2002, the US AN/BYG-1 Tactical Command and Control was selected as Replacement Combat System for the Collins class submarine fleet. To support this acquisition, DST Group was requested to undertake the role of Submarine Combat Systems - Technical Adviser (SMCS-TA). The role of the SMCS-TA was (and continues to be) to provide an enduring source of expert and objective, scientific and technical advice to the DMO and RAN on the evolution of current Combat Systems as well as the acquisition of new submarine combat and related systems.

Part of the role for DST Group for the AN/BYG-1 program, and in the supporting submarine sonar program, is to assist the RAN with the urgent remediation of combat system issues and operational deficiencies. For this case study, we have selected two examples of DST Group providing combat system operational support. The first is a mid-2006 request to augment the intercept sonar processing to address an urgent operational need. The second is a 2011 request to assist with investigation and rectification of an AN/BYG-1 TI06/APB07 issue that significantly impacted boat operations.

Project inputs

DST Group estimates that it committed an average of 2.5 person years per annum between 2006/07 and 2008/09 and 1 person year per annum between 2009/10 and 2014/15 to fulfilling its role as SMCS-TA. DST Group also provided in kind support through access to DST Group submarine sonar research infrastructure over the period 2006/07 – 2014/15.

For the TI06/APB07 project DST Group estimates that it allocated some 4 person weeks. DST Group also provided in kind support through the use of its accumulated knowledge and use of its infrastructure.

A.1.2 Project activities

Hull valve tests and management

DST Group conducted all the scientific testing and analysis including:

- Developing a methodology to introduce corrosion-like defects into valves to simulate extended service life and determine the level of confidence in the valve shock integrity.
- Designing a unique underwater explosive test to apply shock loads to the hull valves in line with the submarine shock requirements specified for Collins Class.
- Using advanced instrumentation and measurement methods to capture underwater shock data to allow the development and validation of models of hull valve response to shocks.

Fatigue testing and management of propellers

The skills and capabilities used by DST Group during its work on this project included:

- *Metallurgy and environmentally assisted cracking*: this knowledge was used to identify the mechanism responsible for the initiation of the cracking
- *Non-destructive testing*: this knowledge enabled the team to develop new and innovative methods to inspect propellers for cracks, including the use of underwater eddy current inspection.
- *Corrosion science*: this provided the capability to measure the electrochemical potential of in-service propellers during submarine operations
- *Instrumentation*: instrumentation was developed by DST Group scientists to measure the strain in submarine propeller blades as they rotate during submarine operations
- *Full scale structural fatigue testing*: this knowledge and experience was used to develop a fatigue test rig for the propeller
- *Coatings and sealants science*: this enabled DST Group to identify appropriate coatings which would protect the propeller alloy from seawater
- *Fracture mechanics*: DST Group applied their skills in this area to predict the rate of growth of cracks which in turn enabled them to determine the appropriate maximum time between propeller inspections
- *Laboratory scale testing*: DST Group conducted fatigue tests on small laboratory scale specimens.

Once the propeller fatigue management plan had been developed it was transitioned to ASC which continues to apply it to this day. See Box A.2 for more information on the fatigue management plan.

BOX A.2 – **PROPELLER FATIGUE MANAGEMENT PLAN**

The Collins submarine propeller fatigue management plan developed by DST Group entails the following:

– The modification of submarine operations to reduce the stresses on the propeller blades which drives the fatigue crack propagation
– Painting the propellers to protect them from the seawater environment. (this stops the de-alloying process which initiates cracking and slows down crack growth should it exist)
– Non-destructive testing of the propellers at carefully defined intervals to ensure that no crack like defects above a critical size are present – which could grow to failure before the next scheduled inspection

Critical to the success of this plan is the work that goes into determining the inspection intervals.

SOURCE: DST GROUP

Hull Structural Assurance and Safety

For a submarine pressure hull the most important fatigue cycle is the surface-to-deep-diving-depth transit which can take many minutes to complete. Because of the effects of sea-water on fatigue DST Group carried out a research program to determine the appropriate test conditions to enable accelerated fatigue testing in the laboratory. This was only possible because of a deep understanding of the processes involved in environmentally assisted cracking. As part of collecting the data necessary for the development of the Weld Management Plan, testing was also conducted to determine the stress corrosion cracking susceptibility and the fracture resistance of the hull and its welds. As part of this research program, DST Group also re-analysed the design fatigue life of the Collins Class to account for environmental effects on fatigue. DST Group also provided analysis of the probable fatigue life based actual submarine usage and planned future usage.

ASC provided welded plates for the project and undertook a complimentary project to develop rapid assessment tools which can be used to undertake structural calculations using the DST Group research

Replacement of Radar Absorbing Materials (RAM) on the periscopes

DST Group carried out research to develop, test, manufacture and fit radar absorbing materials to the submarine periscopes.

DST Group designed the RAM by creating computer code to analyse and optimise the absorbing additive concentrations, individual layer thicknesses, adhesive performance and reflective layer insertion over the frequency ranges required by RAN. Significant advances in measuring material properties at radar frequencies were also undertaken by DST Group, improving both the accuracy of the measurements and sample measurement time. Once an acceptable material was developed in the DST Group laboratories, an Australian firm was contracted to assist with the full scale manufacture and fitment of the RAM to the submarines.

In addition to developing the new material DST Group also developed a new process for bonding the RAM to the periscope which no longer required the use of a toxic chemical which was used as part of the bonding process for the initial RAM.

DST Group continues to develop new RAM and manages the replacement of RAM on the periscopes of RAN submarines today.

In-situ replacement of main propulsion motor armature bands

A full-scale mandrel matching the Collins motor dimensions was constructed to validate the determination of retained tension in armature bands and to establish the procedure for applying high quality armature bands. This was followed by procedure qualification trails on a submarine motor, before final application of a new set of armature bands. DST Group undertook extensive literature reviews, testing and cure model development, specialised spectroscopic, thermal, mechanical and microscopy analysis of samples during process development, provided continuous expert materials advice, reviewed documentation including work instructions and acceptance criteria.

ASC managed the project and conducted the process and procedure development, qualification and final implementation of new procedure. DSME acted as the Engineering Authority and provided additional technical analysis and advice.

Urgent remediation of combat system issues

For the augmentation of the intercept processing DST Group undertook the rapid development, testing and installation of improved active sonar intercept processing software between October and December 2006. The system was implemented within the pre-existing DST Group developed concept demonstration equipment installed on the submarine and sea trialled in January 2007. Beginning in 2008, multiple updated versions have subsequently been provided (update were provided approximately annually) that incorporated operational feedback and addressed emerging needs.

For the AN/BYG-1 TI06/APB07 issue the DST Group activities were the configuration of a combat system laboratory to match the operational hardware and software configuration on the submarine, fault finding and analysis of the issue, in conjunction with Raytheon, DMO and the US Navy to determine solutions of the issues. Additionally the DST Group facilities were utilised in January 2012 to rebuild the Tactical Control System (TCS) to rectify the software fault. This build was not possible anywhere else in Australia at the time as only DST Group had the means to rebuild the TCS from the source code.

A.1.3 Project outputs

Hull valve tests and management

DST Group's analyses of experimental data and physical test results was able to demonstrate that the valves had a high degree of tolerance to the presence of both in-service corrosion and defects. DST Group was able to show that the maximum levels of corrosion predicted to occur between submarine full-cycle maintenance periods (every 8-10 years) would not adversely affect valve integrity.

A potential issue with fasteners in the valve design that increased the valve's susceptibility to shock failure was also identified during this project. DST Group was able to develop and test a solution to this potential problem. If accepted by DMO and ASC this has the potential to improve the shock performance of the submarine. ACIL Allen has not sought to assign a value to this work.

An important part of this project was the development of advanced modelling capabilities for underwater shock response. This capability is expected to be applied in future DST Group projects conducted for the Navy.

Fatigue testing and management of propellers

DST Group's research into the cracking of the Collins' propeller enabled a propeller fatigue management plan to be developed that enabled Australia's fleet of submarines to return to normal operations and to continue to safely operate by reducing the risk of damage to the submarine propellers.
ASC continues to apply the propeller fatigue management plan developed by DST Group.

Hull Structural Assurance and Safety

The collaboration between DST Group and ASC developed the necessary materials property data and the methodology to assess the impact of welding defects on the structural safety of the submarine hull of the Collins fleet and of HMAS COLLINS in particular. Additionally, the Weld Management Plan was developed to provide strategic direction for the verification of weld integrity of the Collins Class Submarines. DST Group provided the analysis of the fatigue life of the submarine hull, based on the materials data collected.

Replacement of Radar Absorbing Materials (RAM) on the periscopes

A new RAM was developed, tested, manufactured and fitted to the Collins Class Submarines. New designs of RAM are currently under development which provide improvements to the current materials.

It takes two technicians two weeks (10 days) to apply the RAM. Assuming each technician has a salary of $100,000 a year then that amounts to $8000 in salary costs. The materials developed during the RAM development program were able to be modified for use on surface ships and aircraft, and are currently installed on other ADF platforms.

The RAM is manufactured under a licence agreement with a local Australian company (Mackay Industries).

In-situ replacement of main propulsion motor armature bands

This project led to the development of a fully qualified procedure for the in situ replacement of armature bands on a marine propulsion motor. A number of innovative changes to the banding procedure were developed, including a reliable analysis of retained tension based on band size. A tested and validated cure prediction tool was also developed and a new glazing procedure developed for ensuring a high quality surface.

Other outputs were a wrapping tape lay-up design tool, a new heating arrangement that allowed all four armature bands to be cured simultaneously, and a special fabric insert to prevent circumferential cracks from developing in the armature bands.

The results of the project have been utilised by ASC now for the replacement of armature bands on three motors. They are continuing to apply the solutions supported as necessary by DST Group.

The analysis and interpretive skills that were developed by DST Group and ASC over the course of this project have since been applied to understanding the causes of a failure of a propulsion transformer on the RAN ship HMAS Choules.

Urgent remediation of combat system issues

The intercept processing software developed by DST Group has been in operational service since being transferred to the fleet and it continues to provide augmentation of the native active sonar intercept processing capability on the submarine.

For the TI06/APB07 software issue the output of the project was a set of procedures that permitted the boat to return to operations, replication of the fault conditions within the DST Group laboratory permitting further investigation and rectification, and the identification of changes to the test process for the software builds.

A.1.4 Status of Outcomes and Impacts

Table A.2 summarises the outcomes and impacts of the Collins submarine project. More detail on the various outcomes and impacts are provided in the sections that follow.

TABLE A.2 – **SUMMARY OF OUTCOMES AND IMPACTS OF COLLINS SUBMARINE PROJECT**

	Project Elements					
Outcome / Impact	Hull valve tests	Collins propeller	Hull structural assurance	RAM for periscope	Armature bands	Combat system
Reduced acquisition cost	Yes	Yes	-	-	Yes	Yes
Deferred acquisition costs	Yes	Yes	-	Yes	Yes	-
Reduced O&M costs	Yes	Yes	Yes	Yes	Yes	Yes
Revenue raised (sales, exports, licence fees, etc.)	-	-		Yes	-	-
Increased availability	Yes	Yes	Yes	Yes	Yes	Yes
Increased capacity	-	-	-	Yes	Yes	Yes
Avoided adverse effects (deaths, injuries, environmental impacts, etc.)	Yes	Yes	Yes	Yes	Yes	Yes
Options			Yes			

SOURCE: ACIL ALLEN BASED ON CONSULTATIONS WITH DST GROUP PROJECT PERSONNEL

Nature of Outcomes and Impacts

The work done by DST Group on the Collins submarine has delivered significant outcomes for Australia. It is arguable that in the absence of DST Group's work Australia may not have been able to deploy its submarine fleet for extended periods of time or perhaps at all. Without the work done by DST Group it is possible that the contract for the submarines could have ended in the courts and the delivery of the vessels could have been delayed for years.

Certainly DST Group's research into propeller fatigue, armature bands and hull valve safety has increased the availability of the Collins class for deployment at sea beyond what would otherwise have been the case. That research provided the technical proof that the lifetime of critical equipment was significantly longer than first thought. For example, the safe lifetime of critical items such as the hull valves was able to be doubled from four to eight years. Similarly, the research into the in-situ repairs on the armature bands significantly reduced the time required to undertake repairs of the bands. The implementation of the Weld Management Plan has provided assurance that weld integrity across the Collins Class is adequately monitored and maintained through the life of the submarine.

DST Group's research also improved the capability of the submarines. Like the research on the anechoic tiles discussed in the Trenberth review, the more recent research on the RAM applied to the periscope delivered a product that was not only of a higher quality but also better suited to the operational circumstances of Australia's submarines.

The outcomes of DST Group's research also helped to reduce costs in a number of ways. For example, the propeller fatigue management plan allowed Australia to avoid the cost of buying expensive new propellers for the submarines. Similarly, being able to confidently double the safe life of hull valves that are critical to the safety of the submarine enabled a reduction in the maintenance costs of the submarine fleet.

Business has also benefited from the DST Group's research. The partnership between the ASC and DST Group has helped the former better service the submarine fleet and increased the efficiency and effectiveness of the maintenance program. The transfer of the RAM technology to an Australian firm has enabled that firm expand its product offering. The RAM technology has already been applied to surface vessels and this is likely to continue.

The urgent research into the remediation of combat system issues by DST Group both improved the fleet's capability (through the resultant improvement in signal processing) and increased the fleet's availability by enabling the boats to return to operations earlier than would otherwise have been the case.

DST Group's research also resulted in environmental benefits. The RAM technology developed by DST Group does not require the use of the highly hazardous chemicals needed as part of the process of applying the material to the Collins periscopes.

Counterfactual

There would be no other Australian organisation with the range and level of skills and capability required to undertake the various research projects discussed in this case study. While it may be possible that overseas organisations could have provided the same research in some cases it is likely that they would have not been able to deliver the necessary outcomes within the same time frame. In situations where timing of results was critical this could have had serious consequences.[11]

In addition, much of the work done by DST Group was designed to ensure that the Collins submarines were optimised for operation in Australian and regional waters. Commissioning such research from an overseas supplier, if possible at all, is likely to have been more difficult, more time consuming, more costly and be less likely to deliver solutions for Australian circumstances.

For example, it would not have been possible to draw on lessons learnt by the navies of nations friendly to Australia since none of our allies operate submarines which use propellers made from the alloy used on the Collins, not do they use open bladed propellers. In addition, each propeller is designed to provide the power requirements for that particular submarine design given the hydrodynamic flow which is particular to the specific submarine hull shape.

Similarly, it is unlikely that research results that increased the capability of the Collins fleet would have been provided by an overseas supplier. Overseas developers of technology that provides a tactical or strategic advantage would tend to restrict the availability of that technology to protect that advantage. Just as Australia has not made the results of its research on RAM available to any overseas buyers.

Collaboration in delivery of benefit

All elements of the work done by DST Group on the Collins project involved the collaboration with different organisations, both in Australia and overseas. Importantly, while there were a number of organisations that contributed to the ultimate outcomes provided from this project, and the delivery of significant benefits as a result, none of those benefits would have been delivered if DST Group had not carried out the work that it did. Consequently, for purposes of impact assessment and valuation and consistent with our stated approach, ACIL Allen has attributed 100 per cent of the benefits flowing from this project to DST Group for the purposes of this report.

Adoption

Adoption of the outputs of DST Group's research has been rapid, partly because the purpose of the research was to address already identified issues with the submarine. Adoption of much of the outputs was effectively necessary if the availability of the submarine for at sea operations was not to be severely compromised.

The rapid transfer of the results of the research to industry was aided by long term relationship built up over time between DST Group and the ASC and between DST Group and Mackay Industries.[12]

---

[11] For example, DSTO's research showed that the likely failure of a propeller was only hours away when the problem was identified. Such a failure could have had extremely serious consequences.

[12] Mackay Industries was the firm that produced the anechoic tiles developed by DSTO.

A.1.5 Assessment of impacts

Hull valve tests and management program

The key benefit of this element of the Collins project has been a better understanding of the durability of the 151 hull valves on a Collins submarine. As these valves are critical to the safe operation of the submarine a conservative approach was adopted to ensure their ongoing structural integrity. This would normally have required all the valves to be replaced after 4 years. Testing by DST Group demonstrated that the safe life of the valves could be doubled to eight years.

This enabled the deferral of the cost of replacing these safety critical valves by four years for each submarine. The cost of the replacement valves is around $1.7 million per submarine (for a total around $10.2 million for the fleet of six submarines).

ASC has estimated that replacing each valve would takes some 40 man hours of effort by two people (to disconnect the piping, fitting harnesses to lift the valves, installing the new valve, etc.). Given that there are 151 safety critical valves then this suggests that the amount of work needed has declined from 6040 hours every 4 years to 6040 hours every 8 years. If we assume a blended hourly rate of $150 for the two people replacing the valves then this would translate to a further saving of about $906,000 per submarine every 8 years, or $5.44 million for the fleet.

The improved understanding of the durability and safety of the hull valves has also led to increased availability of the submarines. If we assume that the time saved by not having to replace the valves is spread evenly across the lengthened period of eight years between valve replacements this would equate to some extra 31 days per year of availability of each vessel.

However, it is unlikely that the entire 31 days a year of extra ‘theoretical availability’ would translate into ‘actual additional availability’. A conservative assumption might be that only 10 per cent of the theoretical availability increase was realised as actual availability. This would translate into three extra days of availability per submarine per year. ACIL Allen understands that the cost having a submarine at sea is about $1.5 million a day. One might argue that this amount could be used as proxy for our willingness to pay for having this capability. This would value the additional availability at $4.5 million per submarine per year (for a total of $27 million a year for the fleet).

Fatigue testing and management of propellers

Propellers are specifically designed for the submarine (they are not available off the shelf). Each propeller would have cost approximately $2m to purchase ($12m for fleet). This is an avoided cost. The cost of labour to fit the propellers is also avoided. If there had been a need to replace the propellers this would have prevented all submarines from being deployed for over two years, while a new propeller was developed and tested.

If we assume that the Collins fleet needs at least 7 propellers in total (one propeller for each vessel plus a spare) at any one time. During the Collins remediation program one modified propeller was purchased and another was cast and completed in the US. This would have left five propellers needing to be replaced if the DST Group program had not developed the analysis and management program that successfully addressed the propeller cracking issue.

The purchase cost of each propeller is around $2 million, which implies a saving across the entire fleet of approximately $10 million. Furthermore, if the fleet had continued to use the original propellers in the same manner as before then the issues with reliability would have continued and caused additional lost Material Ready Days (MRDs) and the need for further periodic propeller replacements. Collins was launched in the mid-1990s. The propellers would normally be expected to last the life of the submarine, however cracking was discovered in 1998 after only some four years of operation.

Clearly DST Group’s research has increased the availability of the fleet for at sea deployment. The estimated lead time for the manufacture of a new propeller is approximately 18 months. This could have been managed by pre-ordering and maintaining a stock of propellers. It would take some two days to replace a propeller. This would normally be done during a mid-cycle docking. However, the two days required to replace a propeller every say 4 years would be lost MRDs for each submarine. If we used the $1.5 million a day that it costs to deploy the submarine as an indication of the willingness to pay for the capability the submarine provides and assumed that say each submarine would have been unavailable for an average of half a day a year then the ‘value’ of those lost MRDs would be around $4.5 million a year. If we assume that the fleet will operate for an additional ten years then the total benefit could be valued at some $45 million.

Hull Structural Assurance and Safety

The provision of the materials data by DST Group for the unique steel used on the Collins Class has enabled ASC to better manage the hull and hull welds through a program of targeted inspections, repairs and refurbishment. Through the Structural Validation Program, ASC has been able to focus on critical structural areas in the submarine, rather than perform an inspection of all hull welds, thus generating potential savings in maintenance time and costs through the avoidance of unnecessary inspections or repairs.

The fatigue life assessment tools for the Collins Class developed by DST Group using the materials data collected has provided the ability to analyse the fatigue life based on actual past submarine usage and planned future usage. Use of these tools enable the potential for the assessment and management of Life-of-Type for the Collins Class for hull structural assurance. Thus, if the Collins Class were required to have a life extension for another full cycle docking (10 years) or mid cycle docking (5 years), the ongoing structural integrity and safety of the submarine hull could be ensured by the DST Group development of the materials data and subsequent fatigue life assessment. The major impact would be the avoidance of a capability gap by ensuring Australia had access to a submarine. The value of this outcome could be measured by reference to ability to defer the costs of having to acquire a new submarine by taking up the option of keeping the Collins Class for longer.

Replacement of Radar Absorbing Materials (RAM) on the periscopes

The RAM initially used on the periscopes was found to deteriorate relatively quickly and it therefore had to be frequently re-applied. The RAM was sourced from overseas and required the use of dangerous chemicals (including Hydrogen Fluoride) during the application process. When it became clear that the initial RAM would need to be regularly replaced OH&S concerns associated with the use of these chemicals led to a proposal in 2010 for a new facility to ensure workers could safely apply the old RAM. The creation and satisfactory testing of the new RAM removed the need to construct a new facility in order to ensure worker safety during application of the RAM. The avoided cost was estimated to be between $5 and $10 million at the time.

Both the old and the new RAM take approximately two weeks to apply to the periscope, however the durability of the new RAM is significantly better than the old RAM. The life of the initial RAM used varied between 12 and 36 months whereas the new RAM lasts for at least twice that. If one makes the relatively conservative assumption that the old RAM would last at least three years and the new RAM for twice that time then this would imply that the use of the new RAM increased availability of the submarines by two weeks every six years. If we used the $1.5 million a day that it costs to deploy the submarine as an indication of the willingness to pay for the capability the submarine provides, then this suggests that the average value of the increased availability would be around $3.5 million a year per submarine. Over 15 years, this benefit would total $52.5 million.

The new RAM also has a lower radar reflectance and is optimised for RAN requirements. If we adopted the approach used by the Trenberth Review we could assign a proportion of the initial purchase cost of the submarine fleet (around $5 billion) as an estimate of the ‘value’ of the additional capability provided by the RAM project. In the case of the anechoic tiles Trenberth judged the appropriate share to be 10%. In the case of the RAM used on the periscope, ACIL Allen would judge the appropriate share to be between 0.5 and 1 per cent. This suggests the value of the improved capability is $25 - 50 million.

The RAM is manufactured under a licence agreement with a local Australian company. There are royalties paid to the Australian government by that firm. Information on the amount paid in royalties is not available, but they are not expected to be significant.

In-situ replacement of main propulsion motor armature bands

The key impact of this project was the improved safety and reliability of the Collins Class submarines as the result of the development of an armature band replacement procedure. The success of the project has significantly reduced the likelihood of an armature band failure in the main propulsion motors and the subsequent unscheduled cost associated with replacing or rewinding the motor. This would require either replacing the armature bands or more likely removing the motor from the submarine and sending it away for rewinding. This would result in a significant loss of submarine MRDs.

The original manufacturer had developed a procedure for the rebanding of the main motors, but this was to be done in a factory location, not in-situ. It is not possible to remove the main motors without cutting the pressure hull of the submarine. The additional cost associated with doing so is many tens of millions of dollars. Hence DST Group was tasked with developing a modified procedure that could be used in-situ.

It would not have been possible to draw on procedures developed by the navies of nations friendly to Australia who are operating similar submarines since they have different propulsion systems.

The best possible outcome if an armature band failed would be an unscheduled replacement of the armature bands which would take some seven months based on experience with a planned band replacement. This would equate to the loss of some 200 MRDs.[13] However, the repairs could potentially take much longer and lead to significantly more lost MRDs due to their unscheduled nature.

Even a relatively conservative assumption that there was a five per cent chance of an armature band failure in any one year would imply an average loss of ten MRDs a year. If we used the $1.5 million a day that it costs to deploy the submarine as an indication of the willingness to pay for the capability the submarine provides, then this suggests that the value of the average increased availability would be around $15 million a year. Over 10 years, this benefit would total $150 million.

The modelling of armature band performance and the improved quality of in situ repairs made possible by this project is likely to help avoid any associated lost MRDs and cost of repairs. The new armature bands are expected to last the remaining life of the submarines, that is, there is a very low likelihood of a failures. The improved confidence in the performance of the motors will in turn facilitate the reduction (or removal) of any operating restrictions and allow a reduction in band inspection frequency. Hence the $15 million a year average benefit could arguably be regarded as a conservative lower bound for the benefits of this project.

Urgent remediation of combat system issues

The key benefit of the sonar work has been the enhancement of the operational effectiveness of the submarine through the improved capability to detect the transmissions from modern active sonar systems. The capability provided by the DST Group developed processing has been very well received by the submarine operational community, with DST Group assisting the RAN by regularly shifting the concept demonstration hardware that the processing runs on between submarines so that the submarines operationally deployed have an opportunity to experience this enhanced capability. More recently, the intercept processing was the first third party software integrated into the Signal Processing Open Architecture (SPOA) system that will replace legacy Collins sonar processing over the next three years. SPOA integration will enable all submarines to have a permanent installation of the DST Group developed intercept processing software

If we adopted the approach used by the Trenberth Review we could assign a proportion of the initial purchase cost of the submarine fleet (around $5 billion) as an estimate of the 'value' of the additional capability provided by the combat systems project. In the case of the anechoic tiles Trenberth judged the appropriate share to be 10%. In the case of the enhanced active sonar intercept even an extremely conservative approach that estimating the appropriate share to be between 0.2 and 0.5 per cent equates to the value for the improved capability of between $10 and 25 million.

The AN/BYG-1 TI06/APB07 software problem within the contract management system was sufficiently severe for the impacted submarine to be forced to return to port. The work undertaken by the DST Group/Raytheon/DMO/US Navy team permitted the development of an initial work around for the issue that allowed the submarine to proceed back to sea. The submarine was able to return to its mission for another two weeks or so (10-14 days). The longer term impact of the work was to identify

[13] *Study into the Business of Sustaining Australia's Strategic Collins Class Capability – Progress review – March 2014*, Issued by Mr John Coles, Commonwealth of Australia, 2014.

changes in the testing process to avoid recurrence of the issue in future software build. This has resulted in changes to the testing undertaken in the US prior to the software builds for the combat system on the Collins class submarines being sent to Australia.

The software solution developed by DST Group increased the availability of the submarine in question by between 10 and 14 days. If we used the $1.5 million a day that it costs to deploy the submarine as an indication of the willingness to pay for the capability the submarine provides, then this suggests that the value obtained is between $15 million (10 days) and $21 million (14 days).

Potential future impacts

DST Group continues to carry out research using the skills and experience gained as a result of the projects discussed in this case study. For example:

— An Interactive Project Agreement under the DST Group and ASC Strategic Research and Development Alliance established in August 2013 has been established to cover any future DST Group support for subsequent replacements of armature bands on submarine motors. This is funded through the In Service Support Contract (ISSC) between ASC and DMO from June 2012.
— DST Group's skills and experience gained through their work on armature bands is being applied across the naval fleet to investigate and manage the potential failure of marine propulsion systems.
— DST Group continues to develop new designs for RAM which further improve capability compared to the current materials. The materials developed during the RAM development program have been modified for use on surface ships, and are currently being installed on RAN frigates.
— DST Group continues to develop new and novel sonar processing which further improves submarine operational effectiveness
— AN/BYG-1 capability improvements (including Collins specific ones) and increased access to Advanced Processor Build (APB) for Australian industry

A.1.6 Benefits attributable to DST Group

The project benefits are drawn from the discussion in section A.1.5.

Hull valve tests and management program

The savings from deferring the replacement of safety valves are valued at approximately $15 million for the fleet of 6 submarines. This includes savings in replacement parts of $10 million and labour cost savings of $5 million.

In addition, the avoided loss in availability of the submarines due to valve replacement has been valued at $27 million a year for the fleet. Assuming that this benefit persists for 10 years, the total benefit conferred on the RAN is $270 million.

The total benefit of this project is therefore $15 million + $270 million = **$285 million**.

Fatigue testing and management of propellers

The avoided costs of replacing propellers across the fleet are approximately $10 million. In addition, the increased availability of the submarines is valued at $45 million, resulting in total project benefits of **$55 million**.

Hull structural assurance and safety

The main benefit of this project is the avoidance of a capability gap by ensuring continued access to a fleet of submarines. However, this benefit has not been quantified.

Replacement of RAM on the periscopes

The project enabled the cost of constructing a new facility in order to ensure worker safety during application of the RAM to be avoided. This is estimated to be worth at least **$5 million**.

In addition, the value of increased availability of the submarine fleet enabled by the project is valued at $53 million over 15 years while the improved capability conferred by the project is estimated to be worth at least **$25 million**.

The total project benefits are therefore likely to exceed $5 million + $53 million + $25 million = **$83 million**.

In-situ replacement of main propulsion motor armature bands

The increased availability of the fleet enabled by this project is valued at approximately **$150 million** over 10 years.

Urgent remediation of combat system issues

The enhanced capability provided by the combat systems project is worth at least $10 million. In addition, the increased availability of the fleet enabled by the project is worth at least $15 million. Total project benefits are therefore likely to exceed **$25 million**.

Total Project benefits

Setting aside considerations of inflation and the time value of money, valued conservatively, the quantified benefits of the 6 projects are shown in Table A.3.

TABLE A.3 – **COLLINS CLASS SUBMARINE REMEDIATION ASSESSED BENEFITS**

Project component	Assessed benefit ($million)
Hull valve tests and management program	285
Fatigue testing and management of propellers	55
Hull structural assurance and safety (Not assessed)	0
Replacement of RAM on the periscopes	83
In-situ replacement of main propulsion motor armature bands	150
Urgent remediation of combat system issues	25
Total	**598**

SOURCE: DST GROUP AND ACIL ALLEN

A.2 P-3 Orion Service Life Assessment Program

BOX A.3 – **KEY FINDINGS – P-3 ORION**

Key finding 1 – DST Group's research enabled Defence to extend the planned withdrawal date of the P-3 Orion fleet out to 2019 without the need to make costly major structural modifications to the aircraft. It also enabled an optimised monitoring and maintenance program to be developed that provides ongoing confidence in its continuing airworthiness. The work also had a significant benefit in terms of increased aircraft availability.

Key finding 2 – ACIL Allen has identified benefits arising from the P-3 Orion project that can be attributed to DST Group to be $432 million, consisting of the avoided cost of replacing the wings on each of the 18 aircraft in Australia's fleet. By being able to avoid taking each aircraft out of service for around a year to replace the wings the aircraft availability was significantly increased. ACIL Allen has not estimated the monetary value of this increase in aircraft availability.

A.2.1 Project origins and inputs

From 1999 to 2006 an international collaborative program titled the P-3 Service Life Assessment Program (P-3 SLAP) was undertaken between the United States Navy (USN) and the Defence Departments of Australia, Canada and the Netherlands. Each contributing country had similar imperatives. The P-3 Orion aircraft in service with their respective forces was running out of structural airworthiness clearance and there was no replacement immediately available.

Australia had just commenced an avionics upgrade of the aircraft and wanted to ensure that it had a reasonable remaining aircraft structural life. Plans were underway for a test program focussed on the most critical component, the wings, supported by a flight test loads program.

The specific RAAF objectives for the SLAP program therefore were to:

— Provide the structural durability data needed to extend the operational life of the P-3 Orion until at least 2015, with enough extra clearance to allow for delays in the anticipated fleet replacement project
— forecast the requirement for any structural modifications
— define the ultimate useful structural life of type of the aircraft
— develop a structural maintenance program optimised to Australian specific usage and environmental conditions.

Each SLAP member country used the data generated to meet their particular P-3 fleet age and replacement program. For example, following the SLAP, and under advice from Lockheed Martin Aeronautics (LM Aero), Canada undertook the wing replacement known as the Aircraft Service Life Extension Program (ASLEP). This involves the replacement of the outer wing, the centre lower wing, the horizontal stabiliser and horizontal stabiliser leading edges. A number of other components, including wing leading edges are replaced. As a result, nearly all of the fatigue critical locations on the airframe are replaced with new structure and many corrosion prone regions are replaced. The USN, although they were planning the replace their P-3 fleet with the P-8 aircraft then under development, also needed to conduct wing replacements on their relatively older aircraft LM Aero (under contract) and performed the role for the USN and Canada that DST Group did for the RAAF in terms of data interpretation and advice.

A.2.2 Project activities

The program involved full scale fatigue tests (FSFT) and analysis as follows:

— Wing/Fuselage – at LM Aero in Marietta, USA
— USN Sustained Readiness Program (SRP) Empennage – at L-M in Marietta, GA, USA
— RAAF Empennage – at DST Group in Melbourne, VIC, Australia
— Main Landing Gear – at Vought in Grand Prairie, TX, USA
— Nose Landing Gear – at Vought in Grand Prairie, TX, USA.

Each P-3 SLAP member country contributed work share and funding. Canada conducted wind tunnel testing and Australia contributed flight test loads data. The USN, Canada and DST Group conducted structural teardown of the test articles. DST Group and Australian industry additionally undertook a teardown of an in-service wing. Fatigue model and tool verification via coupon testing was a joint effort by the partners. Each organisation completed separate test interpretations in line with their flight spectrum and individual needs.

In addition to these components of the SLAP program, DST Group also analysed the defects from all the SLAP FSFTs to assess the airworthiness of the P-3 under RAAF usage (that is, RAAF test interpretation), produced a Structural Management Plan outlining the options for managing and ensuring the airworthiness of the RAAF P-3 fleet and developed an Individual Aircraft Tracking (IAT) system. This work has provided the basis for the Safety by Inspection and fatigue monitoring program that is currently being applied to the RAAF P-3 fleet.

It is worth emphasising that DST Group would have proceeded with its own testing program centred on the most critical wing component in the absence of the other SLAP member countries' interest in testing the structural integrity of the aircraft. However, DST Group and the RAAF recognised the merits that would be likely to flow from participating in a larger and more comprehensive program. By participating in the collaborative program DST Group was able to gain access to a much greater amount of test data regarding the aircraft. This in turn increased the level of confidence that could be assigned to the DST Group advice to the RAAF regarding the safety and durability of the complete aircraft under Australian usage.

In summary, DST Group's contribution consisted of the full scale test and teardown of a P-3 empennage, a contribution to the flight loads test program, the analysis and interpretation of all test results for Australia, the development of a set of inspection instructions and structural life limits specific to the RAAF P-3 operations and the development of an individual aircraft tracking (IAT) system.

Aerospace Division undertook the activities using the experience, facilities, knowledge and client relationships built from 40 years of engagement with the RAAF in the field of airworthiness and structural integrity.

The program drew upon DST Group's understanding of RAAF operations, DST Group's skills in the areas of aircraft loads, stress, full scale testing, fatigue, forensic analysis and airworthiness regulation coupled with DST Group's ability to conceive, conduct and deliver outputs that anticipate RAAF needs.

A.2.3 Project outputs

At the outset it was envisioned that the RAAF would need to undergo a refurbishment program akin to that conducted by the RNZAF known as the KESTREL program. Instead, acting on DST Group advice, the RAAF undertook a program of structural inspections to detect and repair fatigue damage assuring airworthiness of the RAAF fleet until the planned withdrawal date.

A.2.4 Status of Outcomes and Impacts

Table A.4 summarises the outcomes and impacts of the P-3 Orion project

TABLE A.4 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE P-3 ORION PROJECT**

Outcome / Impact	
Reduced acquisition cost	Yes
Avoided acquisition costs	-
Reduced O&M costs	Yes
Revenue raised (sales, exports, licence fees, etc.)	-
Increased availability	Yes
Increased capability	-
Avoided adverse effects (deaths, injuries, environmental impacts, etc.)	-
Options created	Yes

Nature of Outcomes and Impacts

The key outcome is significant life extension to the P-3 Orion aircraft. By extending the structural life, via an inspection program, the structural refurbishment program involving the replacement of wings and tailplanes was not required to be undertaken by Australia.

Supplementary research program from 2006-2012 determined a reduced need for ongoing structural inspection over the remaining life of the fleet.

The original interpretation of the SLAP resulted in the promulgation of an inspection program to maintain airworthiness. The so-called '2010 review' improved the accuracy of the modelling tools and enabled a better prediction to be made which significantly changed the inspection program. The original inspection program had significantly more inspections due before the Planned Withdrawal Date (PWD) of the aircraft in 2018 (now 2019). It included inspections of the wing lower surface panel splices which has thousands of fasteners on each aircraft requiring inspection.

The 2010 review enabled a more efficient packaging of the inspections but also pushed the panel splice inspections beyond PWD resulting in savings from re-packaging of and interval extensions to service inspections.

Reduced acquisition cost

The 'retirement of risk' in relation to structural life allows for greater flexibility in planning for any eventual replacement and the ability to avoid the risk and cost premiums that are normally associated with an accelerated replacement program. ACIL Allen has not sought to assign a value to this benefit.

Reduced O&M cost

The key outcome of this project is a significant life extension to the P-3 Orion aircraft. By extending the structural life, via an inspection program, the structural refurbishment program, involving the replacement of wings and tailplanes did not have to be undertaken by Australia.

The original interpretation of the SLAP resulted in the promulgation of an inspection program to maintain airworthiness. The so-called '2010 review' improved the accuracy of the modelling tools and enabled a better prediction to be made which led to significant changes to the inspection program. The original inspection program had significantly more inspections due before the Planned Withdrawal Date (PWD) of the aircraft in 2018 (now 2019). It included inspections of the wing lower surface panel splices which has thousands of fasteners on each aircraft requiring inspection.

The 2010 review enabled a more efficient packaging of the inspections but also pushed the panel splice inspections beyond PWD resulting in savings from re-packaging of and interval extensions to service inspections.

The program has saved $432 million in avoided upgrade/wing replacement, enabling extension of Planned Withdrawal Date which was initially planned for around 2000 to 2019 when the P-3 can be replaced by the P-8. These savings include $18 million in optimised maintenance savings (fewer planned inspections, over period 2010-2019).

Increased Availability

The life extension has also increased aircraft availability. The time required to replace the wings on the P-3 Orion is around a year, whereas the inspection program introduced as a result of DST Group's work only requires the aircraft to be removed from service for 30 days. Consequently the result of the DST Group's work was a reduction in the likely outage time from 6570 days (365 days x 18 aircraft) for wing replacement to 540 days for inspections of the aircraft.

Converting this improvement in P-3 Orion fleet availability into a monetary value is more difficult in the case of Defence than for aircraft operated by a commercial airline. Airline operations involve predictable schedules against which (an optimal minimum) number of aircraft are assigned. Failure to meet a planned flight can be costed by measuring loss of revenue or the cost of purchasing or hiring replacement aircraft. Defence operations involve some element of schedule operations such as training but fleet size considerations also factor in the requirement for unanticipated high tempo and/or diverse operations and aircraft losses.

While the unavailability of two aircraft would subject 'the system' to increased levels of stress, modelling by the RAAF and DST Group's own cost and asset management research cell concluded that the impact of the reduction in overall fleet availability was marginal. However these conclusions do not take into account other variables such as sudden increases in operational requirements or major aircraft losses or other potential airworthiness issues. The impact of a reduced fleet size therefore comes down to a risk that the RAAF would be less able to satisfactorily respond to urgent and/or persistent operational demands or to a major change from the current peacetime state.

The value of the contribution by DST Group to reducing the risk of a capability shortfall is also difficult to measure but its impact can sometimes be observed. For example, when a fleet of aircraft is deployed to a theatre of operations only a percentage of those aircraft are available for operations at any one time due to the overall logistical arrangements associated with the deployment to that theatre. There is anecdotal evidence (provided by RAAF to DST Group) that during a deployment to the Middle East at the time the SLAP was underway the RAAF generally required half the number of aircraft in theatre to generate the required sortie rate than their major coalition partner. This should provide cost and flexibility benefits to both the RAAF and the theatre commander.

Options created

DST Group involvement has allowed solutions specifically tailored for Australian defence needs that are not always available through overseas solutions.

The basic methodology used in the P-3 Orion project can also be adapted for use on other aircraft, including the C-130, the P8, and C27J.

Counterfactual

The P-3 Orion aircraft in service with their respective forces was running out of structural airworthiness clearance and there was no replacement immediately available. Without this work, there would have either been a loss of capability and/or additional acquisition costs.

If DST Group were not involved, RAAF would have been required to pay the US Navy $12 million to enter SLAP. The subsequent outcome offered from LM Aero would have been to replace the P-3 wings just like Canada, at a cost of $432 million (18 aircraft at $24 million per set). While this would have provided a service life extension in excess of requirements, it would have removed each aircraft from service for around 12 months. The net effect would have been a reduction in aircraft availability of 6570 days.

With the DST Group involvement, innovative test interpretation including applying a probabilistic approach and the development of solutions specifically tailored to RAAF needs allowed a pre-emptive schedule of inspections rather than wing replacement. The analysis was at a cost of $8 million (based on DST Group FTEs and funding from DMO). This increases to $10 million when the full cost recovery of using the DST Group test machines is included.

The cost of inspections is in the order of $36 million (two inspections for 18 aircraft at approximately $1 million per inspection) with each aircraft on the ground for 30 days (15 days per inspection). The net cost therefore has been $46 million, with aircraft removed from service for only 540 days.

Collaboration in delivery of benefits

This project involved collaboration between DST Group and a number of different organisations (including DMO, international partners and private industry). While several of the parties who collaborated on the P-3 Orion project were important to the delivery of a viable (and far preferable) alternative outcome to the counterfactual, that eventual outcome (and its value) would not have been delivered in the absence of DST Group, since the only viable alternative would then have been to adopt the much more expensive approach that Canada did. This approach would also have had significant flow on negative impacts on aircraft availability. Consequently the benefits of this project have been fully attributed to DST Group consistent with our stated approach.

Adoption

The results of the P-3 Orion structural integrity testing project have been adopted by the RAAF. As a result the initial proposal to replace the P-3 Orion wings has been abandoned and instead a tailored program of inspections has been introduced.

The Canadian Air Force has not adopted the capabilities, predominantly due the need for a planned withdrawal date beyond 2019.

A.2.5 Assessment of impacts

Impacts to date

The work by DST Group had two main outcomes. The first was that it allowed the Planned Withdrawal Date of the RAAF P-3 Aircraft fleet to be extended to 2019 without the need for significant (and costly) aircraft modifications. It also enabled an optimised monitoring and maintenance program to be developed.

The second outcome was that by avoiding the need for major structural modifications to the aircraft there was a significant increase in aircraft availability compared to the counterfactual. Rather than a 12 month outage period for a wing replacement, the two planned inspections at 15 days each mean that each aircraft is only off line for 30 days. This is particularly important in situations where fleet of aircraft is relatively small, as is the case for Australia's fleet.

In conducting the program, DST Group received several formal expressions of thanks from its Defence customers. DST Group's demonstration that it was a reliable partner that could "punch above its weight" and has also led to a number of subsequent expressions of interest from the original international partners for collaboration on the next generation of Defence aircraft.

The DST Group team received the Outstanding Defence Output award for their work on this program.

Potential future impacts

The basic test interpretation methodology can be adapted for use with other planes, such as the C-130, P8 and C27J. For example, the approach adopted for the P-3 is also being used for Full Scale Fatigue Testing of the wings for the C-130J. The testing program is a joint RAAF and RAF one, with costs shared between the two air forces. The test is due to finish cycling at the end of 2015, at which point the results will be analysed (interpreted) to determine the actual impact on the RAAF fleet. It is expected to take at least two years to obtain the final answers.

The DST Group have developed a capability and continuity of work flow in this field that exceeds that available in industry, which tends to undertake one-off testing. DST Group's testing can also cost significantly less than industry and DST Group provides an enhanced value to its Defence clients that combines testing with an understanding of the needs and specific usage profile of its service customers and the delivery of advice that is both tailored and understandable to those same customers.

DST Group's capabilities in this area have led to it being asked to undertake tests on submarine propellers for the US Navy. This work is being done under a Memorandum of Understanding between the Department of Defense of the United States of America and the Department of Defence of Australia concerning cooperation on Maritime Research, Development, Test, Evaluation and Prototyping Products.

The RAAF has also expressed an interest in accessing the capability developed by DST Group.

As discussed above, one of the objectives of entering into the international collaboration to test the airworthiness and durability of the P-3 Orion was to gain access to a much larger amount of data on the aircraft. Under the terms of the MOU for the collaborative program Australia is allowed to share all that information with Australian industry for the support of the Australian P-3 fleet. As a specific planned outcome of Australia's involvement in the SLAP, DST Group has provided that information to Australian industry to help increase their capability to service Australia's fleet of aircraft. In addition, the involvement by Australian industry in the SLAP activities has allowed a skills transfer to Australian industry that can be used for similar activities in support of current and future RAAF aircraft.

A.2.6 Benefits attributable to DST Group

As noted in Section A.2.5, in the absence of DST Group's work the RAAF would have needed to replace the wings of its P-3 fleet just like its Canadian counterpart, which would have cost $24 million per set of new wings x 18 aircraft = **$432 million**.

In addition, the wing replacement would have removed each aircraft from service for approximately 12 months, reducing aircraft availability for a total of 6570 days (compared with the 540 days lost to the inspections devised by DST Group). As noted previously, ACIL Allen has not estimated the monetary value of avoiding this loss in aircraft availability.

A.3 Joint Direct Attack Munition – Extended Range

BOX A.4 – **KEY FINDINGS – JDAM-ER**

Key finding 1 – DST Group's research has extended the distance from which the Joint Direct Attack Munition-Extended Range (JDAM-ER) can be launched to three times further away from the target than the standard JDAM munition.

Key finding 2 - ACIL Allen has estimated the total benefits arising from the JDAM-ER project that can be attributed to DST Group to be $852.5 million, consisting of $41.5 million as a result of avoided acquisition costs, $576 million from exports and $235 million due to increased capability. Note that while the ability to launch the munition from a point that is much further from the target will also reduce the risk to both the plane and pilot from anti-aircraft defences, we have not sought to value this benefit due to the uncertainty around the timing and scale of any such benefit.

A.3.1 Project origins and inputs

The Joint Direct Attack Munition – Extended Range (JDAM-ER) is the culmination of a long-running partnership between scientists of the Defence Science and Technology Organisation (DST Group) and Boeing.

The JDAM-ER consists of a set of deployable wings strapped to a standard Joint Direct Attack Munition (JDAM). These modifications convert the JDAM into a long range precision glide bomb, capable of striking its target with an accuracy of 7 metres or less after release from an aircraft up to 74 kilometres (40 nautical miles) away – approximately triple the range of a standard JDAM.

The concept originated at DST Group's Weapon Systems Research Laboratory (WSRL) in Adelaide for a low-cost wing kit that could increase the range of a standard Mk-82 weapon. Coupled with an Inertial Navigation System (INS) and movable tail fins for guidance, the system was a potential solution to emerging threats from new air defence systems. Extensive wind tunnel testing was used to evaluate a number of preliminary designs, leading to successful flight trials in 1989 and 1991.

In the 1990s, Boeing developed the JDAM, a tail kit consisting of a GPS navigation system and movable fins that could convert an Mk-82 weapon into a guided bomb. In 2001 Boeing approached DST Group with a proposal to combine the DST Group wing kit design with the JDAM to create a unique weapon, an extended-range, precision glide munition. A joint Concept Technology Demonstrator (CTD) Project was subsequently formed between DST Group and Boeing.

Once the JDAM-ER concept had matured at the conclusion of the CTD phase the Defence Materiel Organisation (DMO) initiated Project JP3027 to adapt the DST Group wing kit technology for production and conduct final certification of the JDAM-ER on the F/A-18A/B.

As negotiations progressed between DMO and Boeing regarding the acquisition of the JDAM-ER, the Australian firm Ferra Engineering was brought into the process. Ferra Engineering was subsequently selected as the sole supplier of JDAM-ER wing-kits for Boeing, supporting 30 local companies in their supply chain.

Project Inputs

There were three stages to the work that DST Group did in helping to develop the JDAM-ER. The first phase based at WSRL was completed in 1992 and falls outside the scope of this case study. The latter two, the CTD phase and the capability acquisition phase involved 0.6 person years per annum and 1.5 person years per annum respectively.

A.3.2 Project activities

As mentioned above, the development of the JDAM-ER has been a joint effort between DST Group, Boeing, DMO and Ferra Engineering. Initially the effort primarily consisted of the research carried out by DST Group to develop the design of the components of the JDAM-ER. This included extensive wind tunnel testing that was used to evaluate a number of preliminary designs, leading to the successful flight trials of early concept demonstrators.

In 2001 DST Group and Boeing agreed to a joint CTD Project in order to combine the Boeing JDAM with the DST Group developed wing-kit to create a long range, precision glide munition.

The first flight tests were completed in 2006, followed by a second round of tests in 2008 using a new high-wing configuration. The project was a resounding success. During this period the design continued to evolve and DST Group conducted extensive transonic wind tunnel testing and computational fluid dynamic modelling to optimise the aerodynamic performance of the JDAM-ER.

At this point the DMO joined the partnership and an acquisition project commenced with the RAAF as first customer. Successful tests of separation and glide of the munition were carried out at Woomera in late 2013.

The shares of the effort expended on the Project varied as work progressed. Initially DST Group was almost entirely responsible for the work, and then as the CTD phase began it became a joint effort between DST Group and Boeing. During acquisition the effort associated with the project largely shifted towards Boeing and DMO. However, DST Group continued to provide specialist science and technology support to DMO during this phase.

A.3.3 Project outputs

The JDAM-ER allows Royal Australian Air Force (RAAF) pilots to engage targets from beyond the range of hostile air defence systems. The technology is regarded as the most cost-effective standoff technology available anywhere in the world. The outputs from the work done by DST Group include:

- Improved operational capability and flexibility for the RAAF.
- A world-leading, highly affordable, stand-off weapon system.
- The generation of intellectual property, which has been licenced to Boeing. Under the agreement with Boing a percentage of sales will be returned to Commonwealth consolidated revenue in the form of royalty payments.
- The creation of an on-going partnership between Ferra Engineering and Boeing to produce the JDAM-ER wing kits.

A.3.4 Status of Outcomes and Impacts

DST Group reports that the tangible outcomes and impacts of the project include:

- Increased capability for Australian aircraft. By tripling the range of the standard JDAM round and granting greater manoeuvrability, the JDAM-ER allows the RAAF to engage a wider range of targets than previously available with this weapon.
- Improved safety for RAAF pilots as a result of being able to launch their weapons much further away from their targets.
- The opportunity of significant export income for Australian firms.
- Benefits to Australian industry from manufacturing a leading edge product, with 30 local suppliers in the Ferra Engineering supply chain.
- Enhancing Australia's reputation with our Allies as a technologically-advanced partner.

Table A.5 summarises the outcomes and impacts of the JDAM-ER project. More detail on the various outcomes and impacts is provided below.

TABLE A.5 – **SUMMARY OF OUTCOMES AND IMPACTS OF JDAM-ER PROJECT**

Outcome / Impact	Impact?
Reduced acquisition cost	-
Avoided acquisition costs	Yes
Reduced O&M costs	-
Revenue raised (sales, exports, licence fees, etc.)	Yes
Increased availability	-
Increased capability	Yes
Avoided adverse effects (deaths, injuries, environmental impacts, etc.)	Yes
Options Created	-

Nature of Outcomes and Impacts

Below we examine each of the areas where DST Group's work has delivered outcomes and impacts.

Avoided acquisition costs

The JDAM-ER provides a stand-off weapon capability at a fraction of the cost of comparable weapon systems. Weapons with similar capabilities, such as the Small Diameter Bomb II (SDB II) or the Joint Stand-off Weapon (JSOW), cost between $250,000 and $700,000. Assuming the cost of a JDAM is approximately $30,000 a conservative assumption would be that the nominal cost of a wing-kit doubled that cost. This would mean that the total cost of a JDAM-ER munition would be in the order of $60,000. This in turn suggests that the avoided acquisition cost of purchasing a munition with a similar capability to the JDAM-ER is between $190,000 and $640,000 per munition.

If we assumed that the RAAF has an inventory of some 100 JDAM-ER munitions, then the total avoided cost of obtaining a munition with a similar stand-off capability is between $19 million and $64 million. Obviously, the more munitions in the RAAF's inventory the higher the avoided cost would be.

Revenue raised

The JDAM-ER is scheduled to begin deployment with the RAAF in 2016. Twenty seven nations currently have the JDAM in their defence inventories, so the potential for export sales of the wing kits being manufactured by Ferra Engineering is considerable. In August 2013 Boeing announced that it had constructed 240,000 JDAM units.[14] Sales of wing kits to retrofit just 10 per cent of these would generate export sales of around 24,000 wing kits. The price of a wing kit is of course subject to commercial negotiation and agreement. If we used the same assumption as in the preceding section then the value of exports would be $720 million. Even if we made the more conservative assumption that the price per wing kit was only a third of this amount, namely $10,000, then the value of exports would still be around $240 million.

There is also the opportunity to apply the technology developed by DST Group in other ways. For example, a recent fact sheet released by the US Air Force (USAF) stated that it had successfully tested the technology for deploying sea-mines. The fact sheet notes that:

The first ever precision, winged sea mine was dropped by a B-52 bomber of the U.S. Air Force forward deployed to Guam. The demonstration timeline from concept to execution was six months and cost less than $1.1M to execute, which is very rapid and inexpensive for a project of this scale. The effort significantly leveraged technology being developed by the Royal Australian Air Force (RAAF), and the

[14] http://boeing.mediaroom.com/Boeing-Reaches-250-000-Kit-Milestone-for-JDAM-Weapon-Program. Accessed 9 June 2015.

data from this event will be shared with our Australian allies. This event reiterated the value of our science and technology relationship with the Australian military.[15]

Increased capability

The increased capability provided by the addition of the DST Group wing-kit technology to the standard JDAM is significant. It triples the range of the standard munition, allowing RAAF pilots to engage targets at longer range thus reducing the risk to pilot and aircraft from air defence systems. The average cost of an F/A-18A/B "Classic Hornet is about $62 million.[16]

If we adopted the approach used by the Trenberth Review we could assign a proportion of the purchase cost of the aircraft fleet (around $4.7 billion) as an estimate of the 'value' of the additional capability provided by the JDAM-ER project.[17] While it is difficult to quantify an exact figure for the increased capability that results from the use of the JDAM-ER, ACIL Allen believes that a conservative estimate of the increased capability might be of the order of 5 per cent. This suggests the value of the improved capability could be some $235 million.

It should be noted that the value of the improved capability cannot be added to the avoided acquisition costs. This is to avoid double counting, as the SDB II and JSOW have capabilities that equal or exceed that of the JDAM-ER.

Avoided adverse effects (deaths, injuries)

The JDAM-ER has triple the range of the standard JDAM, allowing RAAF pilots to engage targets from much further away, thus reducing the risk to pilot and aircraft from air defence systems. ACIL Allen has not sought to value this benefit since, even though there is undoubtedly a significant reduction in risk to pilots, there remains considerable uncertainty about the timing and scale of those avoided adverse effects.

Counterfactual

DST Group, as the world leader in this area of research, were approached by Boeing to integrate their wing kit technology with the JDAM, as this technology did not reside anywhere else at that time. While there are now other glide bomb systems on the market (SDB II, JSOW), they are all integrated systems, there is currently no equivalent of the JDAM-ER strap on wing kit technology on the market.

Collaboration in the delivery of benefits

DST Group collaborated with a large number of organisations on the JDAM-ER project, including DMO, RAAF, Ferra Engineering and Boeing).

While the support of the private sector firms was essential to the eventual commercialisation of the research done by DST Group and the delivery of the benefits associated with this project, the eventual outcome (and its value) would not have been delivered in the absence of DST Group. It was responsible for the initial development and testing of the wing kits without which this technology would never have eventuated. The benefits have been attributed to DST Group consistent with our stated approach.

Adoption

The commercialisation of the results of DST Group's research is already underway, with the first operational set of JDAM-ER wing kits delivered to the RAAF in April 2015. The JDAM-ER munition will be fully operational in the RAAF by 2016. The prospects are good for export sales of wing kits to other countries. Interest in acquiring the technology has been expressed by armed services of several nations, including the US Navy, Marine Corps and Air Force.

The rapid and successful transfer of the results of the research to industry was aided by long term relationships built up over time between DST Group and Boeing.

---

[15] Quickstrike ER fact sheet released by the US Pacific Command FDO, September 2014 and approved for unlimited public release.
[16] According to McLaughlin, Andrew (March 2005). "*20 Years of RAAF Hornets*". Australian Aviation. No. 214: pp. 52–58, the final cost of the Hornet project was A$4.668 billion.
[17] We have only used the fly away cost in our calculations. The actual cost per plane usually include support costs, which raises the cost per plane to closer to $80 million.

Ferra Engineering recently won a Manufacturing Transition Program grant in excess of $2 million in relation to its work on JDAM-ER. Ferra Engineering is investing over $7 million of its own funds in the project. It will use the funds to invest in new technology, processes and facilities for the ongoing development and production for the JDAM-ER weapons kits.

The $50 million Manufacturing Transition Programme provides grants to help manufacturing businesses become more competitive and sustainable. The Programme supports capital investment projects that help businesses:

- move or expand into higher value or niche manufacturing activities
- build skills in higher value and knowledge intensive activities in new or growing markets.

Ferra Engineering expects that the grant will help transition the firm into a new area of high end defence and aerospace sub-system development and manufacture.

A.3.5 Assessment of impacts

Impacts to date

The benefits of DST Group's research on JDAM-ER include:

- Avoided acquisition costs due to the development of a cheaper technology solution for providing a stand-off munition
- Revenue gained from overseas exports of the technology
- Increased capability
- Improved survivability of RAAF aircraft by being able to deploy the munition from three times the distance of the standard munition.

Potential future impacts

DST Group continues to work with DMO to support the acquisition of JDAM-ER for the RAAF. Although DST Group involvement is beginning to wind down as the acquisition project concludes next year, this does not rule out future involvement as the JDAM-ER enters service.

A.3.6 Benefits attributable to DST Group

Avoided acquisition costs

As discussed in Section A.3.5, the avoided costs of purchasing a munition with a similar capability to the JDAM-ER is estimated at $190,000 to $640,000 per munition. This is based on the assumption that the cost of a JDAM is approximately $30,000 and that the nominal cost of a wing kit doubled that cost, while the cost of a weapon with similar capability (such as the SDB II or the JSOW) is between $250,000 and $700,000.

Assuming conservatively that 100 such munitions would have been purchased in the absence of the DST Group project and taking the mid-point of the range of avoided cost per munition, avoided acquisition costs are estimated to be around **$42 million**.

Exports

As noted previously, in August 2013 Boeing announced that it had constructed 240,000 JDAM units. Assuming that the demand for the DST Group-engineered wing kit is equal to 10 per cent of these units, potential export sales would be 10% x 240,000 = 24,000.

Assuming that a wing kit is priced at $30,000, the value of these export sales would be 24,000 x $30,000 = **$**720 million.

Assuming a "leakage" of 20 per cent from Australian industry due to imported components and raw materials, the value added to the Australian economy from these export sales is estimated to be 80% x $720 million = **$576 million**.

Increased capability

Assuming that the JDAM-ER increased the capability of the $4.7 billion F/A-18A/B "Classic" Hornet fleet's capability by 5 per cent, the value of the increased capability is estimated at 5% x $4.7 billion = **$235 million**.

Avoided loss of aircraft

Assuming that the increased capability of the JDAM-ER avoided the loss of one F/A-18 "Classic" Hornet aircraft, then the avoided loss of aircraft could potentially be valued at **$62 million** (the replacement cost of the aircraft). This does not include the potential loss of life associated with the aircraft loss.

However, given the considerable uncertainty surrounding the timing and scale of any avoided adverse events like the loss of an aircraft we have not included this potential benefit in our overall estimate of the benefits of DST Group's work.

Total Project benefits

Setting aside considerations of inflation and the time value of money, valued conservatively, the quantified value of the various benefits are shown in Table A.6.

TABLE A.6 – **JDAM-ER ASSESSED BENEFITS**

Project component	Assessed benefit ($million)
Avoided acquisition costs	42
Export value	576
Avoided acquisition costs	235
Avoided loss of aircraft and pilot (not included)	0
Total	**853**

SOURCE: DST GROUP AND ACIL ALLEN

A.4 Jindalee Operational Radar Network (JORN)

BOX A.5 – **KEY FINDINGS – JORN**

Key finding 1 – DST Group's research enabled Defence to effectively quadruple the capacity of its OTHR systems without needing the acquisition of additional facilities. It has also enabled the streamlining of the program staging through replacing a traditional 'waterfall' methodology with an incremental 'rapid prototyping' approach, resulting in reduced operating/upgrade costs. The capability developed by this research is considered world leading and has led to export revenue potential and strong research collaboration with the US. It has also led to a strengthening of efficiencies in the Australian industry supply chain.

Key finding 2 – ACIL Allen has identified benefits arising from the JORN Phase 5 project that can be attributed to DST Group to be $1504 million, predominantly the reduced costs in quadrupling the capacity of the existing JORN assets together with some export sales of DST Group-designed equipment.

A.4.1 Project origins and inputs

JORN (Jindalee Operational Radar Network) consists of three sky-wave over-the-horizon radars (OTHRs), located in Queensland, Western Australia and the Northern Territory, the JORN Coordination Centre in South Australia and a series of sounders and transponders around the country.

JORN provides layered surveillance of Australia's northern and western approaches. The radars operate by refracting high frequency (HF) radio waves off the ionosphere, enabling detection ranges of between 1000 and 3000 kilometres, well beyond that of conventional microwave radars constrained by the visual horizon. The key features of OTHR technology that make it a highly attractive for surveillance are its very long range detection capability, ability to detect targets at all altitudes, insensitivity to atmospheric weather and comparatively low cost per unit area under surveillance.

DST Group began investigations into the feasibility of OTHR in the 1950s. The evolution of JORN from that time and the current development plan is summarised in the table below:

TABLE A.7 – **JORN EVOLUTION**

Timing	Phase
1950s-1972	DST Group research into the feasibility of over the horizon radar
1972-2003	Design, construction and ongoing development of the Jindalee Facility Alice Springs (JFAS)
1991-2003	JORN acquisition (JP 2025 Phases 3 & 4)
2006-2013	JORN enhancement (JP 2025 Phase 5). Included integration of JFAS into JORN.
2013-2017	JORN PIC Support Program (JPSP - Air Force Sustainment activity).
2017-2027	JORN major mid-life upgrade (AIR-2025 Phase 6 – in planning)

SOURCE: DST Group correspondence, 2015

DST Group has played a central and evolving role throughout the development of OTHR in Australia. For example, from 1972 until 1987, DST Group was responsible not only for all R&D, but also for design, construction, sustainment and enhancements of JFAS. Transition of JFAS to an operational radar began around 1987 and was formalised in 1993 when it became 50% RAAF operational radar and 50% DST Group experimental test-bed.

Today, DST Group retains R&D authority for JORN, but works in close and effective partnership with its two major partners in the Australian OTHR community:

— OTHR Systems Program Office (OTHRSPO) of Capability Acquisition and Sustainment Group (CASG) – responsible for JORN maintenance and support
— No1 Remote Sensor Unit (1RSU) of the RAAF – responsible for JORN operations.

Inputs

The main input is the R&D expertise and effort of DST Group staff. There are approximately 42 FTE staff supporting JORN, comprising a mix of scientists, engineers and technicians. Major non-salary expenses include:

— Manufacture of hardware components
— Purchase of computing hardware and software
— Conduct of research experiments and trials (travel, freight, hire of assets)
— Research agreements with University and Industry partners
— Travel for collaboration with US partners

A.4.2 Project activities

DST Group R&D activities in support of JORN are shaped by the following principles:

— Rapid transition of R&D to operations, through early exposure to Industry and RAAF operators. This provides risk reduction through improved Industry understanding and improved design through early operator feedback.
— Reduce transition risk by contributing value at multiple points along the innovation chain, from concept through to maintained capability
— Develop IP for major hardware components and systems in-house, except where a compelling COTS solution exists (e.g. computing hardware). This provides significant advantages in terms of performance, total cost of ownership and flexibility.

The above principles are applied in the areas discussed below.

Support to extant JORN systems

These are ongoing activities that ensure JORN performance is optimised as both an engineering system and an operational capability, namely:

— Support to JORN operations and exercises (e.g. DST Group staff advising in the ops room)
— Radar performance assessment (e.g. fault detection, baselining)
— Support to sustainment (advice on, and development of, solutions).

Support to JORN acquisition

These are activities that support projects and programs to enhance and extend JORN capability. For the purposes of this case study, this concerns JP2025 Phase 5 Enhancement (complete), JORN PIC Support Program (in progress), AIR-2025 Phase 6 Mid-life Upgrade (in planning). Activities include

— Needs analysis, development of detailed technical solutions and options
— Technical risk assessment and reduction
— Operational demonstrator development (supports rapid transition)
— Test and evaluation
— Transition support and advice throughout acquisition.

Next generation OTHR program

These are activities that provide a continuous pipeline of future OTHR capability and sustainment options to Defence. In particular, the technical solutions and options being put forward for the AIR-2025 Phase 6 Mid-life Upgrade have been drawn from this program. Broad activities include:

— Development of new concepts and architectures
— Prototype design and construction
— Experimentation and trials

Collaboration with international partners, industry and universities

Collaborations in HF radar provide leverage and peer review for DST Group's R&D program, as well as strengthening the industrial and research base supporting JORN. These include

— Regular technical exchanges with international partners in the US and the UK, including their respective Defence and intelligence agencies. This is focused on the US OTHR community through the biannual AU-US Working Group Meetings. US Working Group participants include the

Relocatable-OTHR Program Office, NORAD-NORTHCOM, Naval Research Laboratory (NRL), MIT Lincoln Laboratory and Air Force Research Laboratory (AFRL). There is also strong on-going engagement with the US Navy Seventh Fleet in support of joint activities with JORN.

- Close engagement with Lockheed Martin and BAe Systems, who are the two main industry partners for OTHR in Australia. This includes support as part of sustainment and acquisition and also research collaboration in areas of mutual benefit, under Strategic Alliances with both companies.
- Research/Project Agreements with:
  - The University of Adelaide: (a) Development of very high performance radar signal sources using sapphire oscillators, (b) Loan of DST Group equipment to support measurements of ionospheric effects on GPS signals
  - LaTrobe University: Supporting space physics/weather research through funding for the TIGER research radar network and a PhD scholarship
  - The University of South Australia: Development of a workshop on radar for high school students.
- Agreement with Space Weather Services of the Bureau of Meteorology for the loan of DST Group ionospheric sounding equipment.

Additional Activities

In addition to the above, DST Group conducts a wide range of other activities that contribute to JORN capability, or are by-products of DST Group's JORN support. This work includes R&D into intelligence functions, missile detection and tracking and surveillance of space. The work is of significant value, but is excluded from treatment in this case study for security classification reasons.

A.4.3 Project outputs

Given that the Trenberth review largely covered the benefits of DST Group's work on the JORN project over the period up to 2003, the focus of this case study is on the benefits delivered as a result of the work done by DST Group since then.

Support to extant JORN systems

DST Group's ongoing support of JORN has provided:

- A regular presence of DST Group staff in the JORN Operations Room
- Technical backing for RAAF operations and exercises
- Investigation and identification of radar performance anomalies
- Solutions to deal with equipment obsolescence.

DST Group's ongoing role in the operation and sustainment of JORN has a range of outputs including improved operator skills and understanding, the provision of advice and support to RAAF on exercise planning, design, conduct and analysis and the preparation of formal and informal reports to RAAF/CASG (Capability Acquisition Sustainment Group). As part of its efforts to address equipment obsolescence a Vertical Incidence Sounder (VIS) Replacement System was installed and is now working as part of the operational JORN system. The OTHRSPO will now carry out the same replacement on the other ten JORN VIS systems with copies of this DST Group solution.

JORN enhancement – Phase 5

This fifth phase of the JORN project introduced major capability enhancements and was successfully delivered in 2014. The project comprised 28 work packages predominantly transitioning DST Group R&D output during the original JORN acquisition (1987-2003). The work by DST Group had a range of outputs, including:

- Improved sensitivity, coverage, accuracy and robustness to electronic attack, including
  - High capacity, COTS-based, signal processing computing architecture
  - DATa EXtrapolation (DATEX) algorithm for doubling coverage or sensitivity
  - Extended range depth coverage[18] by a factor of up to five, through expanded signal processing and display capacity

[18] Range depth is a measure of the size of a processed range cell. A five-fold increase means that five times as many range cells can be processed simultaneously. It does not imply a factor of five increase in the radar operating range.

  - Ship detection enhancements
  - Electronic warfare algorithm suite
  - Tools to mitigate sensitivity degradation due to clutter
  - Improved tracking of manoeuvring targets.
- New capabilities, including airfield surveillance, target altitude estimation.

JORN PIC support program (2014-2017)

The ongoing work on JORN by DST Group is expected to be completed in 2017. However, the project has already made substantial progress in achieving approval for the JORN Major Mid-Life Upgrade AIR-2025 Phase 6 and in defining the Project specification (due to be completed by end-2015). DST Group has also provided software, hardware designs and hardware loans to the OTHRSPO, allowing contractors to build and gain experience on small prototype systems and provide feedback to DST Group.

Facilities and capabilities developed

DST Group's long term contribution to JORN has allowed it to develop a unique collection of R&D facilities and capabilities that are highly valuable for OTHR development and sustainment, including

- Decades long databases of environmental measurements including ionospheric propagation and the HF large signal and background noise environment.
- A comprehensive set of high performance HF radar experimental equipment.
- Dedicated laboratories for advanced component and system development.
- Specialised experiment and trial preparation facilities.
- High performance test equipment and facilities.
- Dedicated advanced computing and data storage.

Published Research

Since 2003, DST Group has also published a large number of HF radar-related, peer-reviewed journal papers (more than 60) and conference papers (more than 150). These publications have detailed the significant theoretical and experimental advances made by DST Group in the field of HF Radar and Ionospheric Physics, most notably:

- Multiple-Input, Multiple-Output (MIMO) Radar
- Small-sample techniques in radar adaptive processing
- High fidelity measurements of ionospheric dynamics, of relevance to the Space Weather community.

A.4.4 Status of Outcomes and Impacts

Nature of Outcomes and Impacts

The JORN system is a recognised world leading capability that has and is being continually enhanced by DST Group's OTHR R&D program. This facility was visited by 150 foreign visitors last year and exemplifies that Australia is an OTHR OEM capable of self-reliant defence R&D in this area. A summary of the outcomes and impacts of the JORN project is provided in Table A.8 and discussed further below.

TABLE A.8 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE JORN PROJECT**

Outcome / Impact	Impact?
Reduced acquisition cost	Yes
Avoided acquisition costs	-
Reduced O&M costs	Yes
Revenue raised (sales, exports, licence fees, etc.)	Yes
Increased availability	-
Increased capability	Yes
Avoided adverse effects (deaths, injuries, environmental impacts, etc.)	-
Options created	Yes

Reduced acquisition cost

The program has resulted in cost savings through innovations that have enabled the capability of the JORN asset to be significantly enhanced. The DST Group's submission to the First Principles Review noted that:

DST Group's application of the DATEX algorithm to the HF radar environment has enabled a significant enhancement in the capacity of JORN (roughly doubled) (Anderson, p. 43)

In addition to this, the range depth capacity of JORN has been increased by a factor of up to five, depending on environmental conditions. A conservative estimate of the achieved range depth enhancement factor is two. As the DATEX algorithm and the extended range depth can be employed simultaneously, this corresponds to a four-fold enhancement of JORN capacity. To obtain the same level of enhanced capability would at the simplest level require either increasing the number of JORN facilities or additional sustained aerial surveillance.

A four-fold increase in capacity is equivalent to building another three JORN's in the same locations and orientations as the existing radars. This would cost $3 billion based on the $1 billion cost of deploying the JORN system in 2003. In practice, however, any additional JORN facilities would be built at new locations and/or in different orientations as this would provide better overall capability for the same cost, including coverage of regions not otherwise accessible. This means that the actual cost of the equivalent capability would not be the full $3 billion. ACIL Allen therefore believes that a conservative realistic estimate of the benefits (or avoided cost) is at least half this figure, namely $1.5 billion.

Reduced O&M cost

JORN Phase 5 experienced serious schedule slips with anticipated cost overruns. In response to this, and based on its experience with the JFAS radar, DST Group proposed the adoption of a two-stage engineering process in which the traditional 'waterfall' methodology is replaced by an incremental 'rapid prototyping' approach. This proposal was supported and implemented jointly by DST Group, OTHRSPO and the RAAF and is credited with successful project delivery.

The first stage of this approach was to develop and implement an experimental capability developed by DST Group that can be evaluated by DST Group, OTHRSPO and the RAAF operators. The second stage, primarily carried out by industry, was to transition the demonstrator prototype to a final product that can be fully supported by industry, including product maintenance and documentation. This two-stage approach lowered the transition risk for operations and industry providing them, in many cases, with access to a working hardware and software full-capability prototype.

This process takes place within an operational environment which enables quick switch back to the previous proven configuration, should it be necessary. Driven by Phase 5 needs, savings in operation and maintenance costs are likely to result from this new approach, particularly for Phase 6 and ongoing sustainment activities.

In addition to the direct savings as a result of DST Group's work, another major benefit of this work lies in the much greater flexibility that this approach offers, not just in terms of technical capability delivered but also that afforded by ownership of the IP and the long and close collaboration between DST Group and Australian industry ensuring the latter has a detailed understanding of all aspects of the hardware and software.

Direct Revenue raising (sales, exports, license fees)

Export revenue potential is somewhat restricted as the IP resides with Australian Government, though DST Group has sold the HF transmitter to MIT Lincoln Laboratories for $2.3 million in 2010-11.

DST Group has a close relationship with BAe Systems. That firm recently manufactured and sold to the US Naval Research Laboratory a DST Group-designed Power Amplifier container for $1.5 million. ACIL Allen understands that there are good prospects for sales of a further two containers. BAe Systems is also commercialising software that DST Group developed for JORN. It is currently being marketed in the US. If successful this is expected to lead to annual revenues of around $5 million.

Exports of DST Group developed technology are important sources of revenue for Australian firms and the strong relationship and level of trust between DST Group and firms such as BAe Systems is likely to generate significant gains for the economy. BAe Systems credits their relationship with DST Group and the confidence that this provides to clients as the driving force for a number of sales of HF radar equipment to the US. The value of existing sales to date is over $15 million and there is currently a contract under consideration that is worth $10 million with an option for a further $12 million. BAe System's conservative estimate of the value of future sales of similar equipment to the US is $50 - 100 million over next 5 to 10 years.

Royalties from sales of DST Group owned IP related to JORN are estimated to be of the order of $60,000. These royalties are sometimes paid in the form of the provision of hardware.

Increased Capability

Numerous enhancements developed by DST Group were implemented as part of JORN Phase 5, enabling JORN to successfully detect and track aircraft and ships, more accurately, over a wider area, in a wider range of environmental conditions and in the presence of hostile counter-measures.

The new capabilities of Airfield Surveillance and Target Altitude Estimation were also transitioned, significantly increasing the value of information reported by JORN to higher command elements.

Options created

Sustainment has been improved through providing long term opportunities to more than 150 subcontractors/suppliers across four states. The development of local knowledge and experience has led to reduction in supply time lags, greater flexibility, and the ability to develop and own leading technology. The nature of the OTHR market is such that without DST Group a commercial scale R&D base would not be possible.

DST Group's expertise in OTHR has enhanced Australia's standing in the international radar and ionospheric physics community. There have also been strategic benefits through positioning Australia as a world leader in OTHR technology. This has led to partnerships with US institutions such as the NRL, AFRL, and MIT Lincoln Laboratory.

Australia's niche expertise in OTHR has the potential to be leveraged in many ways to provide value for Australia via its US engagement, as has already occurred in missile detection and tracking. The JORN capability that DST Group has helped to create may also provide technology and data that is of great benefit to Australia's allies, and can be highly valuable as trade goods.

Counterfactual

The enhanced JORN Phase 5 capabilities would not have been possible without the DST Group R&D. Alternative means for achieving the same increase in capability would require alternatives such as the construction of additional OTHR stations or a sustained program of additional aerial surveillance.

More fundamentally, the implementation of the JORN program by Australian Industry was in jeopardy due to schedule slips and anticipated cost overruns. DST Group was able to change and streamline the course of the program by implementing a two-stage acquisition model. The two-stage approach lowered the transition risk for operations and industry providing them, in many cases, with access a working hardware and software full-capability prototype.

ACIL Allen believes that there are two main possible outcomes if DST Group had not been involved in JORN, namely:

— Cancellation of the contract – this is likely to have led to a protracted legal case with substantial costs incurred. It would have led to considerable delays in Australia acquiring the same capability.
— Delivery of a system with less capability – the flaws in the delivered system would not be discovered until they revealed themselves during operations and deployment. Again this could have led to a lengthy legal case to seek restitution or make-good from the contractor and capability would have been less and or very significantly delayed.

Collaboration in delivery of benefits

This project involved collaboration between DST Group and a number of different organisations (for example, CASG, RAAF and private industry). However, the development and implementation of the DATEX algorithm and the extended range capability are the result of DST Group applying its core capabilities in this area. While several of the parties who provided support for the JORN project were important to the delivery of a viable (and preferable) alternative to the counterfactual, the eventual outcome (and its value) would not have been delivered in the absence of DST Group, as there is no alternative provider with the necessary capabilities. Consequently the benefits to Australia that have flowed from this project have been fully attributed to DST Group consistent with our stated approach.

Adoption

The scientific and technical progress made during Phase 5 has been applied regularly to the JORN program. Indeed the adoption of the two-stage acquisition model designed and supported by DST Group has helped to speed the transition of research results into the deployed JORN program.

Examples of products of this R&D incorporated into the JORN upgrades include:

— Advanced adaptive signal-processing algorithms that improve performance by rejecting noise and interference and reducing signal processing loss.
— Implementation of a live signal-processing performance assessment that automatically selects the best algorithm to deal with an environment with dynamic background noise and clutter. This represents a leading example of what is now termed “cognitive radar” in the current literature.

A.4.5 Assessment of impacts

Impacts to date

The key benefit of DST Group’s work on JORN has been in reducing the cost of sustaining and increasing capability of the JORN system. The R&D work of the HF Radar Branch has been transitioned both into JORN and JFAS Defence capability as well as commercial products produced by Australian industry.

The specific R&D conducted by the Radar Branch has combined applied research, strategic basic research and experimental development which has facilitated international collaboration with members of the USA OTHR community and strengthened knowledge sharing. As an example the US has borrowed and/or purchased DST Group designed hardware produced by Australian industry and will likely continue to do so in the foreseeable future, benefitting both Australian industry and US researchers.

Activities designed to address Applied Research topics frequently also support basic research, as exemplified by the 30-plus-year database of environmental measurements collected at JFAS, the largest database of its type. The Multiple-Input, Multiple-Output (MIMO) work is regarded as leading theoretical work on waveforms and algorithms, with associated experimentation demonstrating the first ever skywave MIMO radar.

In this way, the DST Group work has not only improved Defence self-reliance in areas of unique capability not available elsewhere, but this expertise has also increased Defence cooperation with allies, particularly the US, in areas of complementary expertise and capability. Together with the more flexible acquisition model, this has increased Defence ability to evolve capability quickly to meet emerging threats and opportunities.

Potential future impacts

The forthcoming five-year period is focused on preparing for and delivering the JORN PIC Support program (JPSP – Air Force Sustainment activity) and JORN mid-life upgrade (AIR-2025 Phase 6).

DST Group will continue with the Support-to-Operations and Next-Generation OTHR programs, as well as a number of valuable classified programs. It plans to continue to support Australian industry by transitioning concepts and technology to industry via licensing agreements.

Lessons learned during Phase 5 are to be applied to Phase 6 and will further enhance performance, add capability, and extend the operational utility of the radars to 2038 and beyond.

DST Group’s strategy is to build on Phase 5 achievements with a focus on new architectures, systems and technology that will improve system performance, provide new capability, enhance operator productivity and reduce total cost of ownership. To give one example, the introduction of new digital receiver technology in Phase 6, combined with new algorithms, will provide another factor-of-two improvement in the quadrupled JORN capacity delivered by Phase 5.

During and beyond Phase 6, the Next Generation OTHR program will continue to provide a pipeline of new capability and sustainment options for JORN. For example, the ship detection capability of OTHR, which is generally much more limited than air target detection capability, is expected to be improved significantly by the use of MIMO techniques. DST Group is currently constructing a MIMO radar demonstrator that is scheduled for evaluation trials in 2017.

A.4.6 Benefits attributable to DST Group

The focus of the present analysis is on the Phase 5 software upgrade (2004-2014). The 2003 Trenberth review valued JORN Phase 4 at $1.3 billion, largely based on savings in alternative technologies to achieve the same level of surveillance, and the ability to defer acquisition of technologies to maintain the required capability.

Reduced acquisition cost

As discussed previously in Section A.4.5, the program has resulted in cost savings through the introduction of innovations that DST Group believe have enabled the capacity of the JORN asset to be increased by at least a factor of four.

In the absence of DST Group’s work, to obtain the same capability would require either a quadrupling of the number of JORN facilities or the increased use of additional sustained aerial surveillance.

The additional cost of a four-fold increase is $3 billion but the new facilities could be located and oriented in a way that would result in a greater than four-fold capacity. ACIL Allen therefore considers that a conservative realistic estimate of the benefit or avoided costs of delivering a JORN system with the same approximate four-fold capability as provided by DST Group’s innovations is at least half this figure, namely **$1.5 billion**.

Exports

As noted previously, DST Group sold the HF transmitter to MIT Lincoln Laboratories for around $2 million in 2010-11.

In addition, BAe Systems has sold a DST Group-designed Power Amplified container to the US Naval Research Laboratory for around $1 million, with prospects for sales of a further two containers.

The total value of exports that can be directly linked to DST Group's involvement in the JORN project is therefore around **$3 million**.

Total project benefits

Setting aside considerations of inflation and the time value of money, valued conservatively, the quantified value of the various benefits are shown in Table A.9.

TABLE A.9 – **JORN ASSESSED BENEFITS**

Project component	Assessed benefit ($million)
Reduced acquisition costs	1,500
Export value	3
Total	**1,503**

SOURCE: DST GROUP AND ACIL ALLEN

A.5 F/A-18 Structural Refurbishment (HUG3)

BOX A.6 – **KEY FINDINGS – HUG3**

Key finding 1 - DST Group's work justified an overall safe-life increase of 10% whilst retaining existing levels of safety, and allowing the aircraft to achieve its revised planned withdrawal date.

Key Finding 2 - The number of Centre Barrel Replacements (CBRs) required was reduced from the planned 49 to just 10.

Key finding 3 - ACIL Allen has estimated the total benefits arising from the project that can be attributed to DST Group are about $443 million, consisting of $52 million as a result of increased availability of aircraft, $1 million from overseas contracts and $390 million in avoided costs.

A.5.1 Project origins and inputs

Air combat capability is a critical component of Australia's defence strategy. As stated in the Defence White Paper 2009:

Our military strategy is crucially dependent on our ability to conduct joint operations in the approaches to Australia—especially those necessary to achieve and maintain air superiority and sea control in places of our choosing. Our military strategic aim in establishing and maintaining sea and air control is to enable the manoeuvre and employment of joint ADF [Australian Defence Force] elements in our primary operational environment, and particularly in the maritime and littoral approaches to the continent. (Defence White Paper, 2009, p. 53)

At that time, the RAAF's air combat capability consisted of an aging fleet of 21 F-111C fighter bomber aircraft and 71 F/A-18A/B Hornet aircraft, and an acquisition process to replace the F-111 fleet with 24 F/A-18F Super Hornets was underway. In 2010 the then remaining fleet of 21 F-111C long-range strike and reconnaissance aircraft was withdrawn from service, while the current fleet of 55 F/A-18A (single-seat) and 16 F/A-18B (dual-seat) Hornets had been in operational service for up to 27 years.

The replacement F-35A JSF (Joint Strike Fighter) aircraft are not expected to enter Full-Rate Production until 2019, by which time the oldest RAAF F/A-18 would have been in service for 34 years. In order to ensure that Australia continued to have the capability outlined in the 2009 Defence White Paper, the service life of the F/A-18A/B fleet was required to be extended until 2020. The initial structural substantiation program for the F/A-18 Hornet aircraft determined that a major structural refurbishment program was required for the airframe to reach the planned withdrawal date (PWD).

The F/A-18's most critical structure for flight safety is the fuselage centre barrel structure, the primary load bearing structure in the aircraft. It is subjected to high loads during high-g manoeuvres and during aircraft landings, and structural failure of the centre barrel is likely to lead to a catastrophic event. The design-life of the F/A-18 was initially envisaged as being some 6000 hours of flight. This estimate was based on the US Navy's predicted use of the aircraft, which would entail catapult take-offs and arrested landings on aircraft carriers, creating great stresses on the undercarriage and fuselage. In early Australian service, however, the RAAF aircraft experienced higher g and more-g exceedances, and the rate of fatigue accrual was higher than that of the US Navy and they would therefore exhaust their fatigue life far earlier than the manufacturer's specified 6,000 hours, particularly in relation to the centre barrel structure.

The AIR 5376 (Hornet Upgrade Program - HUG) Phase 3 consisted of structural refurbishments to the RAAF's F/A-18A/B Hornet fleet, aimed at ensuring adequate fatigue safe life limits to achieve its current Planned Withdrawal Date (PWD) of 2018-2020. This was already an extension of the original PWD of 2010, and focused on sustaining the Hornet fleet's structural integrity, and hence its ability to maintain the approved level of capability.

A.5.2 Project activities

In August 2007, DMO tasked DST Group to reassess the extant safe life limits of specific centre barrel locations in order to see if there existed any scope for life extension. This would have the potential of offering greater flexibility in the structural refurbishment schedule and potentially eliminate the need for some centre barrel replacements altogether.

The task required the development of new methodologies for assessing metal fatigue life[19]. The work also relied heavily on DST Group's FINAL (Flaw IdeNtification through the Application of Loads) centre barrel test and teardown program and a unique understanding of metal fatigue, and contributed to processes which achieved the desired extensions to the previously promulgated safe life limits. FINAL had been initiated as risk mitigation for HUG3 Structural Refurbishment Program (SRP) Phase1.

Major activities comprised discrete modifications and inspection programs, and in some cases, the entire replacement of the aircraft's wing attachment centre fuselage section (also known as the 'centre barrel'). As noted above, the centre barrel is the major life limiting component and its replacement requires the aircraft to be taken off-line for approximately 12 months.

The HUG3.2 project was divided into two structural refurbishment programs (SRP):

1. SRP2: Centre barrel replacement along with a few other discrete modifications and inspections provided confidence to increase continued airworthiness from 85% to 100% of the intended structural fatigue life.
2. SRP1/1D: A range of other discrete structural modifications provided confidence to increase continued airworthiness from 78% to 85% of the intended structural fatigue life.

DST Group scientists devised a structural test program in which retired centre barrels from US Navy, Canadian and Australian aircraft were tested to destruction in order to enable fatigue damage to be better characterised and modelled, thereby allowing more accurate determination of the aircraft's true safe life without compromising airworthiness.

The majority of the task was completed in June 2008. It drew from several Aerospace Division competencies including:

- Aircraft life assessment
- Experimental crack growth modelling
- Full-scale airframe testing and numerical stress analyses
- Quantitative fractography[20]

The program was sponsored by DMO (Air Combat Systems) as the customer responsible for HUG3 and directed by DGTA-ADF. DST Group staff from the Structures Branch, Aerospace Division, conducted the R&D using existing forensics laboratory and computational facilities. QinetiQ Aerostructures Australia was actively involved in support of the project. QinetiQ followed DST Group guidance and methodologies in contributing to the project. It is estimated that the QinetiQ's contribution to the project deliverables was approximately 15 per cent. DMO provided funding for both DST Group staff and QinetiQ support in 2007-2008.

A.5.3 Project outputs

The results of DST Group's work justified an overall safe-life increase of 10% whilst retaining existing levels of safety, and allowing the aircraft to achieve its planned withdrawal date. The number of Centre Barrel Replacements (CBRs) (SRP2) was reduced from the planned 49 to just 10. The remaining 39 aircraft have undergone the SRP1/1D program.

Aircraft availability was also increased, with a 12 month outage to replace centre barrels avoided for 39 aircraft over the period 2010 to 2015.

[19] Molent L. and Swanton G. The DSTO Contribution to the Fatigue Life Reassessment of the RAAF F/A-18 Hornet Centre Barrel Structure, DSTO-TR-3062, Dec 2014.
[20] The ability to read a fracture surface and relate crack progression markings to discrete events in the life of the component being investigated.

A.5.4 Status of Outcomes and Impacts

The various components of HUG Phase 3 have resulted in the extension of the PWD of the F/A-18A/Bs from 2010–15 (as envisaged during the period 1985 to 2005) to 2018–20 (as envisaged since 2009). The revisions of the retirement date have been planned with the intent of ensuring that the F/A-18A/Bs can continue operating until the F-35A JSF is operational, so that Australia has no 'capability gap' between the retirement of one fleet and the introduction of the next.

As noted in the submission to the First Principles Review, The Hornet Upgrade (HUG) Phase 3 project has resulted in a major saving for Defence. The program has established a new safe life for the centre barrels without compromising airworthiness. It has extended life clearances for the majority of the refurbishments and significantly reduced the number of centre barrels that had to be replaced. This has achieved greater availability of aircraft and increased the flexibility in refurbishment scheduling.

The program has therefore provided increased aircraft availability and life extension, which allowed for delay in JSF procurement. While two aircraft have been purchased for training purposes, the majority of the acquisition has been delayed to 2018.

The same methodologies and testing approach are also applicable to other aircraft. Both the methodology and testing was directly applied to the F-111. The Dutch Air Force has adopted this approach to suspend a wing replacement program, with the DST Group receiving acknowledgement.

Table A.10 summarises the outcomes and impacts of the HUG Phase 3 project.

TABLE A.10 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE HUG PHASE 3 PROJECT**

Outcome / Impact	Impact?
Reduced acquisition cost	-
Avoided acquisition costs	Yes
Reduced O&M costs	Yes
Revenue raised (sales, exports, licence fees, etc.)	Yes
Increased availability	Yes
Increased capability	Yes
Avoided adverse effects (deaths, injuries, environmental impacts, etc.)	-
Options created	Yes

Nature of Outcomes and Impacts

The project delivered on its objectives, with only 10 of the 49 CBRs initially planned conducted. The reduction in the required number of CBRs produced a saving on the order of $400 million, an increase in combat aircraft availability, and the flexibility to deal with the delay in the procurement of JSF.

Avoided acquisition costs

The HUG3 program has extended the safe-life limits of the majority of the F/A-18 fleet by 10 percent, with only 10 aircraft requiring to undergo a centre barrel replacement.

This has also provided bridging capability to accommodate the delay in the Joint Strike Fighter (JSF) procurement from 2010 to 2018.

Reduced O&M cost

The program has reduced the number of CBRs from the planned 49 to just 10. At $10 million per CBR for 39 aircraft, the resultant saving amounts to close to $400 million in total.

Direct Revenue raising (sales, exports, license fees)

As part of follow-on activities, there has been a contract to assist the Finnish Air Force with testing and certification of Hornet fleet wide repair ($150,000 contract).

There has also been a contract with US Navy ($1 million) to test a heat damaged US Navy Centre Barrel repair using the FINAL method. This provided an additional test rig which accelerated the DST Group outcomes to the RAAF.

Increased Availability

As result of the program, the availability of Hornet aircraft which did not have to undergo a CBR was increased by one year (out of a total expected life span of 30 years) an increase of around 3.3 per cent.

Options created

The financial savings have been directed to other ageing aircraft issues to future proof combat capability. The $400 million saving was used to support Hornet sustainment in the out years, in particular through the Project Air 5376 Hornet Structural Assurance Consolidation Program (HSACP). FINAL data has also be used to support international operators providing in-kind benefits to the RAAF.

Counterfactual

The planned 49, rather than only the initial ten, aircraft would have undergone a centre-barrel replacement (CBR) at an additional cost of $400 million. The need to take each aircraft out of service for a year to make the replacement would have led to a drop in the air combat capability below Air Force requirements during the replacement program.

Collaboration in the delivery of benefits

DST Group collaborated with a large number of organisations on the Hornet upgrade project, including DMO, RAAF, QinetiQ Aerostructures Australia and Fortburn.

While the support of other organisations contributed to the eventual delivery of the benefits associated with this project, the outcome (and its value) would not have been delivered in the absence of DST Group. It was responsible for the development of new methodologies for assessing metal fatigue life to enable fatigue damage to be better characterised and modelled, thereby allowing more accurate determination of the aircraft's true safe life without compromising airworthiness. Without this work the life extension and avoided costs would never have eventuated. Consequently the benefits have been fully attributed to DST Group consistent with our stated approach.

Adoption

The results of the testing methodology and the use of DST Group test facilities developed have been adopted into the F/A-18 structural refurbishment program.

The test rig (though not necessarily the methodology) has also been used by the Finnish Air Force and the US Navy. The testing methodology was used by the Dutch air force.

A.5.5 Assessment of impacts

Impacts to date

The research conducted over 2007-08 enabled the avoidance of 39 planned Centre Barrel Replacements. This also increased the aircraft availability, avoiding the 12 month service outages required to replace the centre barrels.

The dollar savings were directed to other aging aircraft issues to future proof the combat capability, notably the Project Air 5376 HSACP.

A DST Group staff member instrumental for the development of the methodology used to predict metal fatigue in this program was awarded the Defence Science Award in October 2010.[21]

[21] Scientist cracks jet lifespan code, http://www.theage.com.au/action/printArticle?id=2013638, October 2010.

No patents were sought or granted, and there has been no commercialisation of any the R&D results to date.

An externality/spillover is that industry continues to use the methodologies established for the HUG 3 program[22]. QinetiQ Aerostructures are able to use the methods to analyse other Hornet issues or for other aircraft.

Potential future impacts

The methodologies are generic and can be applied to aircraft other than the Hornet.

Discussions underway with Royal Air Force regarding use of the techniques developed assist in similar life time testing of the JSF STVOL variant.

The testing methodology and facilities are also being considered for use on other future platforms, including the testing of the Hawk 127 lead-in fighter, which prepares qualified Air Force pilots for operational conversion to F/A-18A and F/A-18B Hornets and F/A-18F Super Hornets.

A.5.6 Benefits attributable to DST Group

Reduced O&M Costs

As discussed in Section A.5.5, DST Group's work reduced the number of CBRs from the planned 49 to just 10, at $10 million per CBR, this saving is valued at 39 aircraft x $10 million = **$390 million**.

Export value

As noted previously, the follow-on activities resulted in a $150,000 contract with the Finnish Air Force to assist in the testing and certification of fleet-wide repairs to that air force's Hornet aircraft. In addition, there was a $1 million contract with the US Navy to test a heat damaged USN central barrel repair using the FINAL method.

The total value of overseas contracts is therefore around **$1 million**.

Increased availability

A CBR results in a Hornet being taken off-line for approximately 12 months. Assuming that each F/A-18A/B Hornet costs $40 million and has an operational life of 30 years and applying the same approach as adopted in the Trenberth review, the increased availability can be valued at 1 / 30 x $40 million = $1.33 million per aircraft.

The total value of increased availability enabled by DST Group's work is therefore 39 aircraft x $1.33 million is around **$52 million**.

Total Project benefits

Setting aside considerations of inflation and the time value of money, valued conservatively, the quantified value of the various benefits are shown in Table A.11.

TABLE A.11 – **HUGS PHASE 3 ASSESSED BENEFITS**

Project component	Assessed benefit ($million)
Reduced O&M Costs	390
Export value	1
Increased availability	52
Total	**443**

SOURCE: DST GROUP AND ACIL ALLEN

[22] Molent L. and Swanton G. The DSTO Contribution to the Fatigue Life Reassessment of the RAAF F/A-18 Hornet Centre Barrel Structure, DSTO-TR-3062, Dec 2014.

A.6 E-7A Wedgetail Radar

BOX A.7 – **KEY FINDINGS – E-7A WEDGETAIL RADAR**

Key finding 1 – DST Group's research has helped to ensure that a lengthy and costly period of litigation with the supplier was avoided and that the Wedgetail AEW&C aircraft was delivered with close to the required capability without any additional costs having to be incurred.

Key finding 2 - ACIL Allen has conservatively estimated that the lower bound for the benefits arising from the Wedgetail project that can be attributed to DST Group is $350 million. Given that there are a number of benefits which have not been quantified, and the potential for future benefits, this amount is likely to be substantially below the true net value delivered as a result of DST Group's work.

A.6.1 Project origins and inputs

The concept of an Airborne Early Warning and Control (AEW&C) capability for Australia has existed for a considerable time, but did not gain any significant momentum until the late 1990's. AEW&C is a well-established concept, but prior to this project Australia did not operate an AEW platform.

There have been many iterations of AEW radar systems dating as far back as the1940s with the RAF using a Vickers Wellington bomber fitted with a rotating antenna array in the Battle of Britain. The first US experimental AEW&C system was developed by the US Navy in 1944. It entered production in 1945 as the TBM-3W fitted with an APS-20 radar. The next generation of AEW&C emerged a decade later when the APS-20 radar was fitted to the Lockheed Super Constellation airliner (designated as the EC-121 Warning Star by the US Air Force and WV-2 by the US Navy). Post-war UK developments also used the APS-20 radar fitted to Skyraider, Gannet and then Shackelton airframes.

In the 1970s the Boeing E-3 AWACS (Airborne Warning and Control System) was developed using the much larger Boeing 707 and the APY-1 radar. The E-3 remains the global benchmark in AEW&C capability. Britain's E-3D AWACS was introduced after the collapse of the UK developed British Aerospace Nimrod AEW3 program, due to numerous problems with the radar design (due to unstable requirements), engineering and systems integration. No modern AEW&C system has been fielded without a protracted development and testing cycle.

The DST Group activities in support of the Wedgetail AEW&C project were borne out of the need to understand the detailed technical challenges with the development of an airborne early warning radar capability. While the specific topic was new for Australia, it was built on a substantial background capability in airborne microwave radar systems. The project supported a programme of risk focused research into those areas where DST Group believed there were technical challenges and where there may be alternative solutions to the ones that were being pursued by the suppliers.

The delivery of an AEW&C System was the subject of a tender process from DMO and had three bid teams short-listed to meet the requirement. Most of the early research executed by DST Group was addressing common risks to all of the proposed solutions although with differing details.

The key events timeline for the DST Group radar system programme were:

- 2000: Wedgetail Contract Signature
- 2001: DST Group and JPL Joint Radar Clutter Trial
Wedgetail Radar Preliminary Design Review
Wedgetail Radar Critical Design Review
- 2002: Wedgetail System Critical Design Review
- 2004: Wedgetail First Flight
- 2009: Wedgetail Operational Utility Demonstration
- 2011: Wedgetail Initial Operating Capability
- 2015: Wedgetail Final Operating Capability

The project has been funded jointly by DST Group and DMO, with DST Group staff undertaking the research. Initially existing laboratories and facilities were used, but post 2006 a laboratory was repurposed to support the needs of the project for radar system data analysis. The first contribution to the project from the DST Group microwave radar team was the inclusion of two subject matter experts in the resident team that DMO established with the prime contractor and the radar system supplier. Two microwave radar staff were seconded from DST Group to the DMO posts for 11 years.

A.6.2 Project activities

The project activities were largely undertaken by DST Group, with some data obtained from a joint trial with the US Jet Propulsion Lab and some contractor assistance with radar performance model development.

DST Group made use of a collaborative arrangement that was developed with the US Air Force Research Laboratory (AFRL). This gave Australia access to a high fidelity radar system model and the US access to the DST Group research outputs. The US model had been subjected to extensive validation and verification by the US. This model was used as part of the process of demonstrating that the radar system was not meeting its performance requirements. This government to government collaboration was based on equitable sharing in which AFRL gained access to the wider DST Group AEW&C related research and DST Group gained access to the model.

A.6.3 Project outputs

DST Group staff authored a significant body of scientific literature on the operating environment (clutter), radar resource management, radar signal processing for detection and electronic protection. The unclassified components of this were published in the open literature. This body of knowledge was critical to the DST Group evaluation of the radar system and to the third-party review which lead to the agreement with the suppliers regarding the performance shortfall and the subsequent settlement.

The scientific studies carried out by DST Group staff directly resulted in changes to the radar signal processing implemented on the system for both detection processing and electronic protection. Specific capability improvements that were implemented under the AEW&C Radar Collaborative Study (ARCS) programme can be traced to specific DST Group scientific and technical contributions.

The contribution that DST Group has made on this project (and two other projects —the AP3-C radar improvement and the APG-73 co-development project) has demonstrated the microwave radar team's ability to identify issues and solve problems in radar systems. This has resulted in substantial engagement in a number of other radar system projects which has provided Australian with very much greater insight that would otherwise have been the case, and also the ability to influence US design decisions for radar systems of interest to Australia. This includes the radar systems for Air 7000 phase 1, and phase 2 (P-8 aircraft) and Air 6000 (JSF).

A.6.4 Status of Outcomes and Impacts

The key outcomes of the project have been:

- The development of the knowledge base that was used to focus attention on elements of performance where there were likely to be serious failures in the system.
- The capability to identify significant shortcomings in parts of the Supplier's (Boeing) compliance test programme.
- A way forward with the supplier that would rectify the capability issues and not result in:
  - substantial increased costs to the Commonwealth
  - contract cancellation
  - the need to purchase an alternative solution or incur ongoing and recurring rectification costs.
- The incorporation of DST Group science and technology findings into the radar signal processing resulting in a very significant improvement in performance to achieve a near compliant capability.

Table A.12 summarises the outcomes and impacts of the Wedgetail project.

TABLE A.12 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE WEDGETAIL PROJECT**

Outcome / Impact	Impact?
Reduced acquisition cost	Yes
Avoided acquisition costs	Yes
Reduced O&M costs	-
Revenue raised (sales, exports, licence fees, etc.)	Yes
Increased availability	-
Assured (& increased) capability	Yes
Avoided adverse effects (deaths, injuries, environmental impacts, etc.)	-
Options created	Yes

Nature of Outcomes and Impacts

Reduced or avoided acquisition cost

Without DST Group's contribution one of two alternative outcomes would most likely have eventuated:

1. The first would have arisen if DST Group had not had confidence that the identified shortfalls could be rectified. In that case there may have been a substantial legal engagement on this project and potentially the need to proceed with a new capability acquisition. For example, this is what occurred as a result of the performance shortfalls for the UK Nimrod AEW and the subsequent need to then purchase US E-3 AWACS. Of course, such an alternative acquisition would still have been a development project with substantial associated risks. In addition, all known alternative solutions require either a larger aircraft, with higher operating costs, or less capability.
2. The second possibility was that the air force would have been delivered a capability at near full cost that would have required substantial extra investment to achieve an acceptable level of performance. Whereas the DST Group's work enabled DMO to arrive at a commercial settlement which was used to fund rectification of the shortfalls.

The nominal benefit in acquisition savings has been estimated to be $350 million, the value of the negotiated capability remediation program.[23]

Direct Revenue raising (sales, exports, license fees)

All the technology developed has been provided in full to the Suppliers and also to CEA Technologies. The DMO commercial settlement includes arrangements for the royalties when the outcomes form the ARCS programme are sold to the other users of this platform

Capability assurance

The DST Group AEW&C programme ensured that the Commonwealth avoided being delivered a capability that the Supplier was reporting as meeting the requirement when in fact it had substantial performance issues.

The DST Group research activity established the knowledge base that was able to be used to focus attention on elements of performance where there were likely to be serious failures in the system and also identify the impact of failure to meet key items in the specification. As the project underwent development tests by the Supplier significant performance issues were identified and DST Group demonstrated that the adjustment being performed on the development test results to demonstrate compliance with requirements was flawed, resulting in misleading analysis.

[23] DSTO submission to the First Principles Review, 2014

The background scientific work also helped identify why the performance problems were occurring, and that the Supplier had stopped work on finding a solution. The background scientific work also identified shortcomings in parts of the Supplier's compliance test programme.

The DST Group published scientific work was a significant component of the evidence chain that was used by the independent reviewers to confirm that the DST Group assessment of the performance shortfall and the modification of the testing was correct.

The knowledge base developed also provided a way forward which that rectified the capability issues in a manner that would not result in substantial increased costs to the Commonwealth. This avoided a potential contract cancellation, the need to purchase an alternative or the Commonwealth having to incur the cost of ongoing rectifications to deliver the desired capability.

The DST Group research into alternative options, and close collaboration with the Supplier, identified that the capability issues could be largely addressed. This enabled DMO (now CASG) to develop a commercial settlement with the Supplier that reduced the cost of the initial delivery. The settlement funding was used to address and rectify the performance shortfalls, with payment to the suppliers linked to achievement of performance improvements.

The incorporation of DST Group science and technology findings into the radar signal processing also resulted in a very significant improvement in performance to achieve a near compliant capability.

The AEW&C Radar Collaborative Study (ARCS) has through two phases of work and completion of about 50 study tasks addressed and rectified the majority of the radar capability. The DST Group work on alternatives has resulted in a number of improvements that are directly traceable to the work on alternatives. Specific capability enhancements have included improved detection ranges, reduced false alarm rates, more robust radar system across a wide range of environments.

Increased Capability

The program both avoided delays in achieving the required capability as well as delivering capability enhancements through improved detection ranges, reduced false alarm rates, and a more robust radar system across a wide range of environments. The DST Group engagement has been primarily aimed at ensuring the delivery of the required capability as initially specified. However, some elements of the capability requirement have now been exceeded.

Avoided adverse events (e.g. deaths & injuries, OH&S, environmental)

No specific benefits have been identified. However, the system is used to manage air combat situations. In its originally delivered form, there were substantial risks that the capability would not have supported the level of operational situation awareness necessary to deliver this role. In an operational context this could place aircraft in the wrong place to respond as intended, the consequences of which would depend upon the wider operational context.

The aircraft is currently providing a significant operational contribution to activities in the middle-east which include supporting aircraft operating in combat conditions.

Options created

Use of a collaborative arrangement developed with US AFRL provided DST Group with access to a high fidelity radar system model and the US with access to the DST Group research outputs

DST Group authored a significant body of scientific literature, with specific capability improvements implemented under the ARCS programme. Other outcomes from the DST Group programme include identifying options that will enable the capability to be improved in the future (currently the subject of a radar roadmap development study).

Counterfactual

Without DST Group's contribution one of two alternative outcomes would have eventuated. The first possibility is that the original contract would have had to be cancelled. This would have involved a protracted litigation process in the courts, estimated to have taken as long as ten years. This would also have required a new procurement competition for which all known alternative solutions require either a larger aircraft, with higher operating costs, or less capability.

The second possibility was that the air force would have been delivered a capability at near full cost that would have required substantial extra investment to achieve an acceptable level of performance.

Collaboration in delivery of benefits

This project involved the collaboration of a number of different organisations. The identification of substantial issues with the radar system was achieved by the combined efforts of DST Group and DMO staff.

Importantly, from their research, DST Group was able to identify that the issues with the system could be rectified. DST Group's findings were subsequently confirmed by an independent review by the MIT Lincoln Laboratory. The ARCS program which delivered the rectification was a joint program between the Commonwealth (as represented by DST Group, DMO and RAAF), US and Australian Industry (Boeing, Northrop Grumman and CEA Technologies), and US laboratories (MITRE and MIT Lincoln Lab).

While there were a number of organisations that contributed to the ultimate outcome provided from this project, and the delivery of significant benefits as a result, none of those benefits would have been delivered if DST Group had not carried out the work that it did. Consequently, for purposes of impact assessment and valuation, ACIL Allen has attributed 100 per cent of the benefits flowing from this project to DST Group consistent with our stated approach.

Adoption

The objective of the DST Group project was to understand and monitor the risks to capability delivery and to provide advice on how evolving issues could be addressed. This objective was met in full.

The results from the DST Group AEW&C radar support project have all been adopted to the extent the processing architecture and capacity allow. The results that have not been able to be adopted to date form part of the options set for the ongoing capability maintenance programme.

DST Group advised the Supplier, DMO and RAAF of the results and their implications, decisions on the adoption of results were taken by RAAF/DMO and implemented by the Supplier.

A.6.5 Assessment of impacts

Impacts to date

The Final Operational Capability (FOC) of the radar is substantially improved relative to the capability that was initially delivered—greatly improved detection ranges, substantially reduced false alarm rates and a far more robust radar system performance across a wide range of environments. Operational deployment of the capability has resulted in regular positive feedback from RAAF and USAF users of the AEW&C product.

What was a poorly performing, unstable AEW radar system is now considered to be setting the benchmark for system performance. The aircraft is currently providing a significant operational contribution to activities in the middle-east which include aircraft operating in combat conditions.

The radar system has been the subject of a rigorous performance evaluation programme (both before and after changes) and all performance gains claimed can be fully substantiated by data collected from the operational system. The performance assessments have included the assessment of the system-wide impact of the radar system improvements and not just the internal details of the radar system.

The value of the performance assessment has itself resulted in what was a single air capable "roll-on, roll-off" data capture system being installed on all RAAF Wedgetail aircraft.

The DST Group engagement has primarily been to help ensure that the aircraft capability as initially specified was delivered. However, some elements of that initial capability requirement have now been exceeded. Other outcomes from the DST Group programme have identified options that will enable the capability to be improved in the future (this is currently the subject of a radar roadmap development study).

There have been no patents or commercialisation resulting from the activities. All of the DST Group outcomes have been made available to the equipment suppliers under the ARCS programme (for which there are appropriate commercial arrangements) and also to CEA Technologies. The DMO commercial settlement includes arrangements for royalties to be paid when the outcomes from the ARCS programme are sold to the other users of this platform.

Potential future impacts

Preliminary work in an area of shortfall in performance not expected to be completely addressed via ARCS has commenced and in-flight data collection is planned for late 2016. Implementation of the "best fix" solution should follow in late 2017. The data from the flight trial will then be used for performance enhancement of the capability in the early 2020's using solutions already identified by DST Group, but which cannot be implemented prior to some processing changes (architecture and capacity reasons).

The DST Group programme has also identified a number of performance improvements beyond the initial requirement which have been demonstrated using recorded data but which cannot be implemented at present due to processor capacity limits. The project is currently investigating a processor replacement (the current processor system uses a 1999 vintage computer system) that will enable these enhancements to be implemented.

A.6.6 Benefits attributable to DST Group

Avoided acquisition or rectification costs

As noted in Section A.6.5, DST Group's work avoided a substantial legal engagement and potentially the need to proceed with a new capability acquisition or extra investment to achieve an acceptable level of performance. This benefit has been valued at **$350 million**, the value of the negotiated capability remediation program.

As discussed above, ACIL Allen has concluded that these costs would not have been avoided without the DST Group role. Consequently, for purposes of this DST Group value assessment, the value of benefits attributed to DST Group's role is **$350 million**.

Other unquantified benefits

Other benefits of DST Group's AEW&C program that have not been quantified, due to the lack of precise data, include:

- Capability enhancements through improved detection ranges, reduced false alarm rates and a more robust radar system across a wide range of environments
- Avoided delays in achieving the required capability and potential deaths and injuries to defence personnel in combat situations that might have occurred during the delay
- Future stream of royalties when the outcomes from the ARCS program are sold to other users of this platform.

A.7 NULKA Anti-ship Missile Decoy

BOX A.8 – **KEY FINDINGS – NULKA**

Key finding 1 – DST Group's research has increased the capability of the Nulka and demonstrated that a life extension of five years is justified.

Key finding 2 - ACIL Allen has estimated the total benefits arising from the Nulka project that can be attributed to DST Group to be $452 million, made up of $40 million as a result of estimated efficiency improvements, $12 million from deferred expenditure and $400 million in export earnings.

A.7.1 Project origins and inputs

Nulka is an electronic decoy system capable of defending a ship against advanced sea-skimming anti-ship missiles. When an approaching anti-ship missile is detected Nulka is launched. It flies a pre-programmed path, hovering near the targeted ship and its on-board active electronic warfare payload lures the incoming missile away from the intended target.

Australia's work on the Nulka Decoy Project began in the early 1970s.[24] It followed the pioneering work on off-board decoys carried out by the United States Naval Research Laboratory (NRL) during the 1960s and early 1970s. Nulka involved the development, testing and proving of several new technologies in order to meet requirements for decoying.

One was the development of the thrust vectored rocket, 'Hoveroc', which solved the problem of how to develop a small carrier vehicle which could fly relatively slowly while supporting a sizeable payload mass. In addition, there was a significant advance in the design of the payload antenna that greatly simplified the mechanics of decoying, and thus increased the system's operational effectiveness.

While NRL had done some of the early work that led to this project, for most of the 1970s and much of the 1980s the US and most NATO countries failed to appreciate the need to counter advanced western sea skimming anti-ship missiles such as the Exocet. Consequently, for most of this period Australia largely worked alone on the project. However, the scale of the threat posed by sea skimming missiles was recognised after the dramatic sinking of HMS Sheffield during the Falklands war.

In 1986 Australia and the United States formed a joint project, called Nulka. The project name subsequently was adopted as the name of the decoy.

Project Inputs

The Nulka Program, SEA1397 is made up of numerous Phases. The current phase (SEA1397 Phase 5) features a number of sub-projects;

— 5A (Capital) for the acquisition of current in service rounds
— 5B (Capital) for a planned upgrade to the current in ship based launching system[25]
— 5C (Capital) for participation in a joint US Australian development project.
— 5D (Capital) for the future acquisition of Nulka rounds.
— CN24 (Sustainment) for sustainment of the Nulka Capability

The SEA1397-5 program represents over $500 million of Australian investment into the Nulka capability.

Joint US Australian initiatives are funded in accordance with Government to Government agreements detailed in a Memorandum of Understanding. In general non-recurring development costs are shared on an equitable basis whilst a user pays model is used for acquisitions.

[24] The early development of the decoy technology was carried out under Project Winnin. This project consisted of an Advanced Feasibility Study, a flight demonstration of the first rocket-propelled vehicle called 'Hoveroc' and a Concept Development phase.
[25] Note that SEA1397-5B is an Australian only activity.

DST Group provides technical support across the entire scope of the Nulka program. DST Group has provided/will provide around 0.8 person years per annum between 2008/09 and 2017/18 in addition to around $2 million per annum on average non-salary project funding provided to DST Group.

Funding arrangements between DMO and DST Group are in place to support approximately $9 million of support over the next 3 financial years. Planning is underway for additional work scope pending Government approval in principle of the Defence Capability Plan.

A.7.2 Project activities

DST Group leads all Australian Government based and tasked R&D on Nulka. This specifically includes but is not limited to:

- Support for joint Australia US Initiatives
  - Science and technology to support the sustainment and life extension activities for the current in service Nulka round
  - Science and technology contribution to the joint development program(s)
  - Science and technology in the development of potential future Nulka capability
- Support for National (Australian) Nulka activities
  - Development, Testing and Evaluation (DT&E) associated with ongoing sustainment and optimisation of RAN based Nulka System capability
  - Science and technology analysis into improved/enhanced Nulka deployment techniques against existing and newly identified ASM threats

Australia's R&D contribution has a strong focus on improving the overall Nulka system effectiveness through:

- Improving how the Nulka decoy is employed against ASM threats
- Improving the performance of the Nulka electronics decoy cartridge
- Improving the efficiency of the Australian shipboard systems

Considerable progress is reportedly being made and some argue that elements of the R&D being performed by DST Group is world leading. In performing the science and technology and R&D activities DST Group is working to ensure that Australian industry has an ongoing opportunity to contribute to and actively participate in the Nulka program by identifying firms with the potential to partner in future Nulka acquisitions.

The staff who have worked on Nulka were drawn from various precursor and feeder projects. Some of the important DST Group skillsets brought to bear on this project include:

- Combat system integration
- Human machine interface requirements identification, specification and assessment
- Operational analysis to support effectiveness assessments
- Guidance and control
- RF (Radio Frequency) modelling, design and performance assessment
- R&D activity to characterise operational environments (i.e. propagation)
- Characterisation of RAN surface platforms and RAN electronic warfare environment
- Characterisation and Development Test and Evaluation of system performance.
- Energetics Materials (including Rocket Motor Aging program).

The project made use of existing research infrastructure and facilities, including

- The ANZAC Combat System Integration Laboratory (ACSIL)
- RF Technologies Laboratories
- Ship Air Defence Model (SADM) Simulation Capability
- Weapon System Laboratories
- Rocket motor Test Facility
- Explosives Ordinance Precinct
- Missile Simulation Centre

Major upgrades of infrastructure or facilities were funded under the project to support the required Science and Technology tasking.

A.7.3 Project outputs

Some of the key project outputs generated as a result of the work done by DST Group include:

- The tactics for deploying Nulka
- Characterisation of Nulka System and sub-system performance,
- Verification of Nulka effectiveness
- Environment RF propagation characterisation
- Generation of Objective Quality Evidence to support service life extensions
- Capability Optimisation.

A.7.4 Status of Outcomes and Impacts

DST Group reports that the tangible benefits from the project include:

- Simple direct cost savings to the program exemplified by service life extensions, independent oversight of contractor designs (support to risk/issue management) and mobilisation of Australian industry to support emergent requirements.
- Re-affirmation of current capability and capability extension through development of updated and new employment techniques in accordance with Navy requirements.
- Supporting data to enable cost versus capability trade off studies.
- Significant export earnings from sales of the Nulka to both the US and Canadian navies.
- Table A.13 summarises the outcomes and impacts of the Nulka project. More detail on the various outcomes and impacts is provided below.

TABLE A.13 – **SUMMARY OF OUTCOMES AND IMPACTS OF NULKA PROJECT**

Outcome / Impact	Impact?
Reduced acquisition cost	Yes
Deferred acquisition costs	Yes
Reduced O&M costs	-
Revenue raised (sales, exports, licence fees, etc.)	Yes
Increased availability	-
Increased capability	Yes
Avoided adverse effects (deaths, injuries, environmental impacts, etc.)	-
Options	Yes

Nature of Outcomes and Impacts

The Trenberth Review identified the net benefits the Nulka program as being some $898 million in 2003.[26] The magnitude of the implied saving was expressed on a 'per vessel saved' basis. This was based on modelling of ANZAC ship through life costs conducted by ACIL Tasman which suggested that the average annual cost of sustaining an extra frigate on the water (including periodic acquisition).

This case study does not revisit the benefits identified by Trenberth. Rather we look at how the skills and experience built up over the period covered by the Trenberth Review has delivered a number of significant outcomes for Australia. Below we examine each of the areas where DST Group's work has delivered an outcome and or impacts.

[26] Robert J Trenberth and ACIL Tasman, *Review of DSTO's External Engagement and Contribution to Australia's Wealth*, September 2003.

Reduced acquisition costs

DST Group long range R&D and the Defence Science and technology programs have (and are) advising the Nulka acquisition programs in a manner that supports efficient delivery of contractor capability. Specific examples of where DST Group's work has improved capability and efficiency include:

- Nulka IMU (Inertial Measurement Unit) development (to be implemented under SEA1397-5D)
- Nulka APADA (Absolute Pressure Air Data Assembly) development (implemented under SEA1397-5A)
- Nulka EMC (Electro Magnetic Compatibility) and EMC Lite Payload modification (SEA1397-3)
- Nulka shipboard HMI (Human Machine Interface) analysis / development activities (Legacy project).

It is difficult to estimate the monetary value of DST Group's efforts to improve efficiency over the past decade or so. However, ACIL Allen notes that Australia's investment in the acquisition of the Nulka decoy has ranged between $35 and 50 million per year over the past 10 years and only a 10 per cent efficiency gain would be required to offset the costs of DST Group's work on Nulka.

Deferred acquisition costs

DST Group science and technology activity supported the generation of evidence that allowed a Rocket Motor Assembly life extension from 15 to 20 years to be granted. This has enabled the deferral of expenditure of approximately $12 million for replacing old rocket motor units. Further science and technology activity is ongoing to support a further life extension to 25 years.

Export revenue

The then AWA Defence Industries (later BAe Systems) was contracted for the engineering development of the Nulka system and rocket vehicle. The United States companies Lockheed Martin Sippican Inc and ADI-Thales were engaged to develop the electronic payload and rocket motor respectively. In 1996 Australia and the United States commenced joint production of the Nulka decoys for their respective navies.

Nulka has been Australia's largest regular defence export for many years. In 2010 the 1000th Nulka round was delivered.[27] Current figures indicate around 1500 Nulka decoys have been delivered. The sales of Nulka have led to the creation of some 400 jobs and export sales in excess of $500 million.[28]

Increased capability

DST Group science and technology and DT&E has resulted in improved decoy deployment techniques. These improvements provide both a more robust and operationally current capability against known RAN anti-ship missile threats. ACIL Allen has not sought to assign any value to this benefit although we note that the Trenberth report effectively valued the capability provided by Nulka in 2003 at almost $900 million.

Counterfactual

As the Nulka concept has many of its origins within DST Group it is highly unlikely that the product and capability that has been and is being delivered to the RAN today would exist today. Certainly there is no equivalent 'off-the-shelf' equivalent of the Nulka.

Collaboration in the delivery of benefits

DST Group collaborated with a number of organisations on this project, including DMO, RAN, US Naval Research Laboratory and Industry (Lockheed Martin, Sippican, ADI-Thales and BAe Systems Australia). While several of these parties who provided valuable support for the NULKA project which contributed to the delivery of the eventual outcome (and its value), that outcome would not have been delivered in the absence of the vital role played by DST Group, particularly in relation to the development of the hovering rocket.

---

[27] *NULKA : a compelling story*, D Gambling, M Crozier, D Northam, DSTO, 2013
[28] DSTO submission to the First Principles Review

While the initial focus of DST Group was on the hover rocket, they now provide technical support across the entire scope of the Nulka program. In particular they are now recognised as world leaders in decoy package electronics. ACIL Allen has attributed 100 per cent of the benefits from this project to DST Group consistent with our stated approach.

Adoption

The commercialisation of the results of DST Group's research should be regarded as an excellent success story. Nulka is now Australia's largest and most successful defence export, with approximately 1500 rounds produced to date. Nulka is now deployed on over 150 ships in the Australian, US and Canadian navy. Export earnings from the production of the Nulka decoy are estimated to be over $500 million.

The rapid and successful transfer of the results of the research to industry was aided by long term relationship built up over time between DST Group and Australian industry. In particular DST Group has sought to assist Australian industry to be ready to partner with a both Australian and US primes to manufacture specific components of Nulka.

A.7.5 Assessment of impacts

Impacts to date

The benefits of DST Group's research into Nulka include:

— Greater survivability of naval vessels. This was valued at close to $900 million by the Trenberth Review in 2003.
— Export earnings in excess of $500 million from the sales of Nulka to the US and Canadian navies
— Increased life expectancy of Nulka which defers the cost of having to purchase replacement Nulka rounds.
— Improved capability of the Nulka System.
— Support to business cases to continue to invest in the Nulka capability
— The lessons learnt and infrastructure developed, supported and used by the Nulka program have been applied to other national and international defence initiatives.

Potential future impacts

DST Group continues to carry out research using the skills and experience gained as a result of its work on Nulka. This research continues to consider and seek optimised performance across the entire Nulka system ranging from shipboard HMI through to highly specialised RF component development and packaging.

This effort supports the ongoing operational viability of the Nulka capability by ensuring that the system keeps pace with changes in technology and the threat posed by anti-ship missiles.

A.7.6 Benefits attributable to DST Group

Efficiency gains

As noted previously, Australia's investment in the acquisition of the Nulka decoy has ranged between $35 million and $50 million per year over the past 10 years.

Assuming total expenditure on acquiring the decoy to be $400 million over that time period and an efficiency gain of 10 per cent, the benefits from supporting efficiency delivery of contractor capability are estimated to be 10% x $400 million = **$40 million**.

Deferred acquisition costs

DST Group's work produced evidence that enabled the useful life of the Nulka's Rocket Motor Assembly to be extended from 15 to 20 years. The deferral of expenditure for replacing old rocket motor units has been valued at **$12 million**.

Export revenues

As discussed previously, DST Group's work on Nulka has enabled export sales of at least $500 million.

Assuming that 20 per cent of this amount is lost from Australian industry due to "leakage" (from the purchase of imported raw materials and components), the value added to the Australian economy of these export sales is approximately 80% x $500 million = **$400 million**.

Total Project benefits

Setting aside considerations of inflation and the time value of money, valued conservatively, the quantified value of the various benefits are shown in Table A.14.

TABLE A.14 – **NULKA ASSESSED BENEFITS**

Project component	Assessed benefit ($million)
Efficiency gains	40
Deferred acquisition costs	12
Export revenues	400
Total	**452**

SOURCE: DST GROUP AND ACIL ALLEN

A.8 Advanced Short Range Air to Air Missile

BOX A.9 – **KEY FINDINGS – ASRAAM**

Key finding 1 – DST Group's research on the ASRAAM project was critical to enabling Australia to maintain the capability provided by the ASRAAM missile until the planned retirement date of the F/A 18. I also helped to ensure that the capability of the missile was maintained over the life of the missile. It also ensured that the operation of the missile was tailored to meet Australia's needs.

Key finding 2 - ACIL Allen has conservatively estimated that the total benefits arising from DST Group's work on ASRAAM are around $110 million ($100 million in avoided costs to replace the ASRAAM missile and $10 million in savings associated with the improved software for the missile). This is likely to be a conservative estimate of total benefits as there are a number of benefits which, while likely to be substantial, ACIL Allen is not able to quantify.

A.8.1 Project origins and inputs

The Advanced Short Range Air-to-Air Missile (ASRAAM) is an imaging infrared air-to-air missile carried by the Australian Classic Hornet (F/A-18A/B) and UK Typhoon and Tornado aircraft.

ASRAAM was selected for the Air-5400 project in 1998. DST Group assisted development of the missile capability and integration of the missile onto the F/A-18A/B and it was introduced into Australian service in 2004. ASRAAM gave a vastly superior capability over the previous AIM-9M weapon system. However, it was appreciated during the capability requirement phase that a software-based weapon in the early stages of development would likely enter service with a base-line capability. Science and technology support would be necessary to enhance capability through incremental software updates, improving performance in complex environments and against new threats with evolving countermeasures.

Science and technology support has also been required to aid extension of the service life of energetic components and sustain other subcomponents which are currently out of production. The weapon was purchased with war stocks requiring no maintenance and a 10 year guaranteed storage life. This was sufficient to last until the original expected in-service date for the Joint Strike Fighter (JSF) of around 2013. With the delay in the entry into service of the JSF, ASRAAM must be safe to operate and maintain its effectiveness until the life-of-type of Classic Hornet in 2020. DST Group assisted DMO in the creation of a joint AUS/UK service life plan.

The objectives of the DST Group R&D were two-fold: to improve the capability and tactical use of the existing ASRAAM hardware through software updates; and to aid life extension through energetics studies and assistance to the UK in development of replacement subsystems.

The project was undertaken under the auspices of the MOUDEP and follow-on AUMICE (Australia-UK Memorandum of Understanding on Military Capability Harmonisation and Equipment Cooperation) bilateral agreements with the UK. It only proceeded because of the close government-to-government relationship which allowed co-operative development of a key weapon system. Throughout the project there was a close partnership between DST Group, Dstl (UK Defence Science and Technology Laboratory), DMO, DE&S (UK Defence Equipment and Support), RAAF and RAF. All parties contributed to the project and funded work by MBDA UK (the ASRAAM developer and engineering manager), which passed on some of the Australian work to their sub-contractor BAe Systems Australia.

The Australian DMO provided the funding to support software development. This was provided to DST Group to support the development of the airborne pods, HWIL (Hardware in the Loop) and field test capabilities. A significant contract was supplied to MBDA to develop software loads.

DST Group supplied staff and expertise to develop and run the HWIL, airborne pod and field test facilities. DST Group also guided software development and provided modelling support.

RAAF provided performance assessment of the current ASRAAM based on observation of seeker performance during training and information provided by DST Group on missile kinematic performance. Information was provided in the form of the MECA 5 Degree of Freedom model and tables of Launch Acceptability Regions. RAAF personnel prioritised the possible improvements to ASRAAM software and rated their importance, guiding the process. Target aircraft (mostly F/A-18), missiles, countermeasure flares, airfield facilities and range access were provided by the RAAF to support the development of Australian software Load 3. In return Australia provided testing of developmental seeker hardware which also aided Australian missile life extension.

The missile life extension studies were funded by both UK MoD (DE&S) and DMO. The role of DST Group was to facilitate a coordinated study which would enable maximum read-across from the UK missiles to Australian missiles (which had undergone different storage histories and experienced different vibrational environments whilst carried on Australian Hornets). DST Group was also funded by DMO to undertake rocket motor ageing studies and test firings on Australian assets to complete the life extension study.

A.8.2 Project activities

The project activities are broken into two sections: ASRAAM capability and tactics enhancement through incremental software loads; and ASRAAM life extension up to when the F/A-18A/B is scheduled for withdrawal from service (in 2022).

ASRAAM capability and tactics enhancement through incremental software loads

In 2005 DST Group partnered with DMO, MBDA UK and BAE Systems Australia to form the DST Group-based Australian ASRAAM Software Support Capability. This team worked closely with RAAF to provide a regular software upgrade path for the missile and to support Australian tactics development. The initial support contract was for 5 years from 2005 to 2010, with a follow-on contract (omitting BAE Systems Australia) to 2014. New ASRAAM software loads with ever increasing capability were delivered in 2007, 2010 and 2014. The project will continue into 2015/16 to characterise the new capability and support 81 Wing (the operators of the Classic Hornets) in developing tactics.

R&D activities performed by DST Group included:

— Theoretical investigation of missile performance
— Airborne testing
— HWIL testing
— Field testing
— Model development
— Support for firings.

DST Group drove the software improvement program, coordinating R&D and testing developmental software loads. DST Group also undertook the background research to reduce risk and provide the evidence required to convince the partners that particular software changes could produce game-changing advantages. The ASRAAM manufacturer MBDA (and their subcontractor BAE Systems Australia from 2005 to 2010) produced the actual missile software loads but were aided by DST Group in scoping studies and modelling and simulation. DST Group led the trials and analysis of results, and aided in certification of the software.

ASRAAM life extension to F/A-18A/B withdrawal in 2020

As 2014 approached, the most immediate concern was for the safety of the energetic components within ASRAAM. Whilst DMO could contract MBDA to undertake some service life extension studies in partnership with the UK MoD requirements, DST Group was required to use its skills to calculate the vibrational and thermal environments for our own platform (Classic Hornet) and undertake static rocket motor firings (at Edinburgh) for our own specific conditions. These studies are being used to progressively certify life extensions out to 2020.

In addition to live rounds, infrared missiles of this type have training rounds which remain on the aircraft wingtips for months at a time. These training rounds allow the pilots to practice locking the missile on to targets allowing them to learn how to fight within the capabilities of the missile seeker. Training rounds have limited flying hours, suffer wear and occasional damage and so require maintenance and replacement on a regular basis. The most complex and high maintenance section of these rounds is the missile seeker. Over the past few years spares for training rounds have become harder to procure. Further, the US-based manufacturer of the seeker (Raytheon) had been in dispute with the missile manufacturer (MBDA) and had cut off supply of replacement seekers. All further spares had to be managed using the existing inventory of seekers (Block 4) until a replacement could be manufactured in Europe. DST Group was able to engage with DMO, the UK Ministry of Defence (MoD) and MBDA UK to facilitate the speedy development of the European produced replacement seeker (Block 6). This engagement involved lobbying by DST Group scientific experts and the application of unique DST Group capability to de-risk the UK programme to a level where UK MoD was happy to move forward. This has enabled the UK to offer the sale of spare parts (Block 4 Seekers) to Australia for use in maintaining ASRAAM up to the planned withdrawal date of the Classic Hornets in 2020. The UK MoD and MBDA are still working on the development of the Block 6 seeker which is due to start entering UK stockpiles in 2017.

The Block 6 seeker activities included DST Group airborne pod trials, DST Group field trials at Port Wakefield and several rounds of DST Group HWIL testing. These trials included testing performance against advanced and experimental flares. The projects to develop Australian software Load 3, and the replacement seeker (Block 6) made substantial use of existing infrastructure, skills and facilities. The two projects became heavily interwoven as the organisations pursued a common interest.

The lead Division for both of the activities above was Weapons and Combat Systems Division (WCSD) and the lead MSTC was Weapons Guidance Technologies (WGT).

The lead Client Group/External Agency was the Air Combat Group (ACG) / RAAF. External partners were UK MoD, RAF, MBDA UK and BAE Systems Australia.

A.8.3 Project outputs

The main outputs of DST Group's work were improvements in ASRAAM capability and extension of ASRAAM life. Each of these is discussed in turn below.

ASRAAM Capability

DST Group was the driving force behind the three software loads delivered in 2007, 2010 and 2014. This has resulted in a greatly improved capability for both Australia and the UK. A secondary output has been the development of a unique and world-leading DST Group-based trials and testing capability and a resulting depth of knowledge of missile operation which has enabled detailed advice to RAAF for tactics development. The DST Group capabilities are now in demand by UK MoD and Industry.

ASRAAM Life Extension

DST Group expertise on rocket motor life extension studies and the development of the new seeker have enabled ASRAAM to remain in service and it is now expected to last for the full service life of the Classic Hornet.

DST Group effectively created a trade-space with UK Ministry of Defence in which unique DST Group expertise and capability could be applied to a high-priority UK activity (the new seeker development) in exchange for RAF trials support to an Australian software development and access to replacement missile subcomponents.

A.8.4 Status of Outcomes and Impacts

Nature of Outcomes and Impacts

Table A.15 summarises the outcomes and impacts of the ASRAAM project.

TABLE A.15 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE ASRAAM PROJECT**

Outcome / Impact	Impact?
Reduced acquisition cost	-
Avoided acquisition costs	Yes
Reduced O&M costs	Yes
Revenue raised (sales, exports, licence fees, etc.)	Yes
Increased availability	-
Increased capability	Yes
Avoided adverse effects (deaths, injuries, environmental impacts, etc.)	-
Options created	Yes

The key outcomes have been a greatly improved air-to-air capability for RAAF (through enhanced ASRAAM software and tactics development) and the extension of ASRAAM service life which will maintain this capability to 2020 and has avoided integration of a new missile onto the Classic Hornet.

DST Group has led a step-change improvement in the effectiveness of ASRAAM for use in modern complex operational environments. Unclassified enhancements include much more robust performance against a range of targets and countermeasures in difficult environments, improvement in situational awareness for the pilot in conjunction with a reduction in workload, and a much larger employment boundary. The first two software loads were developed by a DST Group-industry partnership based in Adelaide, with the second load (in 2010) rapidly certified by the UK in preparation for Operation Ellamy (Libya) and later the defence of the London Olympics. The third load has been developed in close collaboration with the UK MoD and gives a step-change improvement in capability. It was delivered in 2014 and is due to enter service in 2015.

DST Group also aided DMO in facilitating an integrated Australia/UK program to address service life limits. This included the DST Group rocket motor tests which contributed to the overall life extension. DST Group used its unique missile guidance test capabilities to reduce risk and aid development of the UK replacement seeker, enabling release of existing UK seeker spares for the Australian fleet. The missile is now likely to be available through to the end of life of Classic Hornet in 2020. The DST Group expertise gained during this programme is currently being used to assess the impact of the ongoing MEA Operations on missile life.

Avoided acquisition cost

There are three elements to the avoided cost benefit, each of these is discussed below.

— **$100 million cost of integrating a replacement missile has been avoided**

A key outcome was the ability to apply DST Group expertise and support the international partner, enabling a service life extension of ASRAAM in Australian service. A life extension well beyond the original certified missile life has been achieved through close partnerships. The alternative course of action considered by DMO was to replace ASRAAM on the classic F/A-18A/B with the AIM-9X missile. This would have given the advantage of common war stock with the F/A-18E/F, but would have reduced F/A-18A/B capability and cost a minimum of $100 million to integrate. The additional cost of war stock is not included here as those war rounds might still have been useful after the F/A-18A/B finishes its planned service life in 2020.

— **$10 million in software development**

DST Group facilitated savings of more than $10 million during the development of software load 3.

This comprises:

1. Using scientific expertise to reduce the cost of the load 3 software by more than $1 million during contract negotiations in 2012.
2. Additional work undertaken by DST Group (in lieu of MBDA) which the company costed at more than $4 million.
3. Negotiations with UK MoD resulting in provision by UK MoD of trials support including multiple live firings against drones, the conservative value of which is $5 million.

— **$7 million facilitated to UK MoD with resultant reduction of spare supply risks to Australia.**

DST Group has undertaken research which has so far saved UK MoD $7 million during development of the replacement seeker (the value as costed by MBDA). This is a direct saving to UK MoD who is funding the project. The indirect benefit to Australia is access to the UK stockpile of spare seekers. Without this access RAAF pilots would not be able to train with ASRAAM as there is no other supply path.

Reduced O&M cost

Close partnership with UK MoD under the MOUDEP/AUMICE ASRAAM engagement has enabled DMO to negotiate transfer of subsystem replacement components (e.g. rocket motors) to Australia at greatly reduced cost in an informal exchange for Australian software load 2. This cannot be directly quantified but is in the millions of dollars.

Revenue raised (sales, exports, license fees)

The software development, subsystem analysis (including the new seeker) and life extension studies have been undertaken as a joint Australia/UK programme in partnership with industry. MBDA retains the intellectual property in the form of ASRAAM software and subsystems, but it is available for use by the two governments. Commercial benefits for MBDA will result from the sale of ASRAAM to India, and possibly other customers. The contribution of this program to the overall value of ASRAAM is minimal. The return to Australia has been in the form of capability enhancement for our own fleet and the ability to sustain the missile out to 2022.

Increased Capability

The air-to-air capability of the RAAF (and RAF) has been significantly enhanced through the provision of new ASRAAM software and related tactical options. The improvements have included optimisation for Australian use and reduction in pilot workload, as well as a range of very significant enhancements in missile guidance and the acquisition and tracking of targets in complex environments. ASRAAM can be employed more flexibly over a bigger engagement envelope, improving survivability of the F/A-18A/B aircraft. Whilst specific details cannot be given here, by any measure the improvement is at least an order of magnitude.

Avoided adverse events

While it is possible to be reasonably confident that the ASRAAM capability enhancements have enhanced aircraft and pilot survivability, RAAF F/A-18 aircraft have not been employed in operational situations that have required air-to-air missiles to be fired since the improved capability entered into service. Therefore the improved ASRAAM capability has not directly prevented any loss of aircraft or personnel.

Options created

This work has created an opportunity for Air Combat Group to radically modify their tactics to improve operation in aerial engagements. This will improve survivability of the F/A-18A/B in any future engagements and improve mission success. If just one aircraft and pilot is saved, the cost of this work will have been covered (notwithstanding the other savings listed here).

The DST Group capabilities developed to support ASRAAM are unique and can now be applied to other programmes. They include a hardware-in-the-loop (HWIL) laboratory comprising a hydraulically driven motion table and infrared scene projector interfaced to advanced computer simulators which allow the missile to be 'launched' in the laboratory. Two airborne pods have been built for carriage on a Lear jet, enabling data to be gathered in simulated combat profiles with target fighter jets. A DST Group gas gun flare test capability at Port Wakefield Proof Range enables ground-based testing of seeker performance against countermeasures. As part of the DST Group support to simulation and tactics development, a probabilistic range template tool has been developed to allow test firings in restricted range space. This tool has now been extended to other missile systems. The improvements in DST Group rocket motor test capability and the related expertise in missile life extension can now be extended to other systems.

The UK MoD has approached DST Group with a request to undertake HWIL and airborne trials to further develop the Block 6 ASRAAM. This is a measure of the value of the unique capabilities which have been developed under this program.

The ASRAAM software development team (including DST Group) received a highly-valued innovation award issued by MBDA in 2014. This programme has created a trade space with UK MoD and Industry which will endure through the AUMICE bilateral beyond the work on ASRAAM.

Innovation, science excellence and leading-edge technology in missile systems has enabled greatly improved RAAF capability, reduced the risk in sustaining the capability and also saved Defence far more than the direct cost of the work.

Counterfactual

Without this work the RAAF (and RAF) would still have a base-line performance from ASRAAM. The software updates not only improved performance, but gave RAAF a unique opportunity to tailor the operation of the missile to its own requirements. Such an opportunity does not exist for other weapons. The level of capability achieved is not available from equivalent air to air weapons.

Without the life extension work all missiles would by now be time-expired and the F/A-18A/B would have totally lost the capability for 'within visual range' air to air combat. The only recourse would be the integration of a new missile (likely AIM-9X).

The DST Group evaluation of the replacement seeker could not be undertaken by UK industry, as DST Group has world-leading experimental capabilities in this area. The DST Group trials revealed several major effects/defects which needed rectification. Given the fast-track schedule it is likely that these would not have been picked up until after production had started, causing extensive costs for MBDA and UK MoD and programme slippage which would have meant a lack of seeker supply to Australia.

Collaboration in the delivery of benefits

DST Group collaborated with a large number of organisations on this project, including DMO, RAAF, UK Ministry of Defence (MoD), RAF and Industry (MBDA UK and BAe Systems Australia).

While several of the parties who provided support for the ASRAAM project were important to the delivery of a viable (and preferable) alternative to the counterfactual, the eventual outcome (and its value) would not have been delivered in the absence of DST Group, as it has the world leading expertise in this area and there is no alternative provider with the necessary capabilities. In relation to the service life extension the addition of DST Group trials and expertise (particularly on rocket motor analysis and the replacement seeker development) were crucial to delivering the desired outcomes.

DST Group also drove much of the activity and lobbied UK MoD over several years to get movement on their programmes so as to support the Australian timelines. DST Group was also in a position to ensure that the operation of the missile was tailored to suit Australia's needs, something which would not otherwise occurred. Consequently the benefits have been fully attributed to DST Group consistent with our stated approach.

Adoption

The software loads are being adopted by both Australia (RAAF) and UK (RAF). The life extension work had common elements across both nations and has been used to extend the ASRAAM service life.

DST Group is playing an ongoing role in support to RAAF in development of tactics which make the most of the new capabilities. The 81 Wing Fighter Combat Instructor course is currently working on the first phase. DST Group support is being provided via HWIL testing, modelling and advice on detailed missile performance characteristics.

A.8.5 Assessment of impacts

Impacts to date

The air-to-air capability of the RAAF has been significantly enhanced through the provision of a more capable missile. In addition, a life extension well beyond the original contracted missile life has been achieved through close partnerships, thereby avoiding the significant cost of integrating a replacement missile.

The new ASRAAM capabilities enabled by the software improvements have had a series of significant effects on the way 81 Wing F/A-18A/B aircraft can operate in aerial engagements. While it is not possible for security reasons to be explicit these capabilities, they will enable the missiles to be used differently, with a bigger engagement envelope and provide better 'survivability' for the F/A-18A/B.

Loss of total ASRAAM capability was averted by the application of DST Group expertise and support to the international partner, enabling a service life extension of ASRAAM in Australian service. A life extension well beyond the original certified missile life has been achieved through close partnerships. The alternative course of action considered by DMO was to replace ASRAAM on the classic F/A-18A/B with the AIM-9X missile. This would have given the advantage of common war stock with the F/A-18E/F, but would have reduced F/A-18A/B capability and cost a minimum of $100 million to integrate.

MBDA retains the intellectual property in the form of ASRAAM software and subsystems, but it is available for use by the two governments. Commercial benefits for MBDA will result from the sale of ASRAAM to India, and possibly other customers.

It was demonstrated that Australia can contribute to the development of weapon software in partnership with the government and industry of another country. A series of software upgrades have been fielded in response to the capability priorities set by RAAF, and the UK RAF has also adopted the new software.

Development of a replacement seeker for ASRAAM has been supported through testing that would be very expensive for MBDA to carry out in other ways, and probably not achievable in the time frame available. This has provided savings for the UK MoD, enabled a tight production timeline and most important for Australia made replacement seekers available for aircrew to continue training.

Australian industry (BAe Systems Australia) was involved in the first 5 years of this programme, but was removed when DMO rationalised its ASRAAM support contract in 2010. MBDA UK are the manufacturers of ASRAAM and have been a key partner. A sale of ASRAAM to India has been achieved, providing additional funding for renewed development and production. Australian involvement has been valuable for the promotion of ASRAAM to other customers.

Potential future impacts

The tactical use of ASRAAM by RAAF will continue to evolve over the next few years, improving operational capability in aerial engagements.

The Australian Joint Strike Fighter will have its own weapons integrated by the US but the UK MoD is integrating ASRAAM onto their JSF for the RAF, leaving open that option for Australia in the future.

There is ongoing collaboration with the UK MoD to share military technology, under the Australia-UK MOU on Military Capability Harmonisation and Equipment Cooperation (AUMICE) agreement, covering science and technology R&D, logistics and testing capabilities.

A.8.6 Benefits attributable to DST Group

Avoided cost of integrating a new missile

As discussed in Section A.8.5, DST Group's work to extend the service life of the ASRAAM avoided the need to replace the ASRAAM on the F/A-18A/B Hornet with the AIM-X missile, which would have cost at least **$100 million** to integrate.

Reduced software development costs

As discussed previously, DST Group facilitated savings of more than **$10 million** during the development of software load 3, as a result of the following:

— Using their scientific expertise to reduce the cost of the load 3 software by more than $1 million during contract negotiations in 2012.
— Undertaking additional work (in lieu of MBDA) which the company costed at more than $4 million.
— Negotiating with the UK MoD to get their support for trials, including multiple live firings against drones, the conservative value of which is $5 million.

Reduced O&M cost

As noted previously, close partnership with UK MoD under the MOUDEP/AUMICE ASRAAM engagement has enabled DMO to negotiate transfer of subsystem replacement components (e.g. rocket motors) to Australia at greatly reduced cost in an informal exchange for Australian software load 2. The benefit of this cannot be directly quantified but is likely to be in the millions of dollars.

Total Project benefits

Setting aside considerations of inflation and the time value of money, valued conservatively, the quantified value of the various benefits are shown in Table A.16.

TABLE A.16 – **ASRAAM ASSESSED BENEFITS**

Project component	Assessed benefit ($million)
Avoided cost of integrating a new missile	100
Reduced software development costs	10
Reduced O&M cost (not quantified)	0
Total	**110**

SOURCE: DST GROUP AND ACIL ALLEN

A.9 Wideband Global SATCOM System JP2008 Phase

BOX A.10 – **KEY FINDINGS – WIDEBAND GLOBAL SATCOM SYSTEM**

Key finding 1 – DST Group's research was critical to enabling Australia to negotiate a much more favourable access arrangement to the Wideband Global SATCOM System. The MOU that was able to be negotiated based on the evidence provided as a result of DST Group's analysis extended the time during which capacity on the system would be available to Australia by several years. It also provided Australia with a more favourable access regime to a higher percentage of satellite beam resources.

Key finding 2 - ACIL Allen has conservatively estimated that the total benefits arising from the improved access to the SATCOM system that can be attributed to DST Group are around $350 million.

A.9.1 Project origins and inputs

The Wideband Global Satellite Communications Systems (WGS) is the ADF's primary long range communications system. The WGS system delivers wideband satellite services that provide large bandwidth, high data rates communications to military forces around the globe. When the system is completely operation it will consist of nine satellites[29]. The last satellite is scheduled to be launched in 2018.

In December 2006 the US first indicated to Defence representatives that WGS opportunities might exist for Australia. In February 2007 formal exploratory discussions on a potential memorandum of understanding (MOU) regarding a partnership between the US and Australia commenced. That partnership was based on Australia buying into the WGS program through funding the USAF to execute an option in the existing contract with Boeing for a final satellite. For commercial reasons, if Australia wanted to take up this opportunity the decision on whether to do so had to be taken by November 2007, so there was considerable pressure to make what was in effect a very rapid decision on how best to proceed.

DST Group recognised that WGS (then called Wideband Gapfiller Satellite) represented an important technology innovation and used its links with the US DoD research community to establish contact with the US subject matter experts on WGS. In 2004, DST Group had its initial meeting with US ARSTRAT[30] to discuss the technology roadmap for military wideband satellites. Since that period DST Group has developed a close technical relationship with ARSTRAT.

In 2005 DST Group started to develop its capability to model satellite communications systems.[31] Under sponsored research activity supporting JP2008 Phase 4, from 2006 DST Group started developing a database that captured the then existing SATCOM system as well as the plans for its future expansion. That database also captured the ADF's then existing use of satellite communications services and the potential future demand for such services. The database was developed to support a high fidelity model, being built by industry for DST Group, in the anticipation that Defence would need an independent ability to evaluate industry proposals for future ADF wideband satellite communications capability.

Following the invitation to consider joining WGS, DST Group finalised the industry work program and continued the development of the modelling suite internally, focussed on WGS, under extreme time pressure due to the commercially generated deadline. This proved essential to the successful MoU negotiation as the business case to Government for approval to participate relied on the analysis provided by DST Group using the WGS system model. DST Group was able to build this model because of the long standing engagement with ARSTRAT, its ability to interpret technical publications

[29] The AUS-USA MoU concerns the first six WGS satellite and supporting infrastructure. Following the execution of the bi-lateral MoU, the US DoD decided to expand the constellation to nine satellites and invite further international partners based on the partnership model developed with Australia.
[30] The US Army Strategic Command organisation is embedded in US Strategic Command (STRATCOM) and is appointed as the US DoD Space Systems Expert (SSE) for all US wideband communications satellites (including WGS).
[31] Note that DSTO has had a mandate and a capability to study SATCOM technologies since the program was initiated in the 1980's.

on component of the WGS system, the ability to seek and incorporate technical information from the US DoD[32]

Project Inputs

DST Group contributed approximately one person year over the life of this project from 2005/06 to 2007/08.

A.9.2 Project activities

DST Group was involved in the MOU negotiations from the outset due to its good relationship with CDG and DMO who lead the negotiation team. The US invited Australia to meet with its technical experts[33] to explore the two countries' requirements for satellite communications capacity to deliver the services required by the two defence forces. DST Group views this access as being in large part due to the recognition that DST Group brought considerable expertise to the negotiation and that this expertise would assist in developing a mutually beneficial agreement. As a result of the prior work done in building capability in this area DST Group was able to significantly strengthen Australia's negotiating position, rather than just supplying a spreadsheet with a high level assessment of Australia's future satellite capacity requirements.

DST Group was able to bring to the negotiating table an endorsed database of satellite terminals, detailed Information Exchange Requirements and well developed vignettes for operational requirements under different scenarios. DST Group had also written an interface to the database to allow the extraction of communication link information based on projected terminal populations and the operational vignettes. This allowed them to produce a set of capability needs which exceeded in detail those able to be produced by the equivalent US modelling tools.

At the first technical meeting in April 2007 the US noted that they would not be able to digest Australia's data set in the time available due to the level of detail provided by Australia and limitations in the ability to import significant volumes of data. However DST Group was able to create a model of the WGS satellite system during the meeting that allowed an initial estimate of Australian needs to be prepared. This estimate was sufficient to allow the US negotiators to seek approval from senior officials for the deal. Between the first technical meeting and the development of the business case for 1st / 2nd pass approval of Australia's involvement in the WGS system in June 2007, DST Group continued to refine the satellite system model to provide the data that underpinned the value for money arguments of Australia's participation in the WGS system.

A.9.3 Project outputs

The project outputs that resulted from the work done by DST Group included:

— An endorsed database of satellite terminals
— Detailed Information Exchange Requirements
— Well-developed vignettes for operational requirements under different scenarios
— A model with an interface to the database to allow the extraction of linked information based on projected terminal populations and the operational vignettes. This allowed them to produce a set of capability needs which exceeded in detail those able to be produced by the equivalent US modelling tools.

The capability built up by DST Group in this area is regarded as world leading. There is recognition that Australia is an equal in this area to the USA, and significantly in advance of other WGS international partners, and this helps to ensure that Australia has ongoing high level access to the internal details of an important US space based communications system. That recognition in relation to the WGS system has also helped to improve Australia's access in other areas of collaboration with the US.

A.9.4 Status of Outcomes and Impacts

There were four significant outcomes achieved as a result of the work done by DST Group, namely:

[32] Note that full technical information on the WGS system was not available to Australia due to ITAR restrictions and the time pressure for the decision. DSTO was able to validate key assumptions for the system model through technical exchanges with US subject matter experts.
[33] It should be recognised that this was a challenging time for ARSTRAT as the MoU negotiations occurred during the lead up to the launch of the first WGS satellite and this was their highest priority.

— To clearly demonstrate that the initial US offer for access at the start and end of the period covered by the MOU was unfair to Australia.[34] Once presented with evidence to support this argument the US quickly agreed and provided a much more favourable offer that extended the availability of capacity to Australia at the end of the agreement by a number of years.
— Enabling Australia to negotiate a more favourable access regime for the ADF that provided a higher percentage of satellite beam resources (and a lower percentage of power and bandwidth). DST Group's modelling had demonstrated that beam coverage was the limiting factor for forecast ADF operations.
— DST Group was able to provide clear evidence to the US that Australian access to the overall system capacity would be beneficial to the US over the life of the MOU. This supported US negotiators who had to convince US stakeholders and decision makers that the MOU was advantageous to both nations.
— To demonstrate that ADF access to the WGS planning software and near real time satellite configuration data was essential to address sovereignty concerns that had been raised by some stakeholders. This is a unique feature of the WGS MOU. This benefit that has not been provided to any other partners in any other satellite communications MOU negotiated by the US.

On 17 January when announcing the signing of a new MOU to extend the WGS partnership to include Canada, Denmark, Luxembourg, the Netherlands and New Zealand the US spokesman noted that:

The current demand for battlefield information is as high as it has ever been and is increasing exponentially for the US and our partners who are developing, acquiring and using systems that rely upon satellite communications.

The spokesman went on to state that:

This agreement builds upon a similar and hugely successful model established with Australia. Like that agreement, this new six country agreement was only made possible as a result of the close, trusted, proven relationships among the signatories.

The MOU between the US and Australia allowed for the expansion of the WGS system by the launch of a sixth satellite. Australia's contribution to the WGS was limited to no more than US$741 million.[35] The MOU with the additional five partner nations covered the launch of a ninth satellite at a cost of around US$620. Total cost of the WGS system is US$11,271 million. In terms of financial value it is the US' largest space capability International Armaments Cooperation program.

Table A.17 summarises the outcomes and impacts of the Global Wideband SATCOM system project.

[34] The MOU defines a 'scaled access regime' which describes how resources are allocated during the deployment of the system (as satellites are launched) and at the end of the system's life (as satellites degrade and decay).
[35] The actual cost of the contract was reportedly less than this amount due to factors such as exchange rate movements.

TABLE A.17 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE GWS PROJECT**

Outcome / Impact	Impact?
Reduced acquisition cost	-
Avoided acquisition costs	Yes
Reduced O&M costs	-
Revenue raised (sales, exports, licence fees, etc.)	-
Increased availability	Yes
Increased capability	Yes
Avoided adverse effects *(deaths, injuries, environmental impacts, etc.)*	-
Options	

Avoided acquisition costs

The first of the three outcomes listed above is the easier to value. A US Department of Defence report entitled Satellite Communications Strategy Report released in August 2014 concluded that buying bandwidth from commercial satellite providers is nearly four times more expensive than using military-owned communications satellites.[36] The report argues found that the US Department of Defence paid about US$14,200 per megahertz-month of WGS bandwidth in 2013, compared with US$56,220 for comparable commercial bandwidth in that year. The report also noted that, since 2010, commercial bandwidth prices have risen more rapidly than WGS bandwidth — some 11.5 percent compared with 4.4 percent.[37]

The improved access at the end of the MoU negotiated on the basis of DST Group analysis delivered an additional 87,384 MHz-months of capacity. Based on DST Group's modelling this represents more than two years of additional capability life that was available as a result of the revised MOU with the US the benefit of the additional capacity was very conservatively valued at $350 million at the time based on the published global average cost of commercial Ku band satellite capacity in 2007 dollars.[38] This benefit will accrue between 2022 and 2028.

ACIL Allen notes that this estimate of the benefit is likely to be conservative and should be seen as a lower bound, with considerable potential for the benefit to be significantly higher than that estimated above. For example, if the more recent estimates of the cost of comparable commercial bandwidth contained in the 2014 report prepared by the US Department of Defence were used to determine the potential benefit then it would be closer to US$5 billion.

Increased availability

Ongoing US development of the WGS system that increase capacity (through advanced ground terminals) and resilience to electronic warfare or cyber warfare are largely accessible by Australia. This translates as increased availability of the capability. The alternate procurement strategy to partnering in WGS would have been to acquire commercially based satellite technology (similar to Optus C1) or hosted payloads (similar to Intelsat-22) which would have resulted in far more limited scope for evolution of the capability based on cost, export controls and the number of satellites available (two at most).[39]

[36] *Satellite Communications Strategy Report*, Senate Report 113-44 to Accompany S.1197 National Defense Authorization Act for FY 2014, US Department of Defence, August 2014.
[37] http://spacenews.com/42261pentagon-report-says-commercial-bandwidth-is-four-times-more-expensive/#sthash.5Ujv6MLd.dpuf Accessed 11 June 2015.
[38] At the time this was approximately $4,000 per megahertz-month.
[39] In June 2003 Optus announced the successful launch of its Optus C1 satellite. The cost of the satellite at the time was said to be $500 million. https://media.optus.com.au/media-releases/2003/optus-c1-satellite-successfully-launched/

ACIL Allen has not sought to value this increase in availability, however, given the high cost of purchasing comparable commercial bandwidth the WGS would not need to be unavailable for long before the costs of maintaining the required capability began to become considerable.

Increased capability

The ability to access US WGS planning tools and near real time system management information provides Australia with increased capability compared to other WGS partners. The ability to do independent planning and monitoring allows greater assurance and flexibility. The tools developed by the US DoD for managing WGS are significantly in advance of the management tools delivered by Singtel Optus under JP2008 Phase 3D.

The ability of Defence to partner in the primary wideband US satellite constellation also has flow on effects in a number of other Defence capability programs. For example, the planned acquisition of P-8 and Triton means that any US spiral development for those platforms to incorporate high-capacity satellite communications should be available to Australia at lower risk (subject to export approval).

Any future US developed weapons system acquired by Australia should result in lower acquisition costs and risks as they will be designed to operate over WGS. This will also result in increased interoperability with the USA, five eyes partners (Canada and New Zealand) and some NATO countries.

Counterfactual

The close relationship between DST Group and the major US stakeholders was essential to achieving the above outcomes. Without that relationship the US would not have been willing (or able) to provide access to vital US government data that was essential to the modelling and analysis done by DST Group that was instrumental in delivering the successful outcome of this project.[40]

ACIL Allen understands that to provide for communications coverage over the Indian and Pacific Oceans the Department of Defence would need at least two satellites. Based on the reported cost of the Optus C1 satellite, this would have cost in the order of $1 billion (in 2003). It must however be stressed that this alternative approach would not have delivered anywhere near the same capability or level of global coverage provided by the WGS system.

Collaboration in the delivery of benefits

The US DoD would not have been able share the data required for the analysis that drove the successful outcomes of this project with anybody outside the Australian government employees means that means that ACIL Allen has attributed 100 per cent of the benefits from the successful outcome of this project to the DST Group consistent with our stated approach.

Adoption

The benefits in terms of the avoided cost of acquisition of satellite capability resulting from DST Group's work on this project will be realised in 2022.

A.9.5 Assessment of impacts

Impacts to date

The quantifiable benefits of DST Group's research on the GWS system are primarily the avoided acquisition costs associated with the conditions of the improved MOU that Australia was able to negotiate as a result of DST Group's modelling and analysis.

Potential future impacts

The DST Group team that delivered the results for this project continue to work on how to improve the efficiency of the WGS system in the most efficient way possible.

In addition, DST Group continues to support and prepare the ADF for possible future areas of operations (including countermeasure techniques, FPEC systems, FPEC test & evaluation, etc.)

[40] The US DoD is only able to share US Government data with Australian government employees.

A.9.6 Benefit Analysis

Avoided acquisition costs

As discussed previously in Section A.9.5, the improved access at the end of the Memorandum of Understanding negotiated on the basis of DST Group analysis delivered an additional 87,384 MHz-months of capacity, representing more than two years of additional capability life.

Based on the published global average cost of commercial Ku band satellite capacity in 2007 ($4,000 per MHz-month), DST Group conservatively valued the benefit of the additional capacity (which will accrue between 2022 and 2028) at **$350 million**.

A.10 Force Protection Electronic Countermeasures

BOX A.11 – **KEY FINDINGS – FPEC**

Key finding 1 – DST Group's research is likely to have already saved the lives of and prevented serious injuries to a number of Australian and US and Afghan defence personnel serving in Afghanistan, as well as preventing damage to operational equipment. It is also likely to have helped save future lives and significant future damage to operational equipment.

Key finding 2 - ACIL Allen has estimated the total benefits arising from the FPEC project that can be attributed to DST Group to be $51 million, consisting $46 million from exports and $5 million in avoided acquisition and vehicle integration costs. These benefits do not include any estimates in relation to past and future prevention of loss of life and injury (including rehabilitation / dealing with permanent physical and psychological disability) and damage to operational equipment, which apart from the direct cost could further endanger lives.

A.10.1 Project origins and inputs

ADF troops and the land vehicle platforms operating in current areas of conflict face extremely high level threats from Improvised Explosive Devices (IEDs). In the period from 2007 to 2013 fourteen ADF personnel were killed by IEDs.[41] This was over a third of all casualties in Afghanistan over that period. The Defence department does not provide details about wounded personnel, however, IED related injuries are estimated to be in the order of around 100.

DST Group's work to address the threat posed by specific classes of IEDs included many elements. The three most notable of those elements are discussed in this analysis. First, in 2009, DST Group was tasked with developing Counter-IED systems to reduce ADF personnel vulnerability to these life endangering devices. In response the Communications Electronic Warfare Group in DST Group's Cyber and Electronic Warfare Division began a design and development program for a force protection electronic counter measure (FP ECM) system to protect against IEDs.

In 2012/13 the ADF again sought an urgent DST Group solution to an emerging new IED threat against which there was no existing effective countermeasure capability within the ADF or Australia's coalition partner. DST Group responded by rapidly developing and testing a countermeasure technique against this threat suitable for integration with existing ADF systems.

Finally, DST Group developed a family of low-cost, robust Force Protection units under the REDWING program, which have been mass produced and sold to the Afghanistan Security Forces. Two systems have been developed: GREENGUM, a small personal unit; and GREYGUM, designed for use on light vehicles.

Importantly, the science and technology support provided in relation to this case study represents only one part of the overall science and technology support provided to the FP ECM area of Defence by DST Group. Other areas that DST Group have been involved include technical aspects such as blast protection and operational analysis support regarding tactics techniques and procedures.

Project Inputs

The inputs into the above three elements of the work that DST Group undertook to develop force protection electronic counter measures were 10 person years over the period 2009/10 to 2011/12, 4 person years over the period 2013/14 to 2014/15 and 9 person years over the period 2012/13 to 2014/15.

As part of the process to commercialise the technology developed as a result of the first element of this project, DST Group worked with BAE to build the preproduction AN/PLT2000 V2 prototypes. Three Australian firms (BAE, Ultra-Avalon and Micreo) were subsequently brought in to build the devices for operational deployment.

[41] http://www.defence.gov.au/operations/afghanistan/personnel.asp, accessed 6 June 2015.

A.10.2 Project activities

DST Group carried out the following activities as part of their work to deliver the three elements of project described in this case study:

- R&D into the characterisation of IEDs
- R&D into IED countermeasure techniques
- Laboratory and field testing of prototype techniques
- R&D into prototype devices
- Prototype IED countermeasure devices were supplied to the ADF for domestic and international evaluation. The international evaluation was a critical part of the system development and this evaluation had to be conducted under a 5-eyes Defence agency agreement. Testing and evaluation of the prototype devices demonstrated them to be effective in protecting against IEDs
- Preproduction design
- Provision of engineering services
- Licensing of the IP generated by the project to various Australian firms
- Provision of pre-production support
- Provision of production support
- Supporting the delivery into service of the finished products
- Providing operational support

A.10.3 Project outputs

The outputs from the three elements of the work done by DST Group on this project are discussed below.

The first element of the project led to the development of the AN/PLT-2000 V2 personal IED countermeasures system. The technology was successfully tested, then transferred to, and commercialised by, a number of Australian companies. It was introduced into operational service with the ADF in mid-2011, where it has continued to operate as a successful IED countermeasure until the present day.

The IP and capability developed as a result of this project is regarded as world leading. Australia was the first coalition partner to have the capability to protect their personnel in this way. The same technology was also used in equipment supplied by Australian firms to the US.

The second element of the project was carried out in response to an urgent need to respond to a new IED threat to ADF personnel. The ADF's existing countermeasures were ineffective against this emerging threat and Australia's coalition partner was unable to provide a solution.

One option for the ADF would have been a multi-million dollar rapid acquisition of new equipment to address the threat facing ADF troops. However, DST Group were able to rapidly develop and successfully test an enhanced countermeasure technique against this threat suitable for integration in one of the existing ADF systems.

This DST Group countermeasure enhancement has now been introduced into the operational theatre as a fully integrated element of the ADF's suite of IED countermeasures.

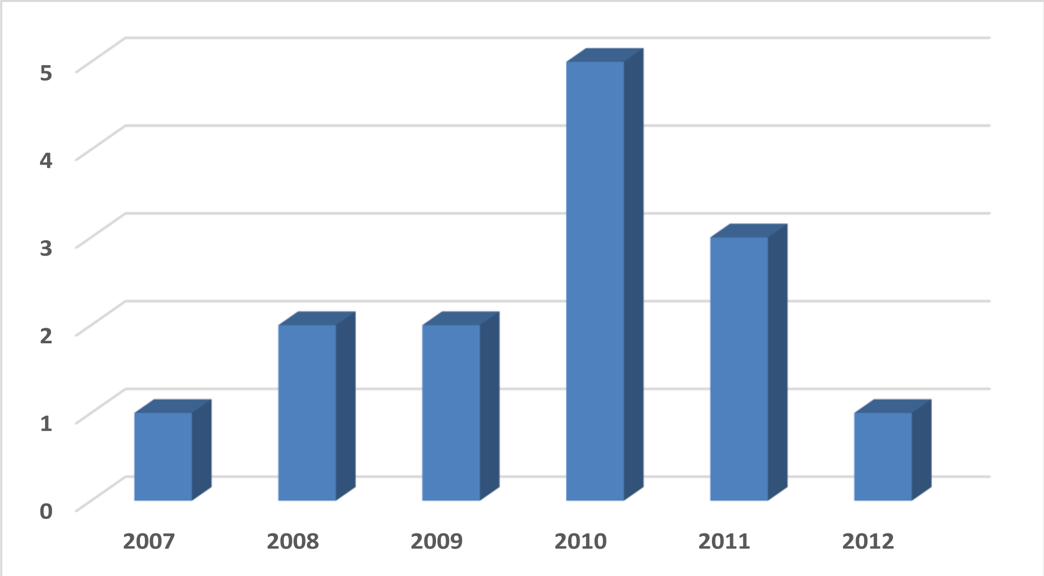
The output of the third element of the project was a family of low-cost, mass produced, robust device to protect Afghan forces. Two systems were developed: GREENGUM, a small personal protection unit; and GREYGUM, designed to protect light vehicles. This technology has been sold to the Afghan security and defence forces to protect their personnel from IEDs.

As part of this FPEC process DST Group has, and will continue to develop, new countermeasure techniques for use in existing operational ADF systems to counter new and emerging IED threats.

A.10.4 Status of Outcomes and Impacts

DST Group reports that its work on this project has had a number of tangible and beneficial outcomes and impacts. The IED countermeasures systems developed by DST Group are now in routine use by Australian troops deployed in Afghanistan (and now Iraq) and are an integral part of the ADF's efforts to protect its personnel in that theatre of operations.

FIGURE A.1 – **ADF DEATHS IN AFGHANISTAN DUE TO IMPROVISED EXPLOSIVE DEVICES**



SOURCE: HTTP://WWW.DEFENCE.GOV.AU/OPERATIONS/AFGHANISTAN/PERSONNEL.ASP ACCESSED 6 JUNE 2015.

In November 2014 the Chief of Joint Operations, Vice Admiral D.L. Johnston, AM, RAN, wrote to DST Group to express his appreciation of the efforts made to help protect ADF personnel deployed in Afghanistan. He stated that:

For over ten years DSTO support to operations has played a critical role in the provision of highly technical Force Protection solutions to deployed forces. While there is no doubt that this effort has saved lives in the past, events of this year have demonstrated that DSTO support is as relevant today as it was during the peak of earlier operations.

In December 2014 the Chief of Army, Lieutenant General D.L. Morrison, AO, also wrote to DST Group. In his letter he stated that efforts of DST Group staff were:

… greatly appreciated as they directly contribute to the safety and welfare of our deployed soldiers.

Importantly, there have been no deaths among ADF personnel from IEDs since October 2012. Given that on average around a third of all casualties prior to then were due to IEDs this has undoubtedly been a very significant impact of DST Group's work in this area. While there is no information available on the number of injuries to ADF personnel specifically due to IEDs, the fact that there have been no deaths from IEDs for almost three years would suggest that the number of injuries due to IEDs is likely to have declined significantly as well.

By mid-2011 Australian industry had supplied around 1100 of the personal IED countermeasure units to ADF troops on the ground.[42] The device is now in continuous use during operations. The DMO contracts to Australian industry for pre-production development were worth around $1.2 million and the development and production contract was worth about $12 million. These firms also have an ongoing DMO sustainment contract worth around $1 million a year. In addition, a contract to supply an additional 1000 units for use by US troops in 2012 was worth an estimated $10 million.

DMO/AMSO has contracts with Australian industry for mass production of the affordable GREENGUM and GREYGUM countermeasures devices for supply to the Afghan security forces. Under that contract Australian industry delivered 105,000 units to the Afghanistan security forces in June 2015.

There are plans for ongoing production of at least 25,000 devices per year by Australian industry. The contract is worth around $20 million to industry in FY 14/15 and about $5 million per year for the next

[42] Due to the urgency of the situation the devices were manufactured and delivered in a 4 month window in the first half of 2011.

three years. The total program to supply the devices is worth around $48 million.[43] The majority of which will flow to Australian industry.

This project is a good example of DST Group innovation, and teamwork within Defence to deliver an important new operational capability that not only increases the safety of ADF personnel, but also supports Australian industry by transferring the technology to them for commercialisation. The Commonwealth will receive a royalty payment from the initial $48 million contract and on future sales of individual devices estimated to be around 5 per cent.[44]

Finally, as a result of DST Group being able to respond to an emerging threat they were able remove the need for Defence to acquire costly new equipment to meet that threat. As a result, DST Group was able to save the Department several million dollars in acquisition and vehicle integration costs. A conservative estimate of the resultant savings is about $5 million[45]. In addition, the ongoing sustainment costs of $1 to $2 million per year were also avoided as a result of not having to support the new equipment.

Increased capability

The FPEC devices developed by DST Group increases the capability of current in-service ADF C-IED systems to provide protection against new and emerging IED threats. It is difficult to estimate the improvement in capability in this field as the ADF previously had no personal FPECM capability in this area, whereas now it has. DST Group has also supplied countermeasure techniques for some ten new threat types, and has improved the performance of the countermeasure techniques against existing threat types. ACIL Allen has estimated that there has been a 20-30% improvement in FPECM capability.

Table A.18 summarises the outcomes and impacts of the Force Protection Electronic Countermeasures project.

TABLE A.18 – **SUMMARY OF OUTCOMES AND IMPACTS OF THE FPEC PROJECT**

Outcome / Impact	Impact?
Reduced acquisition costs	Yes
Avoided acquisition costs	Yes
Reduced O&M costs	-
Revenue raised (sales, exports, licence fees, etc.)	Yes
Increased availability	-
Increased capability	Yes
Avoided adverse effects (deaths, injuries, environmental impacts, etc.)	Yes
Options created	Yes

Counterfactual

While there are some commercial mounted & dismounted hardware systems available, their use is very limited without the 'smart' countermeasure capabilities loaded onto them. It is likely that without DST Group's involvement the ADF's FPEC capability would have:

— Provided less protection to ADF personnel and vehicles
— Been more costly to acquire since all ADF systems and techniques would have had to be sourced and purchased from overseas. For example, the DST Group developed FPEC capability developed in FY

[43] The contract is for US$38 million.
[44] The royalty payment is built into the existing $48 million contract. Any future royalty payments will be paid directly to the Commonwealth.
[45] This estimate is conservative as savings cover around 80-100 kits at $50,000 per kit, plus the cost of vehicle integration kits and the additional costs of undertaking integration and testing in-theatre.

13/14 would have taken a year to purchase at a cost of $5 million dollars compared to the cost of around $800,000 for the DST Group effort.

— Been delivered into service several years later (for example, the AN/PLT2000 capability was delivered into service two years before equivalent coalition systems).

Collaboration in the delivery of benefits

This project involved collaboration between DST Group and a number of different organisations (including, DMO and private firms such as BAe and Micreo). For example, the development of the FPEC benefited from the support provided by the BAe in constructing the AN/PLT2000 prototypes and the Australian firms that now manufacture the devices. While other parties who provided support for the FPEC project were important to the delivery of a viable alternative to the counterfactual, the eventual outcome (and its value) would not have been delivered in the absence of DST Group, as there is no alternative provider with the capabilities required to deliver the solution to the IED problem in the time frame that is ultimately was provided in.

Consequently the benefits from all elements of this project have been fully attributed to DST Group consistent with our stated approach.

Adoption

There was a clear and urgent need for a device to protect ADF personnel deployed in Afghanistan. Hence the commercialisation of the results of DST Group's research was rapid. The FPEC devices were in use in by the ADF in Afghanistan by 2011. Sales of the device to other countries have already occurred. The adoption by Afghanistan of over 100,000 GREENGUM & GREYGUM units also demonstrates the underlying need for this technology solution to the threat posed by IEDs.

The rapid and successful transfer of the results of the research to industry was aided by the long term relationships built up over time between DST Group, DMO, the ADF, International Defence Science partners and the Australian defence industry.

A.10.5 Assessment of impacts

Impacts to date

In summary, the benefits to date of DST Group's research on FPEC include:

— Reduced deaths and injuries to Australian personnel from IEDs.
— Export sales of countermeasures technologies to the US and Afghanistan
— Avoided acquisition and vehicle integration costs
— Savings associated with rehabilitation/dealing with permanent disability
— Avoidance of vehicle damage/destruction
— Enhancement of Force Protection measures and hence maintenance of "freedom of action" for military operations in the presence of the IED threat.

Potential future impacts

DST Group is continues to conduct research and development in the FPEC area. Some recent examples include the work that DST Group is doing to support current operations in Iraq. DST Group is also provides support to domestic security agencies (such as during the G20 summit in Brisbane in November 2014).

In addition, DST Group continues to support and prepare the ADF for possible future areas of operations (including countermeasure techniques, FPEC systems, FPEC test & evaluation, etc.)

A.10.6 Benefits attributable to DST Group

Reduced or avoided acquisition costs

The second element of the project was undertaken in response to an urgent need to respond to a new IED threat to ADF personnel. DST Group was able to rapidly develop and successfully test an enhanced countermeasure technique against this threat suitable for integration in one of the existing ADF systems.

As discussed previously, this enabled savings of at least **$5 million** in avoided acquisition and vehicle integration costs, including in-theatre costs.

Exports

As discussed previously, the contract for the supply of the GREENGUM and GREYGUM countermeasures to the Afghan government is worth approximately $48 million.

Assuming that 20 per cent of this amount is lost from Australian industry due to "leakage" (from the purchase of imported raw materials and components), the value added of this contract to the Australian economy is around **$38 million**.

In addition, a contract to supply 1,000 units of the AN/PLT-2000 V2 personal IED countermeasures system to the US military in 2012 is worth an estimated $10 million.

Again assuming that 20 per cent of this amount is lost from Australian industry due to "leakage", the value added of this contract to the Australian economy is around **$8 million**.

The total benefits of exports that can be attributed to DST Group is therefore around **$46 million**.

Increased capability

The development and deployment of the force protection electronic countermeasures for personnel and vehicles has greatly improved the capability of the ADF to safely deploy its forces in counterinsurgency situations where the use of IEDs were previously dramatically increasing the risk to Australian personnel and equipment. In particular this has allowed "freedom of action" to be maintained for military operations where the IED threat is present. These benefits were not quantified for the assessment.

Lives saved, injuries avoided and equipment destruction/damage avoided

The AN/PLT-2000 V2 is likely to have prevented loss of life and severe injuries to personnel as well as avoidance of equipment damage/destruction from IEDs in the past three years. However, as information on the nature and cause of injuries is not available, no estimate of the benefits from lives saved, avoided injuries and equipment damage has been prepared.

Total Project benefits

Setting aside considerations of inflation and the time value of money, valued conservatively, the quantified value of the various benefits is **$51 million** as shown in Table A.19.

TABLE A.19 – **FPEC ASSESSED BENEFITS**

Project component	Assessed benefit ($million)
Reduced or avoided acquisition costs	5
Export value	46
Increased capability (not quantified)	0
Lives saved, injuries avoided and equipment destruction/damage avoided (not quantified)	0
Total	**51**

SOURCE: DST GROUP AND ACIL ALLEN

B

REFERENCES

ANAO Performance Audit 2003-04 No. 34, 'Wedgetail' Airborne Early Warning and Control Aircraft. (n.d.).

ACIL Tasman and Robert Trenberth. (2003.). *Review of DSTO's External Engagement and Contribution to Australia's Wealth (Vol 2).* Canberra: DSTO.

ANAO Audit Report No.5 2012–13, Performance Audit, Management of Australia's Air Combat Capability–F/A-18 Hornet and Super Hornet Fleet Upgrades and Sustainment. (n.d.).

Anderson, K. (2014). *First Principles Review of Defence: Submission on Defence Science and Technology Organisation.* Majura: DSTO.

Defence White Paper. (2009). *Defending Australia in the Asia Pacific Century: Force 2030.* Canberra: Defence.

Deloitte Access Economics. (2014). *The economic impact of major defence projects.* (unpublished).

DSTO. (2014). *Strategic Plan 2013-2018: 2014 update.* Department of Defence.

DSTO communication. (n.d.). Aide for CERP-I Evaluation. DSTO.

DSTO Communication. (n.d.). *Case study success story: Air-to-Air Weapon Capability Improvement and Life Extension (unclassified).*

DSTO communication. (n.d.). Case Study: P-3 Orion Service Life Assessment Program (P-3 SLAP). DSTO.

DSTO communication. (n.d.). HF Radar MSTC Science and Technology Plan. DSTO.

Fabrizio, G. (2013). *High Frequency Over-the-Horizon Radar: Fundamental Principles, Signal Processing, and Practical Applications* (1 ed.). McGraw-Hill Education.

Main, B. (June 2008). F/A-18A/B – Flaw IdeNtification through the Application of Loads . *Presentation.* DGTA RAAF.

Molent, G., & Swanton, L. (Dec 2014). The DSTO Contribution to the Fatigue Life Reassessment of the RAAF F/A-18 Hornet Centre Barrel Structure. DSTO-TR-3062.

Peever, D. (2015). *First Principles Review.*

Trenberth, R. (2003). *Review of DSTO's External Engagement and Contribution to Australia's Wealth (Vol 1).* Canberra: DSTO.

ACIL ALLEN CONSULTING PTY LTD
ABN 68 102 652 148

ACILALLEN.COM.AU