Assessment of the non-financial benefits of the commercialisation activities of Ploughshare Innovations Ltd

A Report to the Defence Science Technology Laboratory

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SQW

Contents

Executive Summary ..... **i**
1. Introduction **1**
2. Background and approach **2**
3. Economic assessment **8**
4. Benefiting defence and civilian markets **20**
5. Experience of Dstl scientists **27**
6. Towards a balanced scorecard **33**
7. Conclusions **37**

Annex A: Detailed methodology **A-1**
Annex B: List of spin-outs and licensees **B-1**
Annex C: Detailed analysis **C-1**
Annex D: Consultations **D-1**

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Executive Summary

1. SQW was commissioned by the Defence Science Technology Laboratory (Dstl) to undertake an assessment of the non-financial benefits of Ploughshare's commercialisation activities.

Background

2. Ploughshare was established in 2005 as Dstl's Technology Transfer Office to actively pursue the commercialisation of publicly funded research for the benefit of all, whilst supporting Dstl's obligations to MOD. This aligned with the importance attributed to releasing the economic potential of Public Sector Research Establishments (PSREs) through the transfer of good ideas, research results and skills to business and ultimately the UK taxpayer, which was highlighted in the 1999 Baker Report, *"Realising The Economic Potential Of Public Sector Research Establishments"*.

3. However, the process of commercialisation is complex, lengthy and highly uncertain. Dstl technologies come to Ploughshare at low technology readiness levels (TRLs), which means that they require a significant amount of resource to move them towards being market ready, whether through licence deals or spin-outs. A number of factors, including technical constraints, lack of investment and changing markets, can result in honourable dead ends. Moreover, the cycle of development and adoption in potential markets for spin-outs and licensees, such as defence, security and healthcare, can be lengthy.

4. In terms of the financial returns to Ploughshare, therefore, the expected lead times to generating significant income through licence deals and spin-outs can be extensive, for example exceeding five years for licence deals and longer for spin-outs. Against this backdrop of the uncertain process of commercialisation, and the long lead times to potential returns, it is challenging to run Ploughshare as a profitable business.

5. However, the financial benefits represent only one part of the picture, as there are a range of non-financial benefits from Ploughshare's activities. It is these wider benefits that this study seeks to understand. These include:

   - economic benefits (e.g. through company formation and growth resulting in additional economic activity)
   - benefits to the MOD in terms of bolstering UK supply chains in defence and providing new and improved products, and societal benefits if technologies are successfully exploited in other markets such as energy and healthcare
   - wider benefits to Dstl scientists and technical staff as learning from industry engagement is fed back into research and potentially future commercialisation activities.

6. In order to capture the evidence on these benefits, the study has examined available commercial data on spin-outs (e.g. management accounts) and licensees (e.g. royalty fees), and undertaken in-depth consultations with a sample of companies and Dstl staff. Economic benefits have been estimated through modelling employment and economic benefits (in

terms of Gross Value Added, GVA) that are unlikely to have happened without Ploughshare's commercialisation role. The study includes spin-outs and licences that pre-dated Ploughshare's establishment, but which reflect the commercialisation activities undertaken within Dstl prior to 2005.

Economic benefits

7. Our analysis indicates that Ploughshare's commercialisation activities have led to significant economic impacts. Including additional direct and indirect impacts together, the commercialisation activities have led to, or are expected to lead to:

- the creation of around 550 net additional jobs to date (at peak levels), with over 500 jobs in the spin-outs and licensees supported forecast to exist to 2017/18
- the generation of £44m in net additional exports between 2002/03 and 2013/14, with another £179m of exports forecast for the period 2014/15 to 2017/18
- net additional GVA worth over £65m to date (2002/03 to 2013/14) with future GVA forecast to be £126m (over the period 2014/15 to 2017/18) – i.e. resulting in a total GVA effect of over £190 m.

8. In addition, the spin-outs have attracted around £130m in investment from public and private sector sources, and the licensees have invested an estimated £30m into R&D.

9. To put these figures into context, the net cost (i.e. costs less income) to Dstl of funding Ploughshare and the equivalent commercialisation role within Dstl prior to Ploughshare's establishment is estimated to be £7.2m. In understanding the assessment it is important to highlight that some of the effects estimated above have been dependent on further government intervention. In particular, the spin-outs have drawn on government grants (e.g. from Innovate UK) and seed capital from government-backed funds. The assessment has not sought to apportion benefits given the difficulties inherent in doing this. It is important to note that Dstl and Ploughshare provide the ideas at the start of the commercialisation process, which then stimulates subsequent funding to bring about the economic benefits.

Benefits to defence and civilian markets

10. Our analysis has found that Ploughshare's activities have led to several notable wider benefits for both the civilian and defence markets:

- MOD now has access to new defence technologies and capabilities from UK-based firms. These cover a range of technologies including cyber security, armoured vehicles and combatting bio-threat
- there has been evidence of strengthening and enhancement of the UK defence sector supply chain through the development of both technologies and expertise
- the UK has seen the development of new technologies for use amongst the first response and emergency services, improving their overall capabilities. Again, the new technologies cover a range of areas including bio-hazard detection, and the testing of protective clothing.

- new health and well-being products have become available for use in both the defence and civilian markets.

Feeding into Dstl research and subsequent commercialisation

11. A range of benefits were reported by Dstl scientists. Particularly for those with no or limited prior experience of commercialisation, working with spin-outs and licensing activities has significantly improved the awareness of what is required to commercialise ideas, and helped with the development of commercial and research skills. In addition, there was consensus that having gone through a commercialisation experience once (and even on subsequent occasions), scientists are more likely to pursue such activities in the future. Organisationally, some scientists also suggested that this was part of a gradual culture change that is needed to foster more interest and awareness of commercialisation.

12. In addition, for some scientists commercialisation experiences have made them more likely to consider business applications when developing and undertaking research projects, and to draw on industry feedback or networks in developing and undertaking research projects.

13. In terms of personal rewards, the key motivation for scientists is the technical challenge and the potential to see their research applied in products/services that reach the market and make a contribution to defence or civilian life. Whilst not a primary motivator, financial rewards also provide a degree of recognition and 'value' for a scientist's endeavours.

Going forward

14. The feedback from scientists identified a range of barriers to commercialisation and also some solutions to these. This included the following suggestions for Ploughshare, which should be considered as it looks at how it better focuses its resource on commercialisation:

- raising awareness through presentations, perhaps in conjunction with researchers who 'have been there and done it' in order to show the benefits and celebrate success
- related to this, the potential to incorporate some basic introductory training on some of the aspects of the commercialisation processes and how these are implemented
- 'hand-holding' and advising researchers through the process, including through assistance with the industry interface; it was noted that Ploughshare is very good at understanding and helping researchers overcome barriers, and so this is partly a 'business as usual' recommendation and partly about ensuring that researchers are aware of the support that is available
- facilitating the flow of information between industry and Dstl scientists, e.g. asking the questions such as "do you have any technologies/research relevant to market x", though this needs to be done carefully to avoid over-burdening researchers.

15. Finally, the main report includes a series of potential indicators and evidence sources that could be used to inform a balanced scorecard on Ploughshare's performance, recognising that financial performance needs to be considered alongside economic benefits, benefits to MOD and the defence sector, and also benefits to society more broadly

1. Introduction

1.1 SQW was commissioned by the Defence Science Technology Laboratory (Dstl) to undertake an assessment of the non-financial benefits of Ploughshare's commercialisation activities. The specific aims of the study were to:

- estimate the economic contribution of commercialisation, through the establishment of spin-outs and licensing activities, in particular in terms of employment created and Gross Value Added (GVA)
- assess the wider benefits through the application of novel technologies that make a difference in both defence and civilian markets
- assess the benefits to researchers and scientists at Dstl resulting from engagement with industry through spin-outs and licensing activities.

1.2 In addition, drawing on the assessment and wider discussions with senior Dstl and Ploughshare representatives, the study was to make recommendations to inform a 'balanced scorecard' that could be used by Ploughshare to assess its performance in the future. This scorecard was to particularly consider non-financial measures that could be used alongside financial metrics.

Structure of this report

1.3 This report is structured as follows:

- the next section provides the context and background to Ploughshare and an overview of the approach taken to the assessment
- Section 3 provides an assessment of the economic contribution of Ploughshare's commercialisation activities in particular in terms of employment and GVA to date, and the potential future GVA that may be realised, and also through other metrics
- in Section 4, we set out the evidence on the wider benefits to defence and civilian markets, by drawing on case studies of spin-outs and licensees
- Section 5 provides evidence on the wider benefits to researchers and scientists at Dstl, and discusses more broadly the processes of engagement in commercialisation, including the enablers and barriers
- Section 6 discusses the implications from the study for a 'balanced scorecard'
- finally, Section 7 summarises the main findings and conclusions from the study.

1.4 A series of Annexes provide supporting information on the method for calculating the economic contributions (Annex A), a list of the spin-outs and licensees (Annex B), a set of data tables complementing the calculations of the economic contribution (Annex C), and a list of those consulted as part of the study (Annex D).

2. Background and approach

2.1 This section sets out the background to the study and the context within which Ploughshare operates. It also describes the broad approach taken to the work, and this is complemented by a technical annex (see Annex A).

Background

Introduction to Dstl and Ploughshare

2.2 Dstl is a Trading Fund agency of the Ministry of Defence (MOD), established in 2001 following the split of the Defence Evaluation and Research Agency (DERA) into Dstl (which was retained as the public body) and QinetiQ (which was the privatised part of DERA). Dstl exists to ensure that innovative science and technology contribute to the defence and security of the UK. In delivering this purpose, Dstl performs a number of core roles, namely:

- supplying sensitive and specialist science and technology services for the MOD and wider government
- providing and facilitating expert advice, analysis and assurance to aid the decision-making of the MOD and wider government, including as an informed customer
- leading the formulation, design and delivery of a coherent and integrated MOD science and technology programme using industrial, academic and government resources
- managing and commercialising knowledge across the wider defence and security community, and understanding science and technology risks and opportunities through horizon scanning
- acting as a trusted interface between MOD, wider government, the private sector, academia and allies to support military co-operation, capability delivery, diplomacy and economic policy
- championing and developing science and technology skills across MOD, including managing the careers of MOD scientists.

2.3 Employing around 5,000 staff, including over 2,500 scientists, its income is gained entirely through contracts, with turnover in its last financial year at approximately £660m. A large proportion of this comes directly through its MOD research programme of around £400m. Whilst a significant proportion of this is conducted in-house, which in many cases is necessary given the classified nature of the research, 60% is out-sourced to third parties.

2.4 Dstl's research expertise is broad, including both physical and life sciences. The expertise in physical sciences includes areas such as surveillance, advanced materials, armour, cyber solutions and sensors. Expertise in life sciences covers areas such as chemicals, biological detection and vaccines.

2.5 Ploughshare was established in 2005 as Dstl's Technology Transfer Office to actively pursue the commercialisation of publicly funded research for the benefit of all, whilst supporting

Dstl's obligations to MOD. This aligned with the importance attributed to releasing the economic potential of Public Sector Research Establishments (PSREs) through the transfer of good ideas, research results and skills to business and ultimately the UK taxpayer, which was highlighted in the 1999 Baker Report, *"Realising The Economic Potential Of Public Sector Research Establishments"*. Prior to the establishment of Ploughshare as a separate company wholly owned by Dstl, technology transfer activities were undertaken within Dstl.

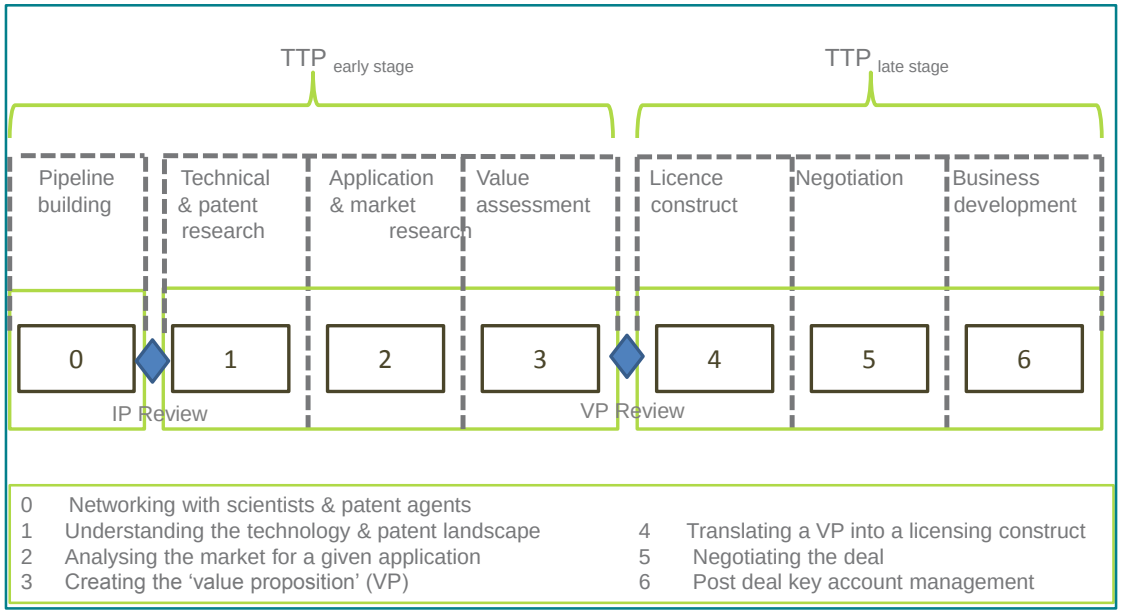
2.6 The aims of Ploughshare are to:

- deliver revenue to Dstl via spin-outs and licensing
- create employment, preferably in the UK
- deliver technology improvements to the market
- provide Commercial Off The Shelf (COTS) technology opportunities.

2.7 In seeking to achieve these aims, Ploughshare engages with scientists and patent agents to identify and develop a pipeline of technologies for review. Following an initial Intellectual Property (IP) review, if there is potential then further technical and market research is undertaken to feed into the development and review of a value proposition (VP). If the VP review shows promise, then Ploughshare will work with scientists and other partners to seek to develop a licensing construct or potential spin-out. The technology transfer process is illustrated in Figure 2-1.

2.8 To give an idea of throughput, Ploughshare currently undertakes around 20 IP reviews per annum across a diverse range of areas, with six to ten reaching VP review stage each year. So far 11 spin-outs have been established (some of which pre-dated Ploughshare's incorporation in 2005), of which two were exited, two failed and seven remain live at varying stages of their development life-cycle. In addition, 115 technologies have been licensed through 50 royalty bearing licence deals.

Figure 2-1: Technology transfer process



Source: Ploughshare

Key issues relating to commercialisation

2.9 The process of commercialisation is complex and highly uncertain. At the outset Dstl scientists are focussed most on their research to meet MOD requirements, rather than in considering commercial exploitation (this is covered in more detail in section 5 of this report), which creates challenges in identifying a pipeline and developing these further. In addition, at the outset Dstl technologies are identified at low technology readiness levels (TRLs), which means that they require a significant amount of resource to move them towards being market ready. In that process, a number of factors including technical constraints, lack of investment and changing markets can result in honourable dead ends.

2.10 Moreover, the cycle of development and adoption in defence and security, key potential markets for spin-outs and licensees, can be lengthy. These markets can be slow-moving, and this alongside large and long-term programmes can result in a slow adoption cycle and a difficult environment. This is particularly the case for spin-outs, but also for licensees that are seeking to develop new technologies. The same can be true in other markets where Dstl technologies may have applications, such as healthcare, which is well-known for the lengthy process of completing relevant trials.

2.11 Establishing and developing spin-outs also requires investors that are prepared to take on high risk, though with the potential for high reward. Ploughshare has worked with government-backed funds such as the Rainbow Seed Fund (RSF) as well as other funds and investors (both publicly and privately backed). It has recently established a partnership with Downing LLP, which will invest up to £5m per year to seek commercial opportunities for further development.

Ploughshare's financial performance

2.12 In terms of the financial returns to Ploughshare, therefore, the expected lead times can be characterised as follows:

- Licensing: fees accrue in early years when licensees take the initial options and when they reach particular milestones. The main royalties (for subsequent commercial sales) take place in later years (after c. five years and beyond) once the technology reaches the market.
- Spin-outs: there is potential for small amounts of royalties if the technology reaches the market (spin-outs normally include a licence for the technology, though the time taken to reach the market varies markedly depending on the technology and market). The main return, however, occurs once the spin-out is exited/sold, which may be 7-10 years or more after establishment. The expectation is that there will be occasional 'star performers' amongst the spin-outs, which may create significant returns for Ploughshare. An important point to note here, though, is that Ploughshare's ownership can become significantly diluted before exit, as new investors are required to progress the spin-outs. There have been only two exits of the 11 spin-outs so far, with others expecting to exit in the next few years.

2.13 Against this backdrop of the uncertain and lengthy process of commercialisation, and the long lead times to potential returns, it is challenging to run Ploughshare as a profitable business. The company has annual costs of around £2m, and turnover of around £1m – meaning a loss

of around £1m per annum. There are two important issues to highlight when considering the financial performance:

- First, Ploughshare is not permitted to take income (from licences) through royalties from sales made to the MOD either directly or indirectly through supply chains. The reasoning for this is that MOD has effectively already paid for the research and it takes the royalty through an equivalent discount provided by its supplier (which is passed through the supply chain if the licensee is not the direct supplier to the MOD). For the public purse there is no net difference; though this affects Ploughshare's bottom line.

- Second, and fundamentally forming the basis of this study, the aims of Ploughshare are not simply to generate a financial return. There are a range of non-financial benefits from Ploughshare's activities, including economic benefits (e.g. through company formation and growth resulting in additional economic activity), benefits to the MOD in terms of bolstering UK supply chains in defence and providing new and improved products, and societal benefits if technologies are successfully exploited in other markets such as energy and healthcare. It is these wider benefits that this study seeks to understand.

2.14 There have been some attempts to change the financial picture, including for example focussing more on licensing, which can be more consistent and stable in terms of income generation. However, this has been at the expense of establishing spin-outs that may have the potential for high returns, and there have been no new spin-outs since 2010.

2.15 The new strategic direction for the company is to become better at identifying and focussing more on the opportunities that are consistent with the need to make commercial returns. At the same time there is acknowledgement of the wider aims associated with contributing to UK economic growth, generating benefits for the MOD, and helping to make a difference to society. There is also a rebalancing of focus, with renewed emphasis on a pipeline of spin-outs, which the partnership with Downing LLP should help to facilitate.

Study approach

2.16 As previously noted, the study's aims were to estimate the economic contribution of Ploughshare's commercialisation activities, in particular in terms of the effects on employment creation and GVA, assess wider benefits to defence and other markets, and examine how experiences of IP exploitation help to develop skills and knowledge of scientists and technical staff.

2.17 This sub-section sets out the broad approach, which follows HM Treasury Green Book logic, and has drawn on wider guidance (e.g. BIS evaluation guidance[1], and Scottish Enterprise guidance on economic impact assessment)[2] to help address the challenges in estimating the GVA contribution of early stage companies and technologies. More detail is provided in Annex A.

[1] Department for Business, Innovation and Skills (2011) *Guidance on Evaluating the Impact of Interventions on Business*, BIS, London
[2] Scottish Enterprise (2008), *Additionality and Economic Impact Assessment Guidance Note*, Scottish Enterprise, Glasgow

Assessing the economic contribution

2.18 The approach to the assessment of the economic contribution has focussed on the key indicators of employment created and an estimate of GVA generated. In both of these cases, we have estimated the effect to date and forecasts (based on projections for up to five years). Other indicators of the economic contribution have covered levels of investment, sales and exports.

2.19 The assessment of GVA generated has drawn on different approaches depending on the varying stages of development of companies or projects being taken forward under licensing deals, and the availability of relevant data:

- For those not yet in sales stages the income approach has been adopted, using employee costs (based on salaries) as a component of GVA. We acknowledge that this may underestimate GVA[3], though this was considered to be the most appropriate and consistent approach given the early stages of some of the spin-outs or the projects being followed under licensing deals.
- For some of those in sales stages, we have: i) drawn on data on turnover and the cost of bought in goods and services (COGS) and estimated GVA as the difference between the two, and ii) used wages + profits. The approach taken for each company (whether spin-out or licensee) has been dependent on data availability.

2.20 Future potential GVA has incorporated available and assumed forecasts for employment (and so employee costs), and turnover and surpluses (for the businesses that are expecting to turn to sales). We have not incorporated the future expected values of companies when they exit. Whilst these may represent a proxy for the downstream value (and so potential income) that buyers of the companies may expect to generate, they are highly uncertain. In any case, for the most substantive exits that are expected in the short-term, forecasts have been included. The main steps in the process of estimating the economic contribution are set out in Table 2-1.

Table 2-1: Estimating the economic contribution of spin-outs and licensees

For spin-outs…	For licensees…
• Collation of financial and other performance data (including business planning forecasts) on the individual spin-outs, covering employment, wages, sales, level of exports, and surpluses. • Consultations with spin-outs to fill gaps in the performance data. • Judgements on the degree of additionality of the spin-outs, i.e. the extent to which they would have been created without Ploughshare's commercialisation role, drawing on consultation feedback. • Judgements on other additionality factors for leakage (based on whether employment activity is located overseas), displacement (based on known/anticipated competitors and markets) and multiplier effects (based	• Collation of available data on royalty fees for licensees, and other relevant background information. • Consultations with a sample of licensees to collect data on employment, wages, turnover, level of exports and R&D investment relevant to the Ploughshare licensing activities, and consultations with Ploughshare staff. • Judgements on the degree of additionality of the licensees supported, i.e. the extent to which they would have generated employment or new sales without Ploughshare's commercialisation role, drawing on consultation feedback. • Judgements on other additionality factors for leakage (based on whether employment activity is located overseas), displacement

[3] If we consider that GVA represents, philosophically, a measure of 'work done', by considering only the market value of employee inputs (i.e. their salaries) we are not taking into account the value that they add to the company's activities (including in conjunction with other non-employee inputs such as the use of capital equipment).

For spin-outs…	For licensees…
on coefficients for relevant sectors drawn from ONS input-output tables). • An assessment of the 'net' economic contribution, drawing on company performance data and judgements on additionality factors. • Evidence estimated at the level of each individual spin-out and aggregated to arrive at an overall estimate of economic contribution.	(based on known/anticipated competitors and markets) and multiplier effects (based on coefficients for relevant sectors drawn from ONS input-output tables). • An assessment of the 'net' economic contribution for the sample of licensees consulted, drawing on consultation evidence on growth stimulated by licensing and additionality. • 'Grossing up' the findings from the sample of licensees consulted to the population of companies supported through Ploughshare's activities – using royalty and other licensee fees and judgements based on feedback from Ploughshare staff.

Source: SQW

2.21 We have collected performance information on all of the spin-outs, and undertaken consultations with all seven of the live spin-outs. One of the two exits has also been incorporated drawing on available estimates from Ploughshare[4], though the two failures have been excluded[5]. We have interviewed 15 licensees (out of c. 40 existing licensees) covering 20 licences, representing a 'response rate' of 38%. In 'grossing up' the findings of our licensee sample, we have calculated the proportion of licensee payments to Ploughshare that our sample accounts for. We have then assumed that the benefits associated with our sample account for this proportion of benefits across Ploughshare's entire licence portfolio. For instance, if our sample of licensees accounts for 50% of all payments to Ploughshare, then the economic benefits also represent 50% of the total economic benefits achieved through all licensing activities. There is clearly some margin of error here, in particular given the concentration of benefits within a small number of licensees (as reported in section 3). However, in absence of further specific data on those licensees that were not interviewed, this represents the best approach.

Wider benefits

2.22 For the assessment of benefits in defence-related and other markets we have used the consultation evidence to inform a series of case studies. These case studies are not intended to be representative of the spin-outs/licensees, rather they set out the types of impact that can be generated for the benefit of the defence sector, and in particular the MOD, and for society more broadly. The findings are presented in section 4.

2.23 The assessment of benefits to Dstl staff has drawn on consultations with scientists and technical staff to explore how the experience of working on commercialisation activities has changed their attitudes and behaviours and/or helped them to develop new skills and knowledge. These findings are qualitative and reported in section 5, along with a series of observations on enabling factors and barriers from the perspective of scientists and technicians.

[4] Acolyte Biomedica was included, as estimates of activity were available. Leading Light was excluded because it was noted that it did not generate substantial activity and no information was available. Its exclusion does not affect the results given the limited scale that it reached.
[5] No data was available on these failures. In any case, they are unlikely to affect the results given the limited scale that they reached.

3. Economic assessment

3.1 This section presents our estimates of the economic contribution of Ploughshare. In doing so, we set out the findings on the intermediate effects covering: levels of investment attracted (for spin-outs, covering both public and private sources), R&D investment leveraged (for licensees), employment, and exports. These effects are reviewed before we present the estimates of GVA, the final economic effect of Ploughshare's commercialisation activities. In this section we present the economic assessment separately for both spin-outs and licensing activity, before providing a summary of the aggregated results at the end.

3.2 For each of the indicators of economic contribution (employment, exports and GVA), the assessment provides estimates of the benefits to date as well as a forecast for the future[6].

3.3 Impacts to date cover the period 2002/03 – 2013/14. This includes spin-out firms and licences that, whilst part of Ploughshare's current (or exited) portfolio, originated prior to the formation of the technology transfer organisation in 2005. We have included the impacts associated with these firms and licences as they represent the commercialisation activity that Ploughshare now delivers, but which was undertaken by an in-house group at Dstl.

3.4 It is important to note that the scale of the *economic contribution to date* reflects both the maturity of the Ploughshare spin-out portfolio and also the protracted nature of commercialising certain technologies (as set out in section 2 of this report). Several of the spin-out companies in the portfolio are still in development and/or on the cusp of moving into substantial sales. Similarly, even those licensees that have started to generate sales through commercialising Dstl technology are in the first few years of doing so. As a result, an assessment of the full economic contribution of Ploughshare is not possible for some time. However, in order to provide as full an account of the economic contribution, we have estimated *forecast benefits* using available data on company projections. Forecasts become more uncertain, the further into the future we go. To provide a realistic assessment, forecasts have been made until 2017/18 (i.e. expected out-turns for the current financial year and then forecasts for three further years) or for spin-outs the anticipated 'exit date' (whichever is sooner).

3.5 Several technical terms are used in this section, and their meanings are presented in Table 3-1. Further detail is provided in data tables in Annex A of this report. Within this, it is important to note that:

- ***for spin-outs*** – estimates have been calculated on an individual company basis, and then summed for the portfolio of eight firms[7]. Further detail on the data supporting this section's analysis is provided in Annex A of this report
- ***for licensees*** – due to (i) the number of licences (50[8]), and (ii) the fact that around two thirds of these are no longer 'active' (i.e. either as all agreed royalties have been paid and/or the IP/technology is no longer being used by the company), we have

[6] Forecasts were not collected for investment or R&D investment.
[7] Ploughshare has been involved with nine spin-out firms and has a current portfolio of seven. Two exiting firms were acquired by external parties, but only one, Acolyte Biomedica, was involved in any operational activity of note. As a result, the assessment in the section focuses on the Ploughshare's live portfolio of seven firms, plus Acolyte Biomedica.
[8] This excludes eight licences used by the spin-out firms to avoid any double-counting.

adopted a grossing-up process to estimate the GVA of 30 of the less active licences. This has involved making appropriate estimates as set out in Table 3-1 for 20 active licences across 15 firms and then grossing-up based upon comparison of the royalties and wider fees achieved through these licences with that achieved for inactive licences. Annex A provides further details regarding the grossing up method.

Table 3-1: A note on key terms

Term	Meaning (spin-outs)	Meaning (licensees)
Gross effect	Overall direct effect, e.g. in terms of employment, made by a spin out(s), before any account is made of the influence of contribution made by Ploughshare and other aspects of 'additionality' (as per row below)	Overall direct effect, e.g. in terms of licence related employment, made by a firm(s), before any account is made of the influence of contribution made by Ploughshare and other aspects of 'additionality' (as per row below)
Additional 'direct' effect[9]	The direct effect of a firm(s), e.g. in terms of employment or GVA, that would not have happened without Ploughshare input, and that takes account of potential displacement* and leakage**	The direct effect of a firm(s), e.g. in terms of licence related employment or GVA, that would not have happened without Ploughshare input, and that takes account of potential displacement* and leakage**
Additional 'direct' +' indirect' effect of Ploughshare	The effect defined the row above plus an estimate of indirect supply chain multiplier effects***	The effect defined the row above plus an estimate of indirect supply chain multiplier effects***

*Source: SQW *in the case of both spin-outs and licensees, displacement occurs when a company's activities/market share brought about through Ploughshare activity are offset (partially or fully) by a resulting reduction in the activities/market share of other UK-based companies*
*** for spin-outs, leakage occurs when a company's employment or research activities take place outside the UK; for licensees leakage occurs when the employment or research activities that have been involved in the licence take place outside the UK*
**** for spin-outs, indirect multiplier effects occur when a firm purchases goods and services in the economy, thereby resulting in second and third round employment and GVA benefits; for licensees indirect multiplier effects occur when the operations involved in developing/commercialising licenced technology require the firm to purchase goods and services in the economy*

Summary of impacts for both spin-outs and licensing activity

3.6 The analysis in this section indicates significant additional direct and indirect impact on employment, exports and GVA that is attributable to Ploughshare's commercialisation activities (see text box overleaf). Whilst some of the spin-outs and licensees expect to increase their employment in future years, the forecast employment is slightly below the aggregated peak of jobs created to date. This is because the peak employment figures to date include a significant number of licences that are no longer active, but for which past employment has been estimated.

3.7 There is an important point to make in understanding the assessment of the economic effects of Ploughshare's commercialisation activities. We have assumed that all direct activity of spin-outs and licensees relating to Ploughshare's commercialisation activities can be included within the assessment. Further growth and development is reliant on other interventions as well (both from public investments such as publicly-backed seed funds and government grants, and private investment). The assessment has not sought to apportion benefits given the difficulties inherent in doing this. It is important to note that Dstl and Ploughshare provide

[9] It is important to note that the average additionality level (excluding multiplier effects) is an arithmetic average across the portfolio of companies assessed. It is not possible to simply use this coefficient to move from 'gross' to 'additional' effect, because additionality varies across the companies (and licensees) and the calculation of the additional effect is affected by the relative significance of each company/licensee.

the ideas at the start of the commercialisation process, which then stimulates subsequent funding to bring about the economic benefits.

Summary of impact across both spin-out firms and licensing activity

- ***Investment:*** *The* ***spin-outs have attracted around £130 million in investment*** *from public and private sector sources, and the* ***licensees have invested around £30 million in R&D***
- **Employment:** Commercialisation activity has led to a peak of **550 (net additional) jobs to date**, *with over 500 jobs in the spin-outs and licensees supported forecast to exist to 2017/18*
- ***Exports:*** *Ploughshare-backed technologies have generated* ***£44 million in net additional exports to date****, with another* ***£179 million forecast*** *for the period 2014/15 to 2017/18*
- ***GVA:*** *Between 2002/03 and 2013/14, commercialisation activity has led to net additional* ***GVA worth over £65 million*** *and future net additional* ***GVA is forecast*** *to be* ***£126 million*** *(over the period 2014/15 to 2017/18) – i.e. resulting in a total GVA effect of over £190 million*

Sub-section (i) Measuring the benefits of spin-outs

Investment

3.8 Overall £130.7m of investment has been committed to the portfolio over a period of 12 years. These combine a mixture of private and public sources of investment. It is not possible to provide an accurate split between public and private investment due to gaps in the data.

Employment

3.9 Here we present the employment associated with spin-out activity. As set out in Table 3-2 and Table 3-3 this is shown in terms of (i) gross employment, (ii) additional direct employment and (iii) additional direct and indirect employment. Employment data is presented across three metrics: maximum employment to date (2013/14); current employment (2013/14); and maximum forecast employment (2014/15 – 2017/18)[10].

3.10 Between 2002/03 and 2013/14, the aggregated peak of gross employment across the eight spin-outs was 255 individuals (FTE). In 2013/14, gross employment for the year stood at 166 individuals across the seven live firms (an average of c. 24 per firm). This observed fall in employment can largely be explained by P2i, which employed around 140 staff 2011/12 falling to around 100 in 2013/14, and the exiting firm, which employed 13 at its peak.

3.11 More generally, the trajectory of employment growth is reflective of both a firm's performance and its maturity in relation to its growth model. Indeed, the early stages of development

[10] Maximum forecast employment (and maximum employment to date) is derived from the maximum anticipated for each company based on available forecasts, and then aggregated for the portfolio (rather than maximum across the portfolio at any one point in time).

activity for most Ploughshare spin-outs firms tend to be undertaken by small numbers of highly-skilled technologists. Once firms near production, capacity is required in-house on a full time basis, meaning that job numbers can escalate rapidly. Indeed, looking beyond 2013/14, Enigma diagnostics, which is at the point of moving into major manufacturing mode, has forecast employment to ramp up significantly over the next two/three years.

3.12 In this context, the 'direct'[11] additional impact on employment is presented in Table 3-2. The employment figures are similar to the 'gross' effects given the high levels of additionality. Extending the analysis, Table 3-3 includes the 'indirect'[12] (i.e. including multiplier effects) impact on employment.

Table 3-2: Additional Direct Impact on Employment

Annual Employment Metric	Total
Maximum employment to date	201
Current (2013/14)	122
Maximum forecast (2014/15 – 2017/18)	255

Source: SQW Analysis of Ploughshare data

Table 3-3: Additional Direct and Indirect Impact

Annual Employment Metric	Total
Maximum employment to date	309
Current (2013/14)	187
Maximum forecast (2014/15 – 2017/18)	400

Source: SQW Analysis of Ploughshare Data

Contribution to export sales

3.13 To date (2002/03 to 2013/14), the eight spin-out firms have, in gross terms, exported £46m of goods and services, with a further £202m forecast for the period 2014/15 to 2017/18. Table 3-4 provides an analysis of the direct additional impact on exports, with high levels of additionality resulting in similar 'additional' effects as 'gross effects'[13].

Table 3-4: Additional Direct Impact on Exports

Export Value Metric	Total
To Date (2002/03 – 2013/14)	£33,558,000
Forecast (2014/15 – 2017/18)	£147,929,000

Source: SQW Analysis of Ploughshare Data

3.14 In the period 2002/03 to 2013/14, P2i Ltd and Claresys accounted for £29m of the quoted total additional direct impact. Forecasts for 2014/15 to 2017/18 are also dominated by a small subset of firms, P2i Ltd, Enigma and Claresys accounting for virtually all (c. £145m) of the total impact. The proportion of export sales of the spin-outs indicates a positive effect on net trade, and means that the companies created are contributing to government's wider rebalancing objectives, which include improving the net trade balance. Indeed, for some firms,

[11] 'Direct' impacts result from the expenditure and operation of the spin-out
[12] 'Indirect' impacts result from the expenditure and operation of suppliers to the spin-out
[13] Multiplier effects are not appropriate here, and so have not been incorporated into the assessment of export sales.

exports account for the bulk of sales, most notably Claresys for whom exports account for 95% of total sales.

GVA contribution

3.15 In the analysis below we present: (i) the gross contribution of Ploughshare activity to GVA, (ii) the additional direct impact on GVA, and (iii) the additional direct and indirect impact on GVA (re-visit Table 3-1 for definitions of gross, direct and direct + indirect). For these measures, we show GVA to date (2002/3 – 2013/14) and forecast GVA (2014/15 – 2017/18).

3.16 In the period 2002/03 to 2013/14, the eight spin-out firms contributed nearly £27m in GVA (gross) to the economy. Available forecasts for the 2014/15 to 2017/18 period from the eight spin-outs sum to under £87m in GVA (gross).

3.17 In this context, the 'direct' additional impact on GVA is presented in Table 3-5. As with the employment analysis, the inclusion of 'indirect' impacts (i.e. multiplier effects) has been estimated. Table 3-6, therefore, presents the additional 'direct' and 'indirect' additional impact on GVA. The multiplier effect estimates the knock-on impact on other businesses because of the goods and services purchased by spin-outs[14]. For example, the core of Enigma's staff are based at Porton Down but the firm purchases a wide range of goods and services including scientific instruments, specialist services and other consumables from across the UK (and overseas). It is these purchases of goods and services from across the UK that the multiplier effect seeks to estimate. This model is adopted by other spin-out firms, especially for those that are still in the early stages of development as well as those operating in fields such as biotech where it is increasingly common for specialist services to be outsourced.

Table 3-5: Additional Direct Impact on GVA

GVA	Total
To Date (2002/03 - 2013/14)	£20,063,000
Forecast (2014/15 - 2017/18)	£64,513,000

Source: SQW Analysis of Ploughshare Data

Table 3-6: Additional Direct and Indirect Impact on GVA

GVA	Total
To Date (2002/03 – 2013/14)	£30,892,000
Forecast (2014/15 – 2017/18)	£99,392,000

Source: SQW Analysis of Ploughshare Data

3.18 The text box below provides a case study for Enigma that is forecast to experience significant growth in turnover, employment (and GVA) over the next 3/4 years.

[14] In practice, multiplier effects have been estimated at the level of the portfolio (rather than the firm) using national sectoral multipliers

Case study – Enigma

Enigma was incorporated in 2004 as part of a public-private-partnership with Government to commercialise Dstl diagnostic technology. The technology (which is called PCR - or polymerase chain reaction - real time diagnostics) has enabled Enigma to develop a rapid molecular diagnostic instrument for testing DNA, viruses and pathogens. The major benefit associated with this equipment is that it is fast, accurate, portable (can be used outside of the laboratory environment) and handles complex diseases which supports decentralised and point-of-care provision.

Recognising the potential value of this diagnostic instrument, Enigma has received substantial investment from the public sector and an overseas venture capital investor in the private sector, and has also secured grant funding from the UK Government and European Commission. Currently the firm employs around 40 people – with almost all of these operating from the firm's main base at Porton Down, whilst the remainder work overseas. To date around 60% of these staff have been scientists focused on testing and developing the technology. The remaining staff are focused on a combination of manufacturing, operations and administration. As the firm expects to start to ramp up sales in 2015/16 employment is expected to grow significantly, and by the end of 2016/17 employment is forecast to increase to around five times current levels. The majority of this employment will be based in the UK, with the remainder operating from the firm's overseas offices including its San Diego office.

Turnover is also forecast to grow significantly over the next three/four years, with the UK and Europe, first, followed by the USA and Asia being the main markets. During 2014, Enigma has announced major transactions evidencing the increasing recognition of the importance of their best-in-class 'ML system' and the expected high demand for the ML system and the diagnostic tests. Evidence to support the validity of these forecasts was provided through a press release in October 2014 setting out a $50m Joint Venture Agreement with China investors and in the partnership with Beijing Leadman Biochemistry to support the growing healthcare needs of China's population.

With applications in the healthcare, defence and veterinary fields, the wider benefits brought about through Enigma's PCR diagnostic instrument have the potential to be seriously significant:

- in healthcare, the system can be used to support the decentralisation of healthcare provision and care 'at the point of use'
- in veterinary medicine, off-site diagnostic testing offers a range of benefits, especially with respect to farming and wider environmental management
- in the military and national security, it has the potential to test for a wide range of pandemic viruses wherever testing is required, whether in hospitals or in required detection locations.

Summary of benefits

3.19 A summary of benefits attributed to Ploughshare's role in establishing spin-outs is provided in Table 3-7.

Table 3-7: Spin-outs: summary of Impact Indicators

Indicator	Additional Direct Impact	Additional Direct + Indirect Impact
GVA to Date (2002/03 – 2013/14)	£20,063,000	£30,892,000
Future GVA (2014/15 – 2017/18)	£64,513,000	£99,392,000
Maximum employment to date (2013/14)	201	309
Current Employment (2013/14)	122	187
Future Employment (2014/15- 2017/18)	255	400
Exports to Date (2002/03 – 2013/14)	£33,558,000	-
Future Exports (2014/15 – 2017/18)	£147,929,000	-

Source: SQW Analysis of Ploughshare Data

Sub-section (ii) Measuring the benefits of licensees

3.20 In this sub-section we present the *grossed-up* estimates of the economic contribution of all licensing activity. This is based upon firm-level analysis covering 20 of Ploughshare's most active licences. Aggregated estimates of economic contribution stimulated by these licences can be found in Annex C.

R&D Investment

3.21 Estimates of the grossed-up investment in R&D by licensees is shown in Table 3-8. Overall, this shows that licensees have invested an estimated £30m into R&D to develop further the technologies licensed from Ploughshare. For the licensees that we spoke to, the estimated amount of R&D investment stimulated was £15.4m (which has been grossed up to over £30m). Just over £10m of this R&D was estimated to be on defence-related activities, with the remaining £5m on non-defence related applications. The consultations with licensees were over-represented by defence-related companies, though taking this into account, licensing through Ploughshare is likely to have stimulated around £15m of private sector investment into defence-related R&D.

Table 3-8: Investment in the licensee portfolio

	Total (grossed up)	Average (n = 37 firms covering 50 licences)
R&D investment to date	£31,037,000	£839,000

Source: SQW

Employment

3.22 Here we present the employment associated with licensing activity. As described in Table 3-9 this is shown in terms of: (i) gross employment, (ii) additional direct employment, and (iii)

additional direct and indirect employment. Employment data is presented across three metrics: current employment (2013/14); maximum employment to date; and maximum forecast employment (2014/15 – 2017/18).[15]

3.23 Gross employment in 2013/14 stood at 90 individuals (i.e. approximately four per firm)[16]. Interestingly, the trajectory of employment growth differs from the one observed for spin-outs – this is explained by the fact that a large proportion of activity remains focused on R&D (rather than production and sales), meaning that employment activity is characterised by small, focused research teams. For four of the firms in our sample there was no employment effect as either staff were based overseas or no decision had been made to take up a licence. Across the 15 firms and 20 licences assessed in detail, Thales (RESM technology) exhibited the highest level of both current and forecast employment.

3.24 In this context, the 'direct'[17] additional impact on employment is presented in Table 3-9. The 'additional direct' estimates of employment are somewhat lower than the gross effects, which reflect that some of the employment would have happened anyway. Extending the analysis, Table 3-10 includes the 'indirect'[18] (i.e. including multiplier effects) impact on employment. As can be seen, forecast employment is significantly lower than the maximum peak for the period to 2013/14. This reflects two issues: i) for the current licensees only modest increases in employment are expected over the next few years with most remaining fairly constant; and ii) many of the licences included in the analysis for the 2002/03 to 2013/14 period are inactive and are not forecast to generate any royalties in the future, and so the forecast employment levels are based on a smaller number of licensees.

Table 3-9: Additional Direct Impact on Employment

Annual Employment Metric	Total	Average (n = 37 firms covering 50 licences)
Maximum employment to date (2002/03 to 2013/14)	137	3.7
Current (2013/14)	57	1.5
Maximum forecast (2014/15-2017/18)	68	1.2

Source: SQW Analysis of Ploughshare data

Table 3-10: Additional Direct and Indirect Impact

Annual Employment Metric	Total	Average (n = 37 firms covering 50 licences)
Maximum employment to date (2002/03 to 2013/14)	238	6.4
Current (2013/14)	99	2.6
Maximum forecast (2014/15 – 2017/18)	116	2.1

Source: SQW Analysis of Ploughshare Data

[15] Maximum forecast employment is derived from the maximum anticipated for each company based on available forecasts, and then aggregated for the 15 licensees (rather than maximum across the portfolio at any one point in time).
[16] Please note that this excludes some 43 individuals that were employed in 2007/08 and 2008/09 by Morgan Composites. It also excludes staff employed by licensees that are wholly based outside of the UK – we did not collect specific employment data for these companies as there was no net economic contribution to the UK given their location.
[17] 'Direct' impacts result from the expenditure and operation of the licensee
[18] 'Indirect' impacts result from the expenditure and operation of suppliers to the licensee

Contribution to exports

3.25 The estimates of exports relating to licensing activity need to be treated with caution, because there was limited evidence on exports from the licensees that were consulted. Therefore, our 'grossing up' of findings is based on a small sub-sample. With this caveat in mind, to date (2002/03 to 2013/14), licensing activity has, in gross terms, exported an estimated £25m of goods and services, with a further £65m forecast for the period 2014 to 2018. Table 3-11 provides an analysis of the direct additional impact on exports[19]. This indicates that a reasonable proportion of exports would have happened in any case, which reflects that for the licensees that have exported so far, the level of additionality is low compared to the rest of the licensees consulted.

Table 3-11: Additional Direct Impact on Exports

Export Value Metric	Total	Average (n = 37 firms covering 50 licences)
To Date (2002/03 – 2013/14)	£9,945,000	£269,000
Forecast (2014/15 – 2017/18)	£31,141,000	£842,000

Source: SQW Analysis of Ploughshare Data

3.26 In the period 2002 to 2013, AmSafe accounted for around one-half of the quoted total impact. Forecasts for 2014/15 to 2017/18 are also dominated by a small subset of firms, with Thales and AmSafe accounting for c.82% of the total impact between them.

GVA contribution

3.27 In the analysis below we present: (i) the gross contribution of Ploughshare licensing activity to GVA, (ii) the additional direct impact on GVA, and (iii) the additional direct and indirect impact on GVA (please re-visit Table 3-1 for definitions of gross, direct and direct + indirect). In doing so, we show GVA to date (2013/14) and forecast GVA (2014/15 – 2017/18).

3.28 In the period 2002/03 to 2013/14, the licensing activity contributed approximately £37.5m in GVA (gross) to the economy. Available forecasts for the 2014/15 to 2017/18 period sum to £27.1m in GVA (gross).

3.29 In this context, the 'direct' additional impact on GVA is presented in Table 3-12. As with the employment analysis, the inclusion of 'indirect' impacts (i.e. multiplier effects) can be considered. Table 3-13, therefore, presents the additional 'direct' and 'indirect' additional impact on GVA. The multiplier effect estimates the knock-on impact on other businesses because of the goods and services purchased by licensees[20]. For example, around a fifth of BBI's investment to commercialise licenced technology has substantially involved two supplier firms: an external specialist design firm and a plastics manufacturer – both of which are based in the UK.

[19] Multiplier effects are not appropriate here, and so have not been incorporated into the assessment of export sales.
[20] In practice, multiplier effects have been estimated at the level of the portfolio (rather than the firm) using national sectoral multipliers

Table 3-12: Additional Direct Impact on GVA

GVA	Total	Average (n = 37 firms covering 50 licences)
To Date (2002/03 - 2013/14)	£19,149,000	£518,000
Forecast (2014/15 – 2017/18)	£14,932,000	£404,000

Source: SQW Analysis of Ploughshare Data

Table 3-13: Additional Direct and Indirect Impact on GVA

GVA	Total	Average (n = 37 firms covering 50 licences)
To Date (2002/03 – 2013/14)	£33,826,000	£914,200
Forecast (2014/15 – 2017/18)	£26,244,000	£709,000

Source: SQW Analysis of Ploughshare Data

3.30 An example of a licensee that is forecast to generate significant levels of GVA is provided in the text box below.

Case Study – Tata Steel and steel armour

Tata Steel is a multinational steelmaking company whose European division has UK based research facilities. The firm's engagement with Ploughshare has to date lasted four years. Tata has been keen to become more involved in the defence market and, as such, they have signed a licence agreement with Ploughshare for access to some of Dstl's steel armour technology.

The arrangement has been beneficial both to Dstl and to Tata. Dstl had intellectual property associated with steel armour but neither the resources nor expertise to manufacture the technology. Conversely, Tata Steel had the steel making capabilities but none of the technology or military testing know-how. Dstl scientific researchers remain involved in product development, while Tata has also transferred some of its own IP to Dstl. Licencing and sharing the IP was felt to be an obvious basis for a combined approach to exploit the technology.

Signed in 2010, the licence has already generated small product sample sales worth around £150,000 (FY2013) through sales to armoured vehicle development programmes, drawing on the Dstl technology. The operation is an entirely UK-based one, with manufacturing based at a site in Port Talbot. The deal has also brought benefits to the wider supply chain, with Tata having worked alongside a number of armour integrators in order to develop their product.

The real benefits of the deal are more likely to materialise in the future. Current plans centre on providing up armour to entire fleets of vehicles to the military – Tata representatives believe that such deals could yield multi-million pound benefit to a UK based supply chain. In addition, the Indian defence market remains an opportunity which could be exploited drawing on contacts through Tata Group.

There will also be an additional benefit to the UK in terms of providing the country with on-shore sovereign capability in armour steel.

Summary of benefits

3.31 A summary of benefits attributed to Ploughshare's licensing activity is provided in Table 3-14.

Table 3-14: (i) licensees: summary of Impact Indicators

Indicator	Additional Direct Impact	Additional Direct + Indirect Impact
GVA to Date (2002/03 – 2013/14)	£19,149,000	£33,826,000
Future GVA (2014/15 – 2017/18)	£14,932,000	£26,244,000
Maximum employment to date (2002/03 – 2013/14)	137	238
Current Employment (2013/14)	57	99
Future Employment (maximum to 2017/18)	68	116
Exports to Date (2002/03 – 2013/14)	£9,945,000	-
Future Exports (2014/15 – 2017/18)	£31,141,000	-

Source: SQW Analysis of Ploughshare Data

Bringing sub-sections (i) and (ii) together: summary of benefits

3.32 The analysis reveals significant additional direct and indirect impact on employment, exports and GVA attributable to Ploughshare's commercialisation activities. A summary of key figures is provided in Table 3-15.

3.33 As is evident from the analysis set out in this section, a high proportion of the economic impact is generated by the spin-outs (c. 80% of GVA to date and over 95% of forecast GVA). This reflects the significant contribution made by a small number of the spin-outs, with two employing c. 160 between them.

3.34 To put these figures into context, the net cost (i.e. costs less income) to Dstl of funding Ploughshare and the equivalent commercialisation role within Dstl prior to Ploughshare's establishment is estimated to be £7.2m[21]. Some caution is required in estimating a value for money ratio based on GVA benefits to these net costs for two reasons. First, the £7.2m represents net costs rather than the full costs of funding the commercialisation activities. Second, as highlighted earlier in this Section, the achievement of benefits is also reliant on subsequent investment (including from the public sector through research and development grants and seed capital), with Dstl/Ploughshare ideas and commercialisation representing the start of the process.

[21] This is based on information provided by Dstl on the current inter-company balance, which has been projected backwards to incorporate an estimate of net costs prior to Ploughshare's establishment.

Table 3-15: (i) Spin-outs and (ii) licensees combined: summary of Impact Indicators

Indicator	Additional Direct Impact	Additional Direct + Indirect Impact
GVA to Date (2002/03 – 2013/14)	£39,212,000	£64,718,000
Future GVA (2014/15 – 2017/18)	£79,445,000	£125,636,000
Maximum employment to date (2002/03 – 2013/14)	338	547
Current Employment (2013/14)	179	286
Future Employment (maximum to 2017/18)	323	516
Exports to Date (2002/03 – 2013/14)	£43,503,000	-
Future Exports (2014/15 - 2017/18)	£179,070,000	-

Source: SQW Analysis of Ploughshare Data

4. Benefiting defence and civilian markets

4.1 This section examines some of the wider benefits associated with the commercialisation of technologies, particularly with regards to defence and civilian markets.

4.2 Drawing on information gathered through consultations with individual spin-outs and licensees, and discussions with Ploughshare account managers, it highlights that activity in the physical sciences has brought important benefits to the defence market, whilst life science technologies have had (or are expected to have) an impact in civilian markets.

4.3 A number of the positive impacts of the technologies have been seen already, and others have a strong likelihood of being seen in the near future.

Benefits to the defence market

4.4 Technologies commercialised through Ploughshare have brought about two important benefits to the UK defence sector: an improvement to the country's defence and security capabilities, and developments to the UK supply chain.

UK based defence capabilities

4.5 In several instances, Ploughshare has helped to instigate activity that has enabled UK firms to develop technologies which MOD would ordinarily have had to source from abroad. Aside from helping to keep the economic benefits of Ploughshare's activities within the UK, this is also important from a strategic defence perspective insofar as it helps provide the UK with independent defence capabilities.

4.6 Examples of Ploughshare-supported technologies that have been purchased by MOD are provided below.

- Steel armour: following a licence arrangement between Ploughshare and Tata Steel, MOD now has access to an off-the-shelf steel armour capability. This provides UK based sovereign capability. Previously, the MOD had to turn to French and Swedish manufacturers to obtain similar technology.
- CDCAT: a licence agreement gave APMG, who are an examination institute, accreditation body and certification body for cyber security and IT assurance products, access to technology regarding cyber security. APMG is investing in an IT platform and refining the product further with knowledge and expertise from Dstl. Although primarily aimed at the non-defence market, APMG is developing a version that will also support classified use for Government users including MOD.
- Ceramic armour: a technology licenced by Ploughshare to Morgan Composites and Defence Systems has led to the development of a ceramic armour system for vehicles. The system has subsequently been purchased by MOD with the British armed forces using the technology extensively in Afghanistan (see case study box below for more details).

Case study – Morgan Composites and Defence Systems and Ceramic Armour

Established 40 years ago, Morgan Composites and Defence Systems (formerly NP Aerospace and now part of Morgan Advanced Materials plc) is a composites engineering firm that provides solutions across the commercial and defence markets.

The firm has had a licence arrangement with Dstl (via Ploughshare) over the last 6-7 years, for the use of specialist ceramic technology in vehicle armour systems. Ceramic based amour has a lower weight and volume than more traditional steel armour, making it particularly effective in vehicle and other applications.

The escalation of the war in Afghanistan prompted demand for narrower and lighter vehicles – for deployment on urban operations. Dstl approached the Morgan with a view to developing armour for the Ridgeback patrol vehicle - a key vehicle being procured for use in Afghanistan.

In 2008/09, Morgan Advanced Materials generated around £15 million in sales of the technology to the UK government to help service the needs in Afghanistan. All their operations have been UK-based with some 200 people having been involved in the development of the technology. According to representatives from Morgan Advanced Materials, Ploughshare has played an important role in facilitating bringing the product to market. Without the technology, the firm could not have developed as capable an armour system.

Defence markets are notoriously lumpy, being shaped by the timing and nature of global conflicts. Nevertheless, Morgan continue to invest in their technology portfolio and remain open to licensing further technologies from Ploughshare in the future.

4.7 Even where Ploughshare has supported non-UK based firms, there are potential defence benefits for the UK. For instance, one of the main effects of Ploughshare's licence arrangement with US-based Pharmathene for plague vaccines has been to provide the UK access to a new off-the-shelf product from an allied nation.

Strengthening the defence supply chain

4.8 Drawing on Dstl sources, 60% of MOD's research is out-sourced to the wider supply chain. Our study has shown that some of the Ploughshare supported technologies have had a positive impact on defence supply chains:

- Tata Steel: steel armour itself is of relatively little use. The technology needs to go to armour integrators that use the raw materials to create a final product which can be sold to MOD amongst others. As such, the licence arrangement will not only be beneficial to Tata but to armour integrators as well. Indeed, Tata has worked with MTL Armour Systems to help turn the technology into a sellable product.

- APMG and CDCAT: APMG has developed versions of the software for both defence and civilian usage with the aim being to supply as wide a market as possible. The technology therefore has the potential to improve security across all of MOD's supply chains which in turn will benefit MOD.

- DuPont and BABT test rig: DuPont, a firm leading in market-driven innovation and science, is exploring the use of the BABT rig to develop new standards for personal ballistic protection. The Ploughshare licence provides DuPont with access to Dstl testing equipment and historical data. DuPont aims to provide plans for rigs as well as participating in user groups to recommend revised testing procedures. By increasing awareness of their research, other material suppliers and body armour manufacturers will gain access to realistic testing methodology.

- Claresys: formed as a spin-out in 2008 in order to commercialise world-leading camera lens technology (see case study below).

Case study – Claresys

Claresys was formed as a spin-out in 2008 in order to commercialise and supply the MOD with world-leading camera lens technology to be used in covert- surveillance activities. The firm was also supported from the outset by the Department for Defence in the USA.

The technology was originally developed at Dstl's Fort Halstead site in Kent, but in order to access key skills and markets the firm is now based in Didcot in South Oxfordshire.

Using Dstl licences, Claresys has developed two core products:

Compact Optical Scanning Enhanced (COSE) Pinhole Lenses

Using a patented internal optical scanning arrangement, COSE pinhole lenses offer pan, tilt and zoom (PTZ) capability with no external moving parts, allowing them to scan and zoom onto any target within the instantaneous field of view of the lens.

Flexible Alignment (FA) Pinhole Lenses

Claresys' FA lenses use novel optical technology to overcome issues associated with the sensitivity of pin hole lenses and their 'detectability' in covert surveillance operations.

Ploughshare was instrumental in the formation of the spin-out, helping to attract investment from the Rainbow Seed Fund, and has recently sponsored the negotiations to secure funds from Downing LLP.

As of 2014/15, 95% of Claresys' sales are exports. The USA make up two-thirds of all exports, while Europe and Asia make up the remaining third. Customer markets include investigatory policing, counter terrorism and criminal agencies. In a similar vein, whilst is very hard to evidence the impact of the firm on wider society, it was explained by the CEO that:

> *'people's lives can literally be on the line when using our products – our security customers have very limited budgets so the fact that they carve out the funds for our specialist equipment demonstrates*

the value placed on its use – we know that they have saved lives through the use of our equipment, it's just impossible to evidence'

Claresys has a number of competitors, but none are based in the UK and none can offer the COSE and FA technology. The fact that the USA Government supported the development of the firm and with the USA also Claresys' largest export market underlines the world-leading nature of the technology involved.

Looking forward, Claresys is forecast to grow to treble in staff numbers by 2018 with turnover increasing more than 50% year-on-year. Whilst the specialist nature of the firm means that it is unlikely that it will ever grow to a huge scale, its wider value to society in the UK and allied nations is notable.

The civilian market

4.9 In addition to the defence market benefits, the activity brought about by Ploughshare has also generated benefits for civilian markets, most notably in relation to the emergency services, and the public health industry.

Benefits for the first response / emergency services

4.10 Some of the technologies developed as result of the spin-outs and licences are likely to have benefits for the law enforcement industry:

- DuPont and the BABT test rig: as noted by one of the Dstl researchers who has worked alongside DuPont, the rig will have real future potential in testing the effect of bullets on body protection equipment for police forces (as well as military users).
- BBI and IMASS lateral flow: BBI's licence arrangement with Ploughshare has given them access to technology surrounding the detection of bio threats and explosives. The IMASS device will offer UK 'first response' emergency services new capabilities, especially with regards to identifying biological and explosive threats, and gathering DNA evidence (see case study box below for more detail, including wider benefits to emergency services).

Case study – BBI Detection and the IMASS lateral flow device

BBI is predominately a UK based firm employing around 400 staff. The firm, which is owned by Alere, a large USA based diagnostics firm, has its head office in Cardiff. BBI also has a large research facility located in Dundee, and also operates from Dstl's Porton Down site. In 2008, BBI opened its first facility in the USA in Wisconsin.

As a supplier to MOD, BBI has a long standing relationship with Dstl and, through operating on the Porton Down site, has worked extensively with Dstl researchers on a range of diagnostic technologies. The BBI Group splits into three divisions: BBI Solutions, BBI Healthcare and BBI Detection. BBI Detection was established in 2010 to specialise in the development and supply of innovative technologies for rapid sampling and identification of bio threats and explosives. One of the key

technologies commercialised by BBI Detection has been the IMASS lateral flow device developed in partnership with Dstl. The milestones involved in this process were as follows:

- in 2004/05 a senior member of Alchemy Laboratories, now BBI Solutions, approached a Dstl scientist working in bio-detection to discuss the potential of developing a new ergonomic lateral flow device to be used in the detection of 'white-powder' bio-threats
- in 2006/07 working closely with BBI, the Dstl scientist developed the lateral flow device prototype
- working with Dstl, Ploughshare patented the 'IMASS device' in 2008
- following BBI Detection's formation in 2010, the firm took up the licence to develop and commercialise the IMASS device
- in 2012 BBI Detection successfully launched the IMASS device.

The IMASS device, source: http://www.bbidetection.com/about-us/

As of 2014, sales of the device have grown to around 1,500 per annum and demand for the device has the potential to increase exponentially over the coming years. Indeed, there are plans to launch a variant of the device that can to be used to detect explosives in 2015, whilst exploratory work is underway regarding a variant for molecular application.

The IMASS device has the potential to transform the way that 'first response' emergency services in the UK and abroad identify biological and explosive threats and gather DNA evidence. The challenges associated with realising this potential relate to education and training. Staff using the device need to be trained so that they: (i) use it correctly, (ii) can interpret results within the context of the operating environment, and (iii) understand the protocol for dealing with a positive result.

Health and well-being

4.11 Elsewhere, some of the technologies commercialised through Ploughshare have helped develop products which are expected to have positive effects on public health and well-being. In addition to Enigma, which has developed diagnostics that can be applied in healthcare and veterinary work as well as defence (see case study box in Section 3), the following provide further examples of the wider benefits in health and well-being:

- Pharmathene: this US-based firm has licensed plague and anthrax vaccines that Dstl has developed in their Biomedical Sciences department. Pharmathene has progressed these further still towards product licensure. Although primarily designed to protect troops form biological warfare, the technologies can also be applied to the civilian world if ever needed.

- Droplet Measurement Technologies (DMT) and WIBS: Ploughshare has established a license agreement with the US-based instrument manufacturer DMT, providing DMT with access to technology related to mould and bio-aerosol detection. DMT is currently working with leading companies for use of this new instrument related to bio-aerosol detection and indoor air quality. Although primarily a US-based operation, DMT has sales to the leading research institutions worldwide.

- Cobra Biologics: Dstl worked extensively with Cobra to support the testing and development a new 'expression system' (the ORT VAC technology). The system allows drug combinations to remain 'stable' in a form that can be taken orally, but can also be used for DNA purposes. The untested ORT VAC technology was owned by Cobra Biologics, but they needed the equipment, skills and regulatory clearance of Dstl laboratories to help prove the technology as a viable method for delivering an oral vaccine. With the vaccine capable of being produced on a mass scale, at a consistent quality and at low cost, the expression system has the potential to significantly improve the international response to large scale outbreaks of disease and bacterial infection. All Dstl rights to ORT-VAC were sold to Prokarium Ltd, a spin-out from Cobra, in 2013 and Prokarium is now developing oral vaccines based in part on ORT-VAC.

- ProKyma: Established as a spin-out in 2006 using ultrasound technologies developed for biothreat detection, the original focus was improved molecular detection of bacterial cells in civilian applications. The initial idea was feasible on small volumes, but could not scale up to be of practical use. A new approach was developed to capture the targets of interest by combining magnetism with ultrasound. This was found to be effective in a flow through format, processing the appropriate volumes, and resulted in a patent. The early consortium of five investors have reached their investment limit and were joined by the NWFund Biomedical in 2013, supporting a £0.5m grant from the National Institute for Health Research. This project builds on the company's expertise in molecular detection assays to improve measurement of cancer cells in blood. The company is focusing on two applications: i) measuring cancer cell numbers in real time as a response to treatment; and ii) screening and spotting secondary cancers well before it is possible to do so currently.

Other markets that may benefit

4.12 Although the first response and health sectors are the civilian markets most likely to benefit from Ploughshare activity, other sectors may also benefit from new technologies. For example, one of the spin-outs, SALT, sees one of the major customer groups for its Passive Underwater Beacons technology as being the oil and gas industry. They can use the technology to make sonar usage more effective, particularly to help find new and existing assets.

4.13 Another example from the portfolio of spin-outs, is the application of technologies originally designed for defence in consumer markets, as shown by the example of P2i below.

Case Study: P2i

P2i Ltd has developed advanced coating processes for consumer electronics, enhancing fluid protection without compromising the weight and usability. P2i's founders developed the technology in collaboration with MOD, initially being developed for military purposes to improve the performance of front line battledress. It was established as spin-out from Dstl in 2004.

In recent years, P2i's work has concentrated on the waterproofing of consumer electronics. Initially they focussed on protecting hearing aids, moving on to smart phone protection in more recent times. Although the majority of their markets are overseas (primarily Asia and South America), the firm's R&D operations remain predominantly UK based, employing approximately 70 people at present.

P2i has seen steady year-on-year rises in revenues since 2009 and is expecting to become a profit generating business in the near future. The firm is also looking to expand into alternative markets, most notably wearables.

According to the firm, Ploughshare has played an important role in the firm's development. This was especially true in P2i's early development, helping to provide a commercial focus as well as guidance on how to secure external funding. As the firm has matured, Ploughshare has played a less prominent role, though it still provides input, in particular through its role as an observer on the company's board.

Summary

4.14 The main civilian and defence market benefits generated as result of Ploughshare's activities are summarised below:

- MOD now has access to new defence technologies and capabilities from UK-based firms. These cover a range of technologies including cyber security, armoured vehicles, and bio-warfare products
- the strengthening and enhancement of the UK defence sector supply chain with both technologies and expertise alike filtering down across the sector
- the development of new technologies for use amongst the first response and emergency services, improving their overall capabilities. Again, the new technologies cover a range of areas including bio-hazard detection, and the testing of protective clothing
- the availability of new health and well-being products for use in both the defence and civilian markets.

5. Experience of Dstl scientists

5.1 This section sets out the evidence on the experiences of Dstl scientists in engaging in commercialisation activities, and the benefits that they have got from these experiences.

Background to consultees

5.2 Seven scientists were interviewed as part of this assessment. Several had had a number of engagements with spin-outs and/or licensees spanning a long time period, including some that pre-dated Ploughshare's formation. There was also a mix of current positions, with some consultees now working in the Corporate Centre at Dstl, and others continuing to work as scientific researchers.

5.3 Prior exposure to industry and commercialisation varied amongst those consulted, indicating that there is no particular type of background of researcher that leads on to engagement in commercialisation. This is illustrated as follows:

- Some of those consulted have had long-term research-focussed careers at Dstl. Prior to their first engagement in commercialisation activities at Dstl, their previous engagements with industry had been on an ad hoc basis, e.g. to use pieces of equipment, to take part in specific training led by an industry partner, or because they used compounds purchased from industry. For these individuals, therefore, the first spin-out or licensing experience was unknown territory.
- One consultee had worked in academia and in this environment had gained experience of IP – this individual has been particularly active on licensing at Dstl. Another consultee also had prior experience in commercialisation from previous roles in software development in the telecommunications industry and in the defence industry.

Experience of working with Ploughshare

5.4 Those consulted were positive about their engagements with Ploughshare, though as stated above it is important to note that several experiences of commercialisation pre-dated Ploughshare's existence. The following key points are noted from the experience of working with Ploughshare:

- One consultee particularly highlighted that Ploughshare had a very good understanding of the constraints and barriers facing researchers, in particular issues around dealing with industry partners (including for the first time and in how to address sensitive aspects such as IP), and the constraints on time. In this regard a second consultee also reported the support provided by Ploughshare, e.g. on technical paperwork.
- Related to this, the industry interface provided by Ploughshare, including making introductions, being proactive and suggesting next steps had genuinely been appreciated, and had given confidence to the researchers involved.

- And in terms of the realism of the commercialisation process, Ploughshare's acknowledgement and communication that commercialisation can take a long time, and be a complicated process was also noted as being the right approach. On this particular point, one consultee could not envisage how Ploughshare would be able to provide greater focus to its commercialisation activities given the high degree of uncertainties.

5.5 One frustration was raised, which was when decisions were taken to sell IP rights to a particular technology, which had closed off avenues to exploit this further for commercial gain. The lesson here is perhaps one of communication to researchers as to why commercial decisions had been taken.

5.6 A final point, to which we return in the last sub-section of this chapter, was the lack of visibility of Ploughshare amongst Dstl researchers. The experience of engaging with Ploughshare for one consultee had effectively 'come out of the blue'; whilst the researcher in question rationalised this as Ploughshare looking at potential technology applications behind the scenes, a question was raised as to whether they could do more to raise their profile and the profile of commercialisation opportunities.

Benefits to scientific researchers

5.7 Benefits from engagement in commercialisation activities are broad, and fall into four main categories. These were varyingly referred to by the consultees. The four categories, which are discussed in more detail below, are as follows:

- personal rewards
- development of technical skills, experiences and attitudes that may help with future commercialisation
- benefits relating to industry
- organisational benefits.

Personal rewards

5.8 The primary personal reward (and also personal motivation) for researchers being involved in commercialisation activities was the effect that it has on their job satisfaction. Technically the process of assisting with commercialisation is interesting and challenging. When a researcher sees a technology concept taken to market, this is rewarding, even if this takes nearly 20 years (see case study box below). This process of technical challenge and reward when a researcher sees their technology enter the market potentially reflects the 'self-actualisation' motivation for a scientist.

Case study: Scientist A

In the early stages of his career (c. late-1990s) Scientist A developed a test rig for assessing the threat from high-velocity bullets even though they had been stopped by body armour. UK military operations in Iraq and Afghanistan initiated further work in developing new body armour and assessment methods, including the test rig, which was then considered a research tool. With increasing interest in the test rig, in 2010 it was presented at a conference led by a chemicals company which manufactures armour materials. This company has subsequently taken an exclusive licence to develop the test rig from a research tool to what is hoped may be an industry accepted standard. With a prominent industry leader involved, it is hoped that commercial sales will follow. This is very satisfying for Scientist A, in particular for research that they did right at the start of their career and the work had remained largely untouched for nearly 20 years.

Whilst developed for military-specific armour testing, the technology may also have uses in the civilian environment, e.g. body armour for police forces and for understanding more about bullet-related non-lethal blunt injuries.

5.9 The financial rewards appear to be a secondary motivation for most of the researchers interviewed. It was seen as a 'nice-to-have', but not fundamental; though they also commented that it should be maintained. Those with prior experience of commercialisation were more likely to highlight the importance of financial rewards. *"The Reward to Inventors scheme was important"* for one consultees, who benefited from this. The actual reward itself was important, though it is more about what the monetary payment symbolises, which is the real recognition of value that a researcher has contributed towards.

5.10 Clearly, the importance of financial rewards vary from person to person; for scientific researchers they are less important, though are symbolically critical. Though based on limited numbers of those interviewed, the financial motivation may be stronger for those with prior experience of commercialisation, and who may in their nature be more commercially-minded and have a higher enterprising tendency.

Skills, experience and attitudes

5.11 Several researchers highlighted the skills and experiential benefits gained from working with industry on commercialisation opportunities. There are three particular elements to this.

- First, scientific researchers reported increasing their awareness of what was needed to commercialise, including the challenges in the process, the timescales and the often slim chances of getting to market. This 'awareness-raising' was particularly a benefit for those new to commercialisation.
- Second, some of those interviewed referred to improving their skills, for example in giving presentations, improving knowledge of financial and legal aspects of IP and companies, and in specific skills (e.g. one consultee described the experience of undertaking research in a hospital laboratory environment, which they drew on when doing subsequent work on diagnostics for field hospitals and being able to contextualise what lead times to results would mean).

- Third, there have been attitudinal changes, in that some of those consulted indicated that they were more likely to think about commercialisation opportunities in the future. This applied to both those who were new to commercialisation and those with prior experience.

Case study: Scientist B

Scientist B has been an employee at Dstl (and predecessor organisations) since 1992, and has been involved in three licences and one spin-out (all relating to vaccines), the first in the early 2000s. Prior to these, the scientist had not been involved in commercialisation. Through their experiences, they have a much improved level of awareness and knowledge of commercialisation processes, challenges and lead times. In addition, the scientist indicated that they are more likely to become involved in future opportunities as a result, and has explored other opportunities, e.g. working with veterinary vaccine firms.

5.12 Skills and experiential benefits can contribute to personal benefits for researchers in terms of their own career progression. In particular, two consultees commented that their commercialisation experiences had helped to develop their experience and skillset that has now made them more marketable.

Industry-related benefits

5.13 There was variation in the feedback on benefits relating to on-going engagement with industry. Those who had had prior exposure to commercialisation and/or working for industry noted that their experiences would make them more likely to consider business applications when developing and undertaking research projects, and would also draw on industry feedback or networks in developing and undertaking research projects. Indeed, one of the scientists consulted indicated that this is likely to become more important for them going forward. As a result, their knowledge gained from working with industry would make them more able to deal with the challenge of developing much stronger relationships with industry and overcoming issues relating to the sensitive nature of their work.

5.14 Others could not envisage drawing on industry feedback for their research. This may reflect the very early stage development work that they are involved in. for which there is very limited flexibility. Despite this, other benefits were noted, in particular:

- New people/networks: researchers have made contacts that they would not have done otherwise, and have kept in touch with them subsequently. This could lead to real benefits, with one consultee citing an example of a contact that now runs an antibody company that could be a source for future engagements as a supplier.

- Appreciation of the 'hand to mouth' existence of start-ups: this has meant a greater understanding of the importance of not delaying contracts when working with start-ups/small companies because they are much more reliant on the cash. One scientists stated that, *"whilst this can always be told to you, you never quite appreciate it until you experience it yourself."*

Organisational benefits

5.15 Three long-standing employees at Dstl (and predecessor organisations) also referred to the organisational benefits for Dstl. There were three aspects to this:

- One scientist indicated that the main motivation for supporting the commercialisation of research was to provide some degree of payback to the MOD by recouping a proportion of the research costs in financial returns or value.
- There was also recognition of the need to demonstrate the value of Dstl research to wider society.
- All three of these long-standing employees also referred to some form of peer-to-peer knowledge sharing. One noted the importance of developing recognition within Dstl of the value of the research being undertaken, with the wider societal benefits a key part of this. The other two referred to stimulating interest in commercialisation amongst their peers, with one noting that they had described the opportunities and processes of commercialisation to colleagues, who were now showing greater interest in being involved in commercially-focussed research. The case study box below provides evidence on the third employee, and the role of 'doing' and peer-to-peer discussions in encouraging interest in commercialisation.

Case study: Scientist C

Scientist C was involved in two spin-outs and one licence in the late 1990s and early 2000s. The first experience made the 2nd and 3rd more likely to happen, because of the greater awareness and knowledge that they had gained. There is a general barrier for technical staff and scientists that spin-outs are an 'unknown'. So experiencing it once provides knowledge to facilitate it happening again.

Now that the scientist is in a management position at Dstl, they are more likely to ask questions of their team around IP and the potential application of IP. Seeking to encourage this kind of discussion could result in more patent applications, if not spin-outs.

Future engagement of scientists

5.16 Those consulted referred to a range of barriers and issues for scientists' engagement in commercialisation, but also to the commercialisation process itself. A number of suggestions were also identified that may help to address some of these challenges, and encouragingly there was recognition of the role that Ploughshare already plays in helping scientists. Table 5-1 sets out the barriers and solutions identified.

Table 5-1: Barriers, enablers and potential solutions

Barriers	Enablers/possible solutions
Time – research is a highly engaging process and competing pressures mean that commercialisation can slip off the list	There are no silver bullets here. There was a general observation that there needs to be encouragement for researchers to think broadly, including giving them the time and space. Short-term financial incentives for researchers
Local culture – this is partly the nature of research, which is more likely to generate IP for some Dstl departments more than others. This becomes a virtuous cycle, because they are more likely to go through the experience and so more likely to do it next time.	Ploughshare could help to raise awareness through presentations, perhaps in conjunction with researchers who 'have been there and done it'. Need to celebrate success to show what can be done.
General concern/fear of technical staff, because they are not experts in the commercial world, and have concerns due to sensitivities around Dstl's research and IP	Key role for Ploughshare to 'hand hold' and advise researchers through the process. It was noted that Ploughshare is very good at understanding and helping researchers overcome barriers. Need to emphasise the benefits (as researchers tend to focus on the problems). As part of this, need to celebrate success to show what can be done. To an extent, can cover some basics through training (though ultimately, as reported in the consultations, scientists learn by doing) and awareness-raising.
Being open to dealing with new industry partners – there is a tendency to always go back to previous partners (which is sometimes right), though should be open to others. Related, there is an expectation amongst some of those consulted that Dstl will need to work more in partnership with industry.	Ploughshare has a key role here in assisting with the industry interface. Ploughshare could facilitate the flow of information between industry and Dstl scientists, e.g. asking the questions such as "do you have any technologies/research relevant to market x". Though this needs to be done carefully to avoid over-burdening scientists.
A view that Dstl is increasingly going to need to work in partnership with academia and industry (especially working with Russell Group universities) and this may mean letting IP be taken by others as they are better placed to exploit it.	Whilst IP will rest with the provider, Ploughshare will be able to exploit IP in non-defence related markets where providers have been unable to do so.
Accessing finance for spin-outs.	Downing LLP was mentioned as part of the solution here.

Source: SQW, based on consultations

6. Towards a balanced scorecard

6.1 This section sets out the findings on the supplementary aim of the study, namely to inform the development of a balanced scorecard for assessing the performance of Ploughshare.

Issues framing the balanced scorecard

6.2 In section 2 we set out the importance of adopting non-financial measures in order to most effectively understand the overall performance of Ploughshare. Simply put, the aims of Ploughshare are not just based on financial performance; they also relate to contributing to UK economic growth, contributing to the development of the supply base for the defence sector, and contributing to society more widely through the application of cutting edge technologies. Therefore, a balanced scorecard needs to reflect on all of these aims.

6.3 In contributing to the defence sector, as we reported in section 2, Ploughshare is not permitted to take income (from licences) through royalties from sales made to the MOD either directly or indirectly through supply chains. In these cases, the MOD gets a discount, which is equivalent to the royalty that would be paid. Going forward, Ploughshare is going to collect this data more systematically, so it can track this non-financial benefit.

6.4 The current strategic vision of Ploughshare recognises the commercial imperative and the need to, in the medium- to long-term, move the company to, or at least closer to, a break-even position. Therefore, the current aims could be adapted to the following, namely to:

- improve the profitability of Ploughshare so that it breaks even by focussing on opportunities with the most commercial potential
- support the UK economic growth agenda
- provide benefits to the MOD and defence sector supply chains
- make a difference to people's lives through civilian markets.

6.5 It is difficult to determine a timescale over which Ploughshare might reach a breakeven point, in particular given the lead times to generate income from spin-outs and licences as well as the uncertainty and complexity of the commercialisation process that was reported in section 2. We understand that there is some refocussing of activities to enable Ploughshare to spend more time on the right opportunities that can help it maximise its impact. This refocussing is not straightforward. The feedback from scientists suggested that this will be challenging, and the evidence we have found from spin-outs and licensees indicates that success may come from unexpected avenues. Nevertheless, the improvement in focus and processes within Ploughshare will involve the following aspects:

- More systematic engagement with Dstl scientists on technologies coming through, and potential areas of need by industry (see below on post deal management). This implies that Ploughshare may be facilitating two-way 'knowledge exchange' between industry and the science base, essentially acting as a 'knowledge broker'.

- Engagement/development of technology at an early stage of the innovation cycle, not just when patents exist or are ready to be filed for – in this way, Ploughshare may support the building of businesses on know-how, not simply patents.

- Perhaps most important is the focus on the best opportunities based on key criteria. These criteria are likely to be based on market potential, technological feasibility, and commercial potential (in particular an appraisal of the financial case for Ploughshare). If the commercial appraisal is not promising, then the technology needs to have a strong case in terms of contributing substantively to economic growth, MOD requirements or the defence sector, and/or society more widely. Indeed, this report has shown that these wider benefits (to MOD, the economy or humanity) can be significant, so ought to form part of the appraisal process.

- For those that are not priorities, given the assessment against key criteria, Ploughshare is looking to administer an 'easy IP' process – i.e. making IP available to industry in a straightforward way. This will not generate income for Ploughshare though could contribute to wider benefits. The point of the simple process is to minimise the amount of resource dedicated by Ploughshare.

- More emphasis on post deal management with licensees. This would engender greater engagement with industry which may result in more market-pull – both in how technologies are assessed and developed and to feed in to engagement by Ploughshare with the Dstl research base (linking with the first bullet point above).

- A partnership with Downing LLP , which will invest up to £5m per annum in spin-outs. This ought to help to increase the number of spin-outs and create benefits in the following ways: i) with an interested investor, Downing LLP, alongside others such as RSF, this should increase the flow of spin-outs if the right opportunities exist; ii) where there is a bundle of IP, there may be the potential to create a development company to invest in the opportunities and move them up the TRLs, which may result in spin-outs in their own right; iii) Downing LLP may be a later stage investor as well, which can be helpful to prevent a dominant shareholder coming in for short-term gain at expense of strategic focus.

Potential metrics for a balanced scorecard

6.6 In developing a balanced scorecard, it is good practice to incorporate both 'leading' and 'lagging' indicators. The former can measure progress in the short-term and should give an indication as to whether this will mean that ultimate objectives are likely to be hit. These enable Ploughshare to see how it is progressing. The latter, only measurable later, are more likely to reflect the aims of Ploughshare, in particular in terms of financial performance, economic contribution and wider benefits.

6.7 In Table 6-1, we set out the potential metrics for measuring Ploughshare's performance. These include a series of more immediate leading indicators, and indicators that reflect the longer-term objectives of the company. There are some key aspects of performance that are difficult to capture, in particular how to assess the effectiveness of Ploughshare in focussing on the key opportunities. In addition, the contribution to defence and civilian markets are difficult to assess quantitatively, and so some degree of qualitative feedback will be necessary.

Table 6-1: Potential metrics for a balanced scorecard

Indicator	Source	Commentary
Leading indicators		
No. of patents registered	Dstl	Immediate effect relating to IP generated and worth protecting
No. of spin-outs	Ploughshare account management data	Key 'output' indicator – reflecting immediate effects
No. of development companies established	Ploughshare account management data	Key 'output' indicator – reflecting immediate effects (and potential for further spin-outs)
No. of licences	Ploughshare account management data	Key 'output' indicator – reflecting immediate effects
Value of investment from Downing LLP	Ploughshare account management data	Provides initial 'commercial' view on potential of spin-outs
Value of investment from other investors	Account managers' liaison with spin-outs	Provides subsequent 'commercial' view on potential of spin-outs
No. of licences with forecast income > £100k per annum	Account managers' liaison with licensees	Provides signal of likely future impact
No. of licensees that are repeat customers (i.e. have multiple licences)	Ploughshare account management data	Indication of post deal management and engagement with industry
Awareness/attitudinal indicators amongst scientists in core technology areas	Would require some primary research, e.g. basic survey	Indication of culture change to reflect (i) profile of Ploughshare, (ii) engagement with scientists and (iii) perceptions amongst scientists
Financial indicators		
Current value of shareholdings of spin-outs	Ploughshare account management data	Feeds into ultimate financial objective
Forecast expected values and shareholdings of spin-outs	Ploughshare account management data, based on company forecasts	Potential financial returns
Royalties from licensees	Ploughshare account management data	Feeds into ultimate financial objective
Forecast royalties from licensees	Ploughshare account management data, based on company forecasts	Potential financial returns
Economic indicators		
Non-accrued royalties from licensees selling directly or indirectly to the MOD	Ploughshare account management data	Not collected in the past, but process being put in place going forward
Estimates of employment created in licensees	Account managers' liaison with licensees	Key to ultimate economic contribution objectives – could be used to estimate a GVA effect (based on proxy GVA per job)

Indicator	Source	Commentary
Estimates of employment created in spin-outs	Account managers' liaison with spin-outs / Company accounts	Key to ultimate economic contribution objectives – could be used to estimate a GVA effect (based on proxy GVA per job)
Estimates of sales (& % exports) in spin-outs	Account managers' liaison with spin-outs / Company accounts	Part of economic objectives, and provides an indication of contribution to net trade (a key policy imperative)
Wider indicators		
No. and nature of UK defence supply chains improved	Account managers, spin-outs/ licensees, MOD	Basic number improved provides very partial picture, and nature of improvement may need to be based on qualitative evidence, including case studies
No. and nature of UK civilian markets developed	Account managers, spin-outs/licensees, customers	

Source: SQW

7. Conclusions

7.1 In this concluding section we summarise the main findings of our study, and also examine how the commercialisation process can be improved going forward.

Economic contribution of commercialisation activities

7.2 Our analysis indicates that Ploughshare's commercialisation activities have led to significant economic impacts. Including additional direct and indirect impacts together, the commercialisation activities have led to, or are expected to lead to:

- the creation of around 550 net additional jobs to date (at peak levels), with over 500 jobs in the spin-outs and licensees supported forecast to exist to 2017/18
- the generation of £44m in net additional exports between 2002/03 and 2013/14, with another £179m of exports forecast for the period 2014/15 to 2017/18
- net additional GVA worth over £65m to date (2002/03 to 2013/14) with future GVA forecast to be £126m (over the period 2014/15 to 2017/18) – i.e. resulting in a total GVA effect of over £190m.

7.3 The economic contribution is significantly skewed within the portfolio of spin-outs and licensees, with two spin-outs in particular contributing to a significant proportion of the benefits.

7.4 To put these figures into context, the net cost (i.e. costs less income) to Dstl of funding Ploughshare and the equivalent commercialisation role within Dstl prior to Ploughshare's establishment is estimated to be £7.2m. In understanding the assessment it is important to highlight that some of the effects estimated above have been dependent on further government intervention. In particular, the spin-outs have drawn on government grants (e.g. from Innovate UK) and seed capital from government-backed funds. The assessment has not sought to apportion benefits given the difficulties inherent in doing this. It is important to note that Dstl and Ploughshare provide the ideas at the start of the commercialisation process, which then stimulates subsequent funding to bring about the economic benefits.

Wider benefits

To the MOD

7.5 The study has highlighted that there are several examples, through licensing activities and also a couple of the spin-outs, of where the MOD has benefited from commercialisation activities. These benefits fall into two key categories.

- Access to new defence technologies and capabilities: evidence from Dstl researchers, companies and Ploughshare account managers suggests that the availability of new defence capabilities for MOD was an important benefit. For example, MOD is now able to buy off-the-shelf products across a range of technologies spanning cyber-security,

armour vehicles, and bio-warfare product. Often these capabilities come from UK firms or from firms in allied nations.

- Enhancement of the supply chain: with 80% of MOD's research being outsourced to the wider defence supply chain, any developments to the supply chain will benefit also MOD itself. We have seen evidence of new technology, resources and expertise filtering down the defence supply chain most notably with CDCAT and the steel vehicle armour licences.

To wider society

7.6 Aside from the economic effects of Ploughshare's activities (most notably through employment and wealth creation), wider society has benefited in other ways too.

- Improved capabilities for the first response and emergency services: a range of technologies have been commercialised that will, or are likely to, benefit emergency and security services. Again, these cover a wide range of different areas ranging from bio-hazard detection to the testing of protective clothing.

- Health and well-being benefits: several of the life sciences licences in particular have real potential to tackle public health issues be it developing more efficient mechanisms to deliver medicine, or by progressing research in vaccines against diseases such as anthrax, plagues and cancer diagnosis.

To researchers

7.7 Four main types of benefits were identified in the consultations with researchers, summarised as follows.

- Personal rewards: the key personal motivation for scientists is the technical challenge and the potential to see their research applied in products/services that reach the market and make a contribution to defence or civilian life. This self-actualisation is a key motivation for scientists. In addition, whilst not a primary motivator, financial rewards provide a degree of recognition and 'value' for a scientist's endeavours.

- Skills, experiences and attitudes: as well as improving the awareness of what is required to commercialise ideas, which should not be underestimated given that some scientists have no previous experience, consultees also referred to the development of commercial and research skills. In addition, there was consensus that having gone through a commercialisation experience once (and indeed on subsequent occasions), scientists are more likely to pursue such activities in the future.

- Industry engagement: whilst there was some feedback that commercialisation experiences would make them more likely to consider business applications when developing and undertaking research projects, and that they would also draw on industry feedback or networks in developing and undertaking research projects, there was no consensus on this point. This may reflect the nature of research and the extent to which such industry feedback processes are appropriate.

- Organisational benefits: three long-standing employees referred to benefits to Dstl as an organisation, including through some form of peer-to-peer knowledge sharing. One noted the importance of developing recognition within Dstl of the value of the research being undertaken, with the wider societal benefits a key part of this. The other two referred to stimulating interest in commercialisation amongst their peers, e.g. by describing the opportunities and processes of commercialisation to colleagues, and by asking questions of their colleagues to encourage them to think about wider applications.

Going forward

7.8 The feedback from scientists identified a range of barriers to commercialisation and also some solutions to these. This included the following suggestions for Ploughshare:

- raising awareness through presentations, perhaps in conjunction with researchers who 'have been there and done it' in order to show the benefits and celebrate success
- related to this, the potential to incorporate some basic introductory training on some of the aspects of the commercialisation processes and how these are implemented
- 'hand-holding' and advising researchers through the process, including through assistance with the industry interface; it was noted that Ploughshare is very good at understanding and helping researchers overcome barriers, and so this is partly a 'business as usual' recommendation and partly about ensuring that researchers are aware of the support that is available
- facilitating the flow of information between industry and Dstl scientists, e.g. asking the questions such as "do you have any technologies/research relevant to market x", though this needs to be done carefully to avoid over-burdening researchers.

7.9 We understand that Ploughshare is in the process of some refocussing, including to prioritise opportunities with the most potential for a commercial return, economic return (in terms of job creation), or contribution to the MOD or society. In addition, Ploughshare is examining means of improving its engagement with industry and using this to feed into the development of technologies with commercial potential.

Annex A: Detailed methodology

A.1 This Annex sets out our methodology statement for assessing the economic contribution of Ploughshare Innovations Ltd's (Ploughshare) activities.

The routes to impact from Ploughshare's exploitation activities

A.2 In assessing the benefits of Ploughshare's exploitation activities, there are three key routes to impact. The first two reflect the forms of exploitation of Intellectual Property (IP), namely spin-out and licensing activity, and the third the wider effects of these forms of exploitation. In brief, the three routes are as follows:

- Ploughshare endows new spin-out companies with Dstl IP in return for an equity stake. To date, Ploughshare has enabled 11 new companies to form via this route, with Ploughshare currently holding an equity stake in seven of these.
- Ploughshare grants licence(s) to new and existing companies to use and develop licenced technology/IP in return for an upfront fee, milestone payments and royalties on any revenue generated. To date, Ploughshare has granted over 58 such licences to 50 companies.
- Through its spin-out and licensing activity, Ploughshare:
  - encourages innovation and develops commercial awareness within the Dstl science and research base
  - brings about societal and wider benefits through enhancing sectoral capabilities and supporting Ministry of Defence (MOD) objectives.

A.3 Figure A-1 below provides a logic model for Ploughshare's exploitation activities. This illustrates how each of the three forms of exploitation activity generate outputs, outcomes and impact.

Table A-1: Modelling Ploughshare's routes to economic impact

1. Conditions: (i) Dstl technology and related IP has been developed to meet specific needs which the MOD requires to keep at the forefront of technology. As part of this, effective engagement and technology transfer is required with industry to enable the R&D and commercialisation activity necessary to bring defence and security products to market; (ii) it is also recognised that Dstl technology has the potential to meet complementary or different market needs in the wider economy which again requires effective engagement and technology transfer with industry; (iii) Dstl operates on a commercial basis and as such can seek to secure a financial return from industry from these engagement activities; (iv) the equity and technology licence income (secured by Dstl's technology transfer organisation Ploughshare) do not fully capture the benefits from these activities.

2. Objectives of Ploughshare: (i) to work closely with Dstl to identify IP and associated technologies that a) require industry engagement to bring defence and security products to market for MOD and b) offer the potential to meet wider market needs; and (ii) to assess and forecast the commercial potential of IP and foster its development

4. Impacts: Gross Value Added (GVA), strategic benefits to MOD and enhancements to defence capabilities, wider sectoral capability enhancement

3. Individual logic chains relating to: 1. Spin-outs 2. Licences 3. Societal and wider benefits

Market failures and economic rationale for Ploughshare	Objectives	Inputs and activities	Outputs	Outcomes
The private sector on its own may not invest as much in new research and technology due to uncertainties and time lags to benefits; and caution from Dstl in access to IP may restrict engagement with industry. Commercialisation through Ploughshare activities can address these issues. Sensitivities surrounding Dstl IP may mean that wider civilian markets cannot access and exploit technology. The nature and sensitivity of Dstl operations could lead to an overly cautious and non-commercially minded research base with limited 'feedback loops' from industry (known as 'institutional failure').	To help establish and endow new spin-out companies with Dstl IP To support and advise firms as they undertake R&D and commercialise IP To realise the value of equity stakes held in the spin-outs	Endowment of IP to spin-out companies Extensive prior working with Dstl to identify and release IP and test and develop its commercialisation potential Work with firms to support R&D and commercialisation	Firm formation R&D activity and investment Leveraged inputs from external investors	Employment Commercialisation of IP Sales (incl. exports) Operating profits Income stream to Ploughshare to allow ongoing operations
	To grant licences to companies to enable them to undertake R&D and commercialise IP To secure an income stream from up front, milestone and royalty payments	Granting licences to develop and exploit Dstl IP Extensive prior working with Dstl to identify and release IP and test and develop its commercialisation potential	Firms supported with licences R&D activity and investment Leveraged inputs from external investors Income stream from up front and milestone payments	Employment Commercialisation of IP Sales (incl. exports) Operating profits Income stream via royalties to Ploughshare to allow ongoing operations
	Through spin-out and licensing activity, ensure (i) that strategic MOD objectives are secured; (ii) that wider sectoral capabilities are enhanced and that (iii) innovation is encouraged amongst Dstl research staff	Close working with Dstl to identify and define IP that requires industry engagement to meet objectives (i) and (ii) To work in a collegiate and supportive manner with Dstl research staff	Annual number of technologies identified that are suitable for objectives (i) and (ii) Number of Dstl research staff engaged in commercialisation activities per annum	Achievement of specific MOD objectives (e.g. securing a UK supply-chain for defence products) Commercialisation of technology in civilian markets Innovative and commercially oriented Dstl research base

Source: SQW, drawing on material adapted from Ploughshare's website (http://www.ploughshareinnovations.com) and Dstl's website (https://www.gov.uk/government/organisations/defence-science-and-technology-laboratory)

A.4 This section sets out the approach to assessing the economic and wider benefits of Ploughshare's activities. The first sub-sections focus on valuing the economic benefits of spin-out and licensing activities, in particular covering economic measures, assessing additionality, estimating Gross Value Added (GVA). The last sub-section examines how the wider benefits to society and the research base will be assessed.

Measures of economic benefit

A.5 Given that many of the spin-outs and some of the licenced activity is in pre-sales stages, and with many yet to generate surpluses, we have considered a basket of indicators to reflect the economic contribution of Ploughshare. This follows government guidance (e.g. from Scottish Enterprise), which highlights the importance of considering alternative measures (to GVA) to fully assess the impact of schemes on pre-commercial or early stage businesses[22]. An estimate of GVA is provided as part of the assessment, as per the objectives of Dstl's requirements and in line with Department of Business, Innovation and Skills (BIS) guidance[23], which recommends estimating GVA where this is possible. In Table A-1 we provide the measures of economic benefit to be assessed and the principal sources of evidence[24].

Table A-1: Key measures and principal sources of data

Indicator of economic benefit	Justification	Principal sources of data
Leveraged investment	Provides, in 'gross' terms, an indicator of the leverage of other investment	Ploughshare historic data on company investments Consultations with companies
Level of additionality	Gives an indication of the extent to which Ploughshare is supporting the commercialisation of research and start-up of new businesses that would not have happened otherwise	Consultations with senior Dstl staff and researchers, Ploughshare staff, spin-outs and licensees – qualitative insight to probe on what would have happened otherwise *(and also applied to indicators in rows below)*
New businesses created (and on-going)	Indicates number of *additional* new businesses, and implies levels of survival rates	Data on spin-out portfolio from Ploughshare (including starts, exits, current companies)
Employment created	Provides an indication of economic activity generated	Company account data
Value & proportion of sales that are exports	Injection to circular flow of income to the UK economy	Company account data
GVA	Values the economic contribution that can be compared to other investments	Derived from company account data (on employee costs, and operating surpluses), forecasts and future expected values – methods discussed in more detail below

Source: SQW

[22] Scottish Enterprise (2008), *Additionality and Economic Impact Assessment Guidance Note*, Scottish Enterprise, Glasgow
[23] Department for Business, Innovation and Skills (2011) *Guidance on Evaluating the Impact of Interventions on Business*, BIS, London
[24] We will explore the feasibility of formally setting out the evidence on net R&D expenditure. However, whilst some data on R&D spend is likely to exist, this may not be comprehensive resulting in a partial picture being presented.

Additionality and attribution

Assessing the counterfactual

A.6 BIS guidance on evaluating the interventions on business[25] recommends adopting 'stronger' methods of evaluation design, i.e. using some form of comparison or control group of non-beneficiaries. The identification of a control or comparison group of businesses not engaged by Ploughshare is, in our view, not feasible. There are a number of reasons for this:

- In the case of spin-outs, they have been formed in order to commercialise IP endowed to them by Ploughshare – i.e. there are not a raft of spin-outs that attempted to obtain Dstl IP but failed to do so which could form a well-matched comparison group.
- There are no standard comparisons that can be drawn from standard datasets such as the Small Business Survey or administrative data, and no expected business growth rates given the highly differentiated nature of the businesses.
- In the case of licensees, the technology involved is unique – i.e. it's not possible to identify other companies that are developing similar technologies for similar potential applications which could form a well-matched comparison group.
- The number of companies that Ploughshare has engaged with is small given the highly specialised nature of its activities. This makes statistical comparisons challenging, especially as we expect the variance of key outcomes (such as sales) to be high.

A.7 We have sought to address the counterfactual by testing with informed consultees as to how likely it is (if at all) that businesses would have been started or would have been able to grow/access alternative technologies/IP in absence of Ploughshare's activities (e.g. through investment of private funding, alternative sources of IP, and own investment in R&D). All other things being equal, we would expect additionality to be lower for licences compared to spin-outs. This is because firms may well be combining the licence with other non-Dstl technology and/or may have access to other potential sources of similar or competing technologies – i.e. in the absence of the Ploughshare licence the end product may have still been developed, albeit over a longer timeframe or with differentiating applications and/or characteristics.

A.8 Additionality has been tested with companies themselves and a selection of Dstl/Ploughshare staff. This qualitative insight has informed a judgement on the levels of additionality associated with each spin-out and 20 of the most active/lucrative licences[26]. Additionality has also been used in estimating the 'net' outcomes associated with key indicators, i.e. employment, value of exports and GVA.

Attribution/apportionment

A.9 Closely related to additionality is the issue of attribution or apportionment of benefits (i.e. benefits relating to employment, value of exports and GVA) to Ploughshare versus external support and/or funds provided through other sources. Evaluation practice indicates a need

[25] Department for Business, Innovation and Skills (2011) *Guidance on Evaluating the Impact of Interventions on Business*, BIS, London
[26] Our approach to assessing inactive licences in discussed in detail 'assessment of GVA'

to attribute between various government inputs to assess the benefit attributable to a particular intervention. For example, assuming all other factors hold equal, levels of funding from different public sources can be used to apportion economic benefits on a pro rata basis. However, chronologically Ploughshare's role in endowing spin-out companies and issuing IP/technology licences comes before other potential funding – indeed, it provides the basis for which funding can be sought and invested. Note that there may be some exceptions to this, e.g. with respect to licences whereby firms could in theory be accessing other public support at the same time; we have covered this in the company consultations.

A.10 Therefore, the key measure of deadweight is the likelihood (if at all) that businesses would have been started or would have been able to grow/access alternative technologies/IP. As discussed above, this has been assessed through consideration of additionality. Nonetheless, it is still important to capture the level of subsequent investment to support the commercialisation of Dstl technology. As shown in Table 2-1 private sector investment can be used to estimate the level of *gross private sector leverage* which is an important indicator of economic contribution.

Leakage and displacement effects

A.11 Leakage has been treated in a UK context, i.e. leakage will be deemed to exist if any activity (e.g. employment, purchasing of good and services) is taking place overseas. For spin-outs and active licensees this information has been obtained from Dstl and Ploughshare and from the companies themselves.

A.12 Displacement effects have been assessed by considering two key factors: the location of businesses' markets or likely markets (i.e. are they UK or international); and the location of direct competitors (i.e. are they UK, international or does the business have no direct competitors). The latter factor is the critical one, though the former can be instructive in the absence of conclusive data/perceptions. We have used this evidence to make a judgement on displacement effects on the basis of Table A-2, noting that any available relative proportions between different markets and competitors will inform actual percentage assumptions for displacement (e.g. if 10% of competitors are UK-based, then it may be appropriate to assume a low level of displacement, such as 10%).

A.13 We will assessed displacement for spin outs and licensees through the same method adopted to assess leakage.

Table A-2: Displacement judgements

	UK competitors	**International competitors**	**No direct competitors**
UK markets	Med/High displacement	No displacement	No displacement
International markets	Low/med displacement	No displacement	No displacement

Multiplier effects

A.14 We have used input-output tables from the Office for National Statistics (ONS), drawing on those based on the most closely aligned sectors for individual companies. A selection of relevant output multipliers is set out as follows:

- Aerospace 1.6
- Chemicals 1.7
- Electronic components 1.6
- Medical and precision instruments 1.7
- Pharmaceuticals 1.8
- R&D 1.4.

A.15 In practice, therefore, total employment and GVA estimates, including indirect effects, have been presented by multiplying direct effects by these multiplier values. The alternative to this approach would be to collect specific data on the purchasing of individual companies. This would be very resource-intensive and place an unnecessary burden on companies that we ask to take part in the study. Nevertheless, where possible, examples of purchasing behaviour have been identified through the fieldwork, which have been used to justify (or challenge) the use of multiplier effects in undertaking the economic impact assessment.

Assessment of GVA

A.16 The assessment of GVA benefits have been undertaken in stages to provide a structured analysis that is clear and transparent.

Spin-outs

A.17 The first stage of the analysis has been to estimate GVA to date by looking at employee costs (as a component of GVA). The focus on employee costs follows Scottish Enterprise guidance, which indicates that this is an appropriate approach given the pre-sales nature of many of the businesses[27][28]. We have supplemented these data with:

- forecasts of projected benefits based on individual company projections of employee costs
- data on surpluses/losses for those businesses already in sales phases, and individual company projections of surpluses/losses for those due to enter sales phases
- in some cases data on turnover minus costs of goods and services (where these data are more comprehensive than those available on employment/employee costs).

A.18 The GVA estimates have been presented in different ways, in line with other recent approaches[29], as follows:

[27] Scottish Enterprise (2008), *Additionality and Economic Impact Assessment Guidance Note*, Scottish Enterprise, Glasgow
[28] We note that the PACEC study on the Scottish Seed Fund includes operating losses in calculating GVA to date – see PACEC (2013), *Economic Impact of the Scottish Enterprise Seed Fund*, PACEC, Cambridge. We propose to only include operating surpluses/losses in the future for those businesses in sales stages of development, reflecting more strictly the guidance of Scottish Enterprise. This also reflects that Ploughshare is involved in a number of businesses that remain in R&D phase, and are not expected to generate sales even by the time that Ploughshare exits as a shareholder.
[29] E.g.: PACEC (2013), *Economic Impact of the Scottish Enterprise Seed Fund*, PACEC, Cambridge. Geoff White Inc and SQW (2011), *Derivation and use of BCRs in BIS Evaluations*, recommends greater consistency on this matter with results presented transparently and clearly to take account of appropriate levels of persistence.

- cumulative to date
- projected cumulative.

Duration of benefits

A.19 As indicated above, we have sought to take account of expected benefits in the future, which are attributable to Ploughshare. There is no strong empirical evidence on how long benefits persist for. For major capital works up to 60 years of persistence are sometimes applied (e.g. for transport investments). For capital works in the science and innovation arena up to 30 years of persistence are considered with account taken for the 'decay' in benefit from 15 years onwards as infrastructure becomes more dated. Other agencies, e.g. UK Trade and Investment, allow a maximum of up to 10 years persistence effect for interventions supporting businesses. Therefore, we have considered persistence effects up to 10-15 years, which ought to be appropriate given the age of the spin-out companies. In order to estimate future projected benefits in the absence of individual company projections, we have drawn on consultations to assume a *status quo* a simple trend analysis or an accelerated trend. An alternative approach would be to have drawn on the expected capitalisation value at the proposed Ploughshare exit date – on the assumption that this reflects a discounted return that a buyer of the business may be expected to receive as a result of purchasing the business.

Licences

A.20 The process for assessing and presenting the GVA associated with licensing activity has been similar to that for spin-outs. However, it has differed in two ways.

- Rather than assess the GVA associated with company operations, we have had to isolate the operations associated with investment, development and commercialisation resulting from the licensing of Dstl IP/technology. With this information not routinely held by Ploughshare, we have relied upon the intelligence provided by the companies themselves to calculate relevant employment, employee costs, sales and future projections of sales.
- Due to (i) the number of licences (around 58), and (ii) the fact that around two thirds of these are no longer 'active' (i.e. either as all agreed royalties have been paid and/or the IP/technology is no longer being used by the company), we have had to adopt a grossing-up process to estimate the GVA of around 38 of the less active licences. This has been undertaken by comparing the royalties and wider fees achieved through active licences with that achieved for inactive licences. For example, if inactive licence royalties equal 50% of all licence royalties, we would uplift the GVA achieved through active licences by a factor of two. Within this, we have been mindful to identify any notable exceptions in the development and commercialisation of inactive licences.

A.21 The duration of benefits has been capped at either 15 years, the length of time that the company is contractually permitted to exploit the licence, or the point at which it stops using the IP/technology, whichever comes first.

A.22 The GVA estimates has been presented as follows:

- cumulative to date

- projected cumulative.

Optimism bias

A.23 HMT Green Book advises taking account of optimism bias, with the guidance specifically taken from an *ex ante* appraisal perspective and focussed on capital works (in terms of duration and expenditure). Whilst part of the assessment of Ploughshare is *ex post*, the examination also includes projected benefits. We have considered how projected benefits are estimated by companies and have applied any appropriate adjustments to future benefits.

Social time preference

A.24 In line with HM Treasury Green Book we have discounted future benefits using the social time preference rate of 3.5% per annum.

Assessing societal and wider benefits

A.25 It is difficult to provide quantitative measures of the benefits to society and Dstl research, because contributions to society are likely to vary depending on the technology application and benefits to Dstl research may not be well-defined or quantifiable. Therefore, we have used a selection of case studies, drawing on the evidence collected from consultations and desk-based research to illustrate how Ploughshare's activities have made societal and organisational contributions.

A.26 Through discussion with Dstl and Ploughshare the following initial list of case studies was identified:

- P2i (technology: plasma coating)
- Claresys Ltd (technology: COSE & Lens)
- Tata UK Ltd (technology: SBS)
- Ceramic armour (technology: NP Aerospace)
- ProKyma Ltd (technology: Ultrasound)
- BBI Detection Ltd (technology: Antibodies and LFS device)
- APMG (technology: CD CAT).

A.27 Through the case studies and consultations with Dstl staff we have illustrated the following wider effects:

- supporting wider strategic objectives, and in particular those of the MOD
- enhancement of sectoral capability across the breadth of technology applications, e.g. security and defence, healthcare, and consumer products
- supporting a culture of innovation, commercialisation and job satisfaction amongst Dstl research staff.

A.28 Across all three of these effects, we have highlighted areas where social impacts are not captured by economic metrics such as GVA (i.e. in theory the social contribution may be encapsulated in the value of GVA – unless there are market failures such as externalities).

Annex B: List of spin-outs and licensees

B.1 This annex lists all the spin-out and licensees that fall within the portfolio that has been considered for this assessment.

Table B-1: Portfolio spin-out companies and associated technology

Company	Dstl technology
Enigma	RT-PCR Diagnostic
P2i	Plasma Coating
Claresys	COSE & Lens
SALT	Sonar Reflector
ESROE	ESM software
ProKyma	Ultrasound
Remo	Telemetry
Acolyte Biomedica	Not part of current portfolio
Leading Light Scientific	Not part of current portfolio

Table B-2: Portfolio licensees and associated technology

Company	Dstl technology
AB Precision Ltd	IED Disrupter & Projector Equip
Atkins Ltd	MALPAS & TANKILL
BIRAL	Particle Analysis & Spinning Disk
Honeywell Hymatic Ltd	Cooling Device
Portsmouth Aviation Ltd	NBC Filters
Primetake Ltd	Charge Disrupter
Qinetiq	Maxicandle
Stella Meta	Water Purification
Smiths Detection Ltd	LS-SPR
NP Aerospace	Ceramic Armour & Vehicular Armour
Tata UK Ltd	SBS
ESL Defence	OALV - Dev Licence
Amsafe Bridport Ltd	Tarian Armour Netting & Armour Netting Bracket
Ketech Defence Ltd	V/G Converter
E.I. DuPont de Nemours & Co	BABT Test Rig
Thales	RESM
ESL Defence Ltd	OAL - Dev Licence Ext
E.I. DuPont de Nemours & Co	BABT Test Rig

Company	**Dstl technology**
CQC Opt	UBACS Shirt
Qioptic	OALV
AVON	Respirator
APMG	CD CAT
Lonza Rockland Inc	AK Assay
3M (ex Biotrace)	Cyclone & Continuous Flow + AK
Celsis Internation Plc	AK Assay
3M	Luciferase
Archimedes Dev Ltd	Chitosan Encapsulation
Defyrus Inc	Alpha Virus (VEEV)
Pharmathene UK Ltd	Anthrax Vaccine & Plague Vaccine
Lipoxen Tech Ltd	Liposome Technology
Recipharm Cobra Ltd	ORT-VAC
BBI Detection Ltd	Antibodies + LFD Device
Selective Antibodies Ltd	Explosive Antibodies - Option
Recipharm Cobra Ltd	Bacillus Expression Vector
Pall Corporation	WIBS - Option
DMT	WIBS
Pfizer	Toxioding & Rodenticide
Zoetis	Toxoiding option
Prokarium	ORT-VAC
Cangene	Antibody Fragments

Annex C: Detailed analysis

C.1 In this annex we provide two further sets of analysis:

- The gross effects (from which estimates of additional and additional direct impacts have been calculated).
- The additional and direct impacts associated with the sample of licensees that were interviewed, from which we grossed-up the findings to estimate the total impacts across Ploughshare's overall licensee portfolio.

Gross effects

Table C-1: Gross impacts – spin outs and licensees

Indicator	Gross Impact
Spin-outs	
GVA to Date (2002/03 – 2013/14)	£26,798,000
Future GVA (2014/15 – 2017/18)	£86,923,000
Maximum employment to date (2002/03 – 2013/14)	255
Current Employment (2013/14)	166
Future Employment (maximum to 2017/18)	319
Exports to Date (2002/03 – 2013/14)	£46,064,000
Future Exports (2014/15 - 2017/18)	£202,272,000
Licensees	
GVA to Date (2002/03 – 2013/14)	£37,544,000
Future GVA (2014/15 – 2017/18)	£27,074,000
Maximum employment to date (2002/03 – 2013/14)	247
Current Employment (2013/14)	90
Future Employment (maximum to 2017/18)	109
Exports to Date (2002/03 – 2013/14)	£24,712,000
Future Exports (2014/15 - 2017/18)	£65,322,000
TOTAL	
GVA to Date (2002/03 – 2013/14)	£64,342,000
Future GVA (2014/15 – 2017/18)	£113,997,000
Maximum employment to date (2002/03 – 2013/14)	502
Current Employment (2013/14)	256
Future Employment (maximum to 2017/18)	428
Exports to Date (2002/03 – 2013/14)	£70,776,000
Future Exports (2014/15 - 2017/18)	£267,594,000

Source: SQW analysis of Ploughshare Data

Licensee sample impacts

Table C-1: Licensees: summary of Impact Indicators

Indicator	Additional Direct Impact	Additional Direct + Indirect Impact
GVA to Date (2002/03 – 2013/14)	£9,489,000	£16,762,000
Future GVA (2014/15 – 2017/18)	£13,248,000	£23,285,000
Maximum employment to date (2002/03 – 2013/14)	68	118
Current Employment (2013/14)	51	87
Future Employment (maximum to 2017/18)	60	103
Exports to Date (2002/03 – 2013/14)	£4,928,000	-
Future Exports (2014/15 – 2017/18)	£27,630,000	-

Source: SQW analysis of Ploughshare Data

Annex D: Consultations

D.1 The following have been consulted as part of the study. We are grateful for the time and help they have provided. We also appreciate the time and help provided by: Graham Farnsworth (Dstl) in helping to steer the work; Steve Callister (Ploughshare), Gordon Scott (Ploughshare) and Jim Ashe (Ploughshare) in providing details on how Ploughshare operates and the range of spin-outs and licensees; and Paul Reed (Ploughshare) for assisting with data.

Table D-1: List of consultees

Name	Organisation
Gordon Scott	Ploughshare
Jim Ashe	Ploughshare
Richard Hebdon	Ploughshare
James Kirby	Ploughshare
Mark Alexander	Dstl
Andy Bell	Dstl
Peter Brown	Dstl
Peter White	Dstl
Martin Huddlestone	Dstl
Mel Murphy	Dstl
Sarah Whitfield	Dstl
Dianne Williamson	Dstl
Warren Tam	Dstl
John McKinley	Engima
Andy McLeod	Claresys
Carl Tiltman	Subsea Asset Location Technologies (SALT)
John Roe	ESROE
Ady Moores	P2i
Damian Bond	Prokyma
Peter Connor	Remo
John Reeve	Morgan Composites and Defence Systems
Kevin Edgar	Tata Steel
Matt Chuter	Amsafe Bridport
William Cook	DuPont
Phil Ventress	Thales
Mike Harral	Avon
Richard Pharro	AMPG

Name	Organisation
Alan Smith	Archimedes
Ted Fjällman	Prokarium
Fiona Marshall	BBI Detection
John Lovett	Droplet Measurement Technologies Inc

Source: SQW