Assessment of the economic and wider benefits of Ploughshare Innovations Ltd's commercialisation activities

A report to Ploughshare Innovations Ltd

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SQW

Contents

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Executive Summary

1. SQW was commissioned by Ploughshare Innovations Limited (PIL) to undertake an update of its assessment of the non-financial benefits of Ploughshare's commercialisation activities. This followed the earlier assessment, undertaken by SQW, which was published in January 2015. The overall aim of this new study was to update the assessment of the:

   - economic contribution of commercialisation through the establishment of spin-outs and licensing activities
   - wider benefits from the application of novel technologies in defence and civilian markets
   - benefits to Dstl scientists from their engagement with industry, and the issues and barriers to future commercialisation.

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), which has been reaffirmed in the specific context of defence in the recent 2015 *National Security Strategy and Strategic Defence and Security Review*.

3. In measuring the performance of Ploughshare, financial benefits (through royalties and exits of spin-outs) provide only a partial picture. First, the process of commercialisation is highly uncertain. Dstl technologies come to Ploughshare at low technology readiness levels (TRLs), which means that they require a significant amount of resource, and some good fortune, to move them towards being market ready. A number of factors, including technical constraints, lack of investment and changing markets, can result in honourable dead ends – though there may still be benefits in terms of knowledge developed. Second, for those that do succeed, the process of commercialisation is complex and lengthy. 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. The combination of uncertainty and the long lead times to potential returns means that it is challenging to run Ploughshare as a profitable business.

4. This provides the context for this study's assessment of the range of non-financial benefits from Ploughshare's activities. These include:

   - economic benefits (e.g. through company formation, job creation, investment in research and development, and business growth)
   - benefits to the Ministry of Defence (MoD) in terms of bolstering UK supply chains in defence and providing new and improved products

- societal benefits where 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.

5. 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 Ploughshare 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

6. The analysis undertaken for this updated assessment indicates that Ploughshare's commercialisation activities have led to significant economic impacts. When the direct and indirect effects[1] that are attributable to Ploughshare's/Dstl's commercialisation activities are combined, the economic benefits are estimated to be as follows:

- the creation of around 585 net additional jobs to date (at peak levels), with nearly 440 jobs in the spin-outs and licensees supported forecast to exist in 2018/19
- the generation of £75million in net additional exports between 2002/03 and 2015/16, with another £148million of exports forecast for the period 2016/17 to 2018/19
- net additional GVA worth nearly £118million to date (2002/03 to 2015/16) with future GVA forecast to be £107million (over the period 2016/17 to 2018/19) – i.e. resulting in a total GVA effect of nearly £225million.

7. In addition, and separate to the benefits estimated above, Dstl has developed technology, which is integral to the progression and application of global positioning systems. This has and will continue to deliver significant economic and wider benefits.

8. Whilst Dstl and Ploughshare provide the ideas at the start of the commercialisation process, which then helps to leverage subsequent funding to bring about the economic benefits, it is important to note that some of the effects estimated above have been dependent on further government-funded activity. 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 inherent difficulties of doing so.

[1] I.e. effects on the licensees and spin-outs directly affected, and the companies in supply chains indirectly affected

Comparison to the previous assessment

9. The results of this updated assessment highlight the progression that a number of spin-outs and licensees have made, with the impacts 'to date' now higher. Notably, the net additional GVA to date has moved on from £65million (to 2013/14 – estimated in the previous assessment in 2015) to £118million (to 2015/16), which is encouraging.

10. The net additional forecasts are slightly lower in this updated assessment. The changes in the assessments, especially in the forecasts, reflect changes in the fortunes of different companies within the spin-out and licensee portfolio. Notably, one spin-out, which was forecasting significant growth as part of the previous assessment, is now winding down, whereas another spin-out is now expecting slightly higher levels of growth. There are similar changes in the expected growth of different licensees. These changes are to be expected, and reflect the different development paths of businesses, in particular in markets for innovative technologies that can be unpredictable and/or risky.

11. A final, and related, point to make is that a large proportion of the impacts are concentrated in a relatively small number of high-performing companies – both amongst the spin-outs and licensees. Again, this is to be expected, and serves to highlight how changes in the fortunes of key companies can have a significant bearing on the estimates of impacts.

Benefits to defence, commercial and civilian markets

12. The commercialisation of research through Ploughshare has led to the development of a range of new defence technologies that have been used by the MoD and governments of allied countries. These include applications for vehicle armour, electronic warfare software, and chemical and bio threat detection. As well as the development of useable products and services for the MoD, there are further benefits:

- Through the commercialisation in UK-based companies, there has been a development of UK defence capabilities. This is important from a strategic defence perspective. Illustrative of this is the development of one of the vehicle armour products, for which 85% of the supply chain is UK-based. Researchers from Dstl that were interviewed also commented on how commercialisation has broadened the use of technologies and strengthened the market for, and capabilities in developing, relevant components.

- Defence-related technologies such as bio-threat detection and surveillance have applications that are relevant for domestic security and the emergency services.

- Finally, the development of technologies that have a defence element (e.g. with respect to global positioning systems) have been instrumental in gaining significant diplomatic benefits.

13. The analysis has also found notable applications in non-defence markets. Some examples are noted as follows:

- There are a number of companies operating within the health and life sciences sphere, for instance working on vaccines for a range of diseases, and diagnostic tools. These

may have impacts for healthcare in the future, though for many of these work is still ongoing, reflecting the development timeframes for such applications.

- Detection technology that has been developed for the military in identifying mines has been used in applications for the oil and gas sector to facilitate underwater dredging. It is also in development for use in civilian aerospace markets.
- The research undertaken by Dstl that is instrumental to improvements in global positioning systems technologies has a range of applications, including in precision agriculture, supply chain management, the marine sector, and in emerging areas such as smart cities and autonomous vehicles.

Feeding into Dstl research and subsequent commercialisation

14. All of the Dstl scientists interviewed as part of the study identified personal, professional and institutional benefits stemming from their involvement in the commercialisation process. In particular, these benefits included:

- an added sense of purpose and the technical challenge associated with translating research into a commercial setting
- the fresh perspective provided by collaborating with private sector businesses, and the insights that this provides in better understanding the R&D process and how this evolves into a private sector-led development
- in some cases expansion of professional networks
- more widely, the opportunity for technology to be developed and refined even when it was no longer a priority for Dstl – this was noted as obviously having benefits for the spin-outs/licensees, but then subsequently it has the potential for later benefits for Dstl itself if the technology is returned in a more advanced form subsequently.

15. In terms of going forward in maintaining and stimulating interest in commercialisation amongst researchers, some barriers or issues were highlighted. Whilst the major motivation for researchers to get involved is the technical challenge, some consultees said that they had not received the career progression and commensurate increase in their remuneration that they had expected from engaging in commercialisation. As with the first assessment in 2015, financial motivations were not found to be the significant driver for involvement in commercialisation and this was not a substantive issue this time either. However, it is important for Dstl and Ploughshare to reflect on this in the incentives for researchers to get involved in commercialisation. A second issue highlighted, as noted in the last assessment, was the time-consuming nature of engaging in the commercialisation process.

16. Nevertheless, all said, consultees indicated that they would be willing to engage in the commercialisation process again in future, as it had provided numerous, varied insights and benefits.

1. Introduction

1.1 In January 2015, the Defence Science and Technology Laboratory (Dstl) published SQW's independent report on the economic and wider benefits of its commercialisation activities, including through its technology transfer company, Ploughshare Innovations Limited (Ploughshare). This current report, commissioned by Ploughshare, provides an update to the assessment. It assesses how far the impact has changed since the 2015 study, reflecting how far previously forecast effects have actually materialised, and assessing the evidence on new commercialisation activities. The specific aims of this study were threefold, namely to:

- estimate the economic contribution of commercialisation, through the establishment of spin-outs and licensing activities, particularly 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 the defence and civilian markets
- assess the benefits to researchers and scientists at Dstl resulting from their engagement with industry via Ploughshare.

1.2 The report is structured as follows:

- Section 2 sets out the background to the work, including a brief introduction to Ploughshare's work, a summary of the findings from the last assessment, and an overview of the approach taken. A more detailed description of the method is provided in Annex A.
- Section 3 provides the main findings from the economic assessment, covering an aggregated assessment of the economic benefits as well as separate assessments for the spin-out and licensing activity.
- Section 4 summarises the types of wider benefits to both defence and civilian markets from the technologies that have been commercialised. This particularly draws on case studies of individual technologies and companies.
- Section 5 provides a description of the types of benefits that have been derived by researchers from Dstl – drawing in particular on case study examples of experiences of commercialisation.
- Section 6 summarises the main conclusions to the work.

1.3 A series of Annexes accompany the report, covering a description of the approach (Annex A), lists of the spin-outs and licences (Annex B), details of those interviewed for the work (Annex C), and detailed data tables that accompany the economic assessment (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 provides an overview of the approach taken to the work, which is complemented by technical detail contained in Annex A.

Background

Introduction to Dstl and Ploughshare

2.2 Dstl is now an Executive Agency of the Ministry of Defence (MoD), having previously been a Trading Fund agency until 31st March 2017. It was established in 2001 following the split of the Defence Evaluation and the 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. Its role includes carrying out high-level analysis to support MoD policy and procurement decisions, undertaking technical in defence areas including both physical and life sciences, and carrying out operational work such as the forensic analysis of explosives.

2.3 Ploughshare was established in 2005 as a wholly owned company of Dstl. It was set up to be Dstl's Technology Transfer Office (TTO) to 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 taxpayer, highlighted in the 1999 Baker Report, *Releasing the Economic Potential of Public Sector Research Establishments*[2], and more recently and specifically to defence with the 2015 *National Security Strategy and Strategic Defence and Security Review*[3]. Prior to the establishment of Ploughshare as a separate TTO, Dstl itself managed technology transfer activities.

2.4 In broad terms, Ploughshare aims to bring about commercialisation that can:

- deliver revenue to Dstl via spin-outs and licensing
- create employment, preferably in the UK, and so contribute to economic prosperity
- deliver technology improvements to a range of defence and civilian markets
- provide Commercial Off The Shelf (COTS) technology opportunities.

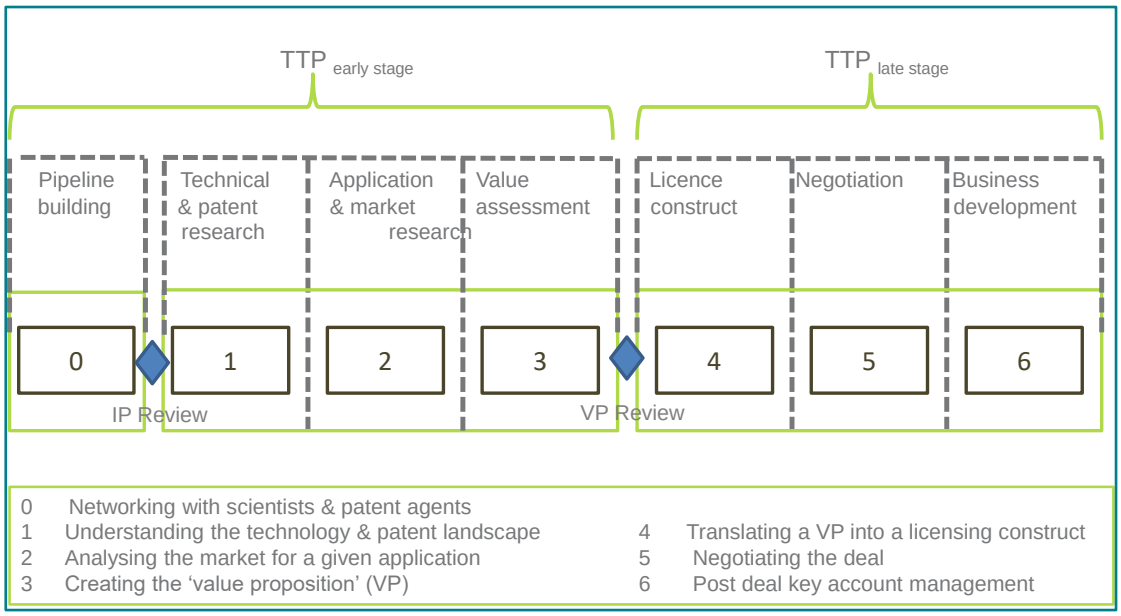
2.5 In seeking to achieve these aims, Ploughshare engages with scientists and patent agents to identify and develop a pipeline of technologies for review. Following an initial intellectual Property (IP) review, if there is potential then further technical and market research is undertaken to feed into the development and review of value proposition (VP). If the VP review shows promise, then Ploughshare will work with scientists and other partners to seek

[2] Baker, J. (1999) *Creating Knowledge, Creating Wealth*, Report to HM Treasury and the Department for Trade and Industry
[3] HM Government (2015) *National Security Strategy and Strategic Defence and Security Review 2015*, HMSO

to develop a licensing construct or potential spin-out. The technology transfer process is illustrated in Figure 2-1.

2.6 To give an idea of scale, so far 12 spin-outs have been established (some of which pre-dated Ploughshare's incorporation in 2005), including a 'daughter' company from one of the spin-outs (i.e. a spin-out of a spin-out). Of these, three were exited (though only one of these remains active and substantially so), four remain live at varying stages of their development life-cycle, one was incorporated but never got investment, one is inactive, and three have failed or are in the process of winding up. In addition, Ploughshare has signed royalty-bearing licence deals with over 50 existing firms.

Figure 2-1: Technology transfer process



Source: Ploughshare

Ploughshare's financial performance

2.7 The financial returns to Ploughshare often occur over long lead times. For licensing, fees may accrue in early years when licensees take the initial options and when they reach particular milestones. The main royalties, however, take place in later years (e.g. after c. five years and beyond) once the technology reaches the market. For spin-outs, there is potential for small amounts of royalties if the technology reaches the market, though the main return occurs once the spin-out is exited or sold. This may be 7-10 years or more after establishment. The expectation is that there will be occasional 'star performers' amongst the spin-outs and these may create significant returns for Ploughshare – subject to any dilution of ownership from subsequent rounds of investment.

2.8 Against this backdrop of uncertain and lengthy commercialisation processes, and the long lead times to potential returns, it is challenging to run Ploughshare as a profitable business. That said the company has returned a profit in the last three years despite its annual running costs of around £2 million 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

rationale behind this is that the 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
  - societal benefits if technologies are successfully exploited in other markets such as energy and healthcare.

2.9 It is the nature and scale of these wider benefits that this study seeks to understand.

Findings from the previous study

2.10 This first assessment identified significant economic impact related to Ploughshare's activities, with the following key headlines:

- the creation of a peak of 550 jobs in the period from 2005 to 2013/14, with forecasts indicating that over 500 jobs were likely to exist in 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
- a cumulative contribution to GVA of over £65 million to 2013/14, plus a further £126 million forecast to 2017/18 – i.e. resulting in a total GVA effect of over £190m
- the attraction by the spin-outs of around £130m in investment from public and private sector sources, and investment by the licensees of an estimated £30m into R&D.

2.11 Two key points were noteworthy on the headlines above. First, given the long timescales to commercialisation and business growth, some of the economic impacts, in particular on GVA, were forecast/projected at the time of the assessment rather than achieved. Second, 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.

2.12 The report also found that Ploughshare's role had opened up new technologies to the MoD and emergency services, and to other sectors of the economy such as health. There was also evidence of the development of skills and knowledge amongst Dstl scientists, with some suggesting that they were more likely to get involved in commercialisation in the future. Organisationally, it was recognised that this was part of a gradual shift for Dstl.

Study approach

2.13 This sub-section summarises the study approach with further detail provided in Annex A. We designed the methodology to take account of various government guidance on economic impact assessment. It follows HM Treasury Green Book logic,[4] and has drawn on wider guidance (e.g. BIS evaluation guidance[5], and Scottish Enterprise guidance on economic impact assessment)[6] to help address the challenges in estimating the GVA contribution of early stage companies and technologies. The methodology for this update assessment is consistent with that used in the previous 2015 report.

Assessing the economic contribution

2.14 The approach has focused on the key indicators of employment created and an estimate of GVA generated. In both cases, we have estimated the effect to date (i.e. 2002/03 to 2015/16), and forecast the future effect based on projections for up to three years (i.e. 2016/17 to 2018/19). Other key economic indicators reported are the levels of sales generated and the proportion of these that are estimated to be exports, and so contribute to the UK's balance of trade.

2.15 The approached used for assessing GVA generated has varied according to the development stage of companies or licenced technologies, and the availability of relevant data:

- For those not yet in sales stages, we have adopted an income approach to calculating GVA. Here we have used employee costs (based on salaries) as a component of GVA While acknowledging that this is likely to underestimate GVA,[7] though we considered this to be the most appropriate and consistent approach given the early stages of some of the spin-outs or projects with licence deals.
- For those in sales stages, we have either (dependent on data availability):
  - drawn on data on turnover and the cost of bought in goods and services (COGS) and estimated GVA as the difference between the two
  - used wages + profits.

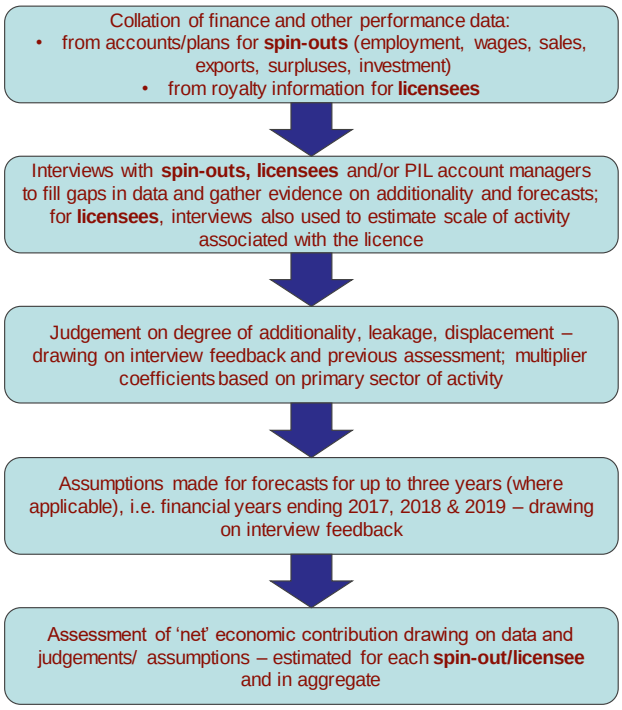
2.16 Future potential GVA has incorporated available and assumed forecasts for employment (and so employee costs), and turnover and surpluses (for the businesses that are expecting to turn to sales). We have not incorporated the actual or future expected exit values of spin-out companies. Whilst these 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 firms that have exited or are expected to do so in the short-term, we have included actual and forecast data (with estimates used where these have been unavailable).

[4] HM Treasury's Green Book provides guidance on the appraisal and evaluation of public sector spending. Its underlying logic highlights how economic benefits can be considered as part of such an assessment.
[5] Department for Business, Innovation and Skills (2011) *Guidance on Evaluating the Impact of Interventions on Business*, BIS, London.
[6] Scottish Enterprise (2008), *Additionality and Economic Impact Guidance Note,* Scottish Enterprise, Glasgow.
[7] 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).

The diagram below summarises our approach to estimating economic contribution. Several technical terms are used in the economic assessment that is presented in section 3, and their meanings are set out in Source: SQW

. Annex A provides further detail on the technical aspects of the assessment.

Figure 2-2: Schematic of approach



Source: SQW

Table 2-1: A note on key terms

Term	Meaning (spin-outs)	Meaning (licensees)
Gross effect	Overall direct effect, e.g. in terms of employment of 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 employment that is related to the licence, 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	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*

Scope of economic assessment

2.17 The study has included within scope the spin-outs and licences that, whilst part of Ploughshare's current (or exited) portfolio, originated prior to its formation in 2005, as well as those originated since 2005. We have include the impacts associated with the earlier firms and licences as they represent the commercialisation activity that Ploughshare now delivers, but which was previously undertaken by an in-house group at Dstl[8].

Wider benefits

2.18 Drawing on consultation evidence, we have developed a series of case studies to demonstrate the benefits in both the defence and civilian markets through commercialisation. These case studies are not intended to be representative of the spin-out/licence portfolio as a whole, but rather they set out the types of impact that have been achieved. These findings are set out in Section 4.

2.19 The study has also examined the benefits of Dstl commercialisation activity (via Ploughshare) on Dstl staff. Using consultations with scientists and technical staff, we have explored to the experience of working on commercialisation activity may have contributed to new attitudes, behaviours, skills and knowledge. These findings, which are qualitative in nature, are reported in Section 6 along with a series of observations on the enabling factors and barriers from the perspective of these scientists and technicians.

[8] A small number of spin-outs and licensees have not been included due to an absence of data. The spin-outs would make limited difference to the overall assessment as they are firms that have not been successful and employed limited numbers of people for limited periods of time. The excluded spin-outs are: Leading Light and Sherwood. There are ten licensees that did not inform the assessment – these have been incorporated in the assessment by adopting a grossing up process, which is explained in Annex A.

3. Economic assessment

3.1 This section presents our estimates for the economic contribution of Ploughshare's commercialisation activities. For each indicator of economic contribution (employment, exports and GVA), we assess benefits to date as well as in the future. First, we present a summary of the headlines on the economic assessment and then provide the key findings for the spin-outs and licensees in turn (a more detailed Annex sets out further findings – see Annex C).

Summary of economic impact

Summary of headlines on economic impact

Taken together, Ploughshare's spin-out and licensing activity has generated:

- **Employment:** commercialisation activity has led to a peak of **585 (net additional jobs to date)**. In 2018/19, it is forecast that approximately 430 net additional jobs will exist.
- **Exports:** Ploughshare-backed technologies have generated **c.£75 million in net additional exports to date**, with another **£147 million forecast** for the period 2016/17 to 2018/19
- **GVA:** between **2002/03 and 2015/16**, commercialisation activity has led to **net additional GVA worth over £117 million** and future net additional GVA is forecast to be **c.£107 million between 2016/17 and 2018/19**. This results in a total GVA effect of over £220 million.

Much of the impact to date has been driven by a small number of spin-out firms. However, we expect future GVA to be generated by both the spin-out and licensee portfolios in equal measure.

In addition, the portfolio of 12 spin-outs have attracted around £140 million of public and private investment since the early 2000s.

Note

3.2 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 that some technologies can take a long time to commercialise (as outlined in Section 2). A few of the spin-outs and licensees are potentially on the cusp of moving into sales phases or expecting to see substantial increases in sales. As a result, there is a significant proportion of the impact that is *forecast*. These have been estimated based on company projections. Forecasts become more uncertain the further we go into the future. As such, forecasts have been made until 2018/19 (i.e. the expected outturns for the current financial followed by forecasts to the two years after that). The degree of uncertainty around forecasts becomes particularly evident when we compare the

estimated impacts from this new updated assessment with those of the previous 2015 assessment – this is covered at the end of this section.

Assessment of the benefits of spin-out activity

Investment

3.3 Overall, around £140 million of public and private investment has been attracted by the 12 spin-outs since the early 2000s. This is likely to be a slight underestimate due to gaps in the data, and it is not possible to separate out the public and private investment amounts.

Employment

3.4 Here we present the employment associated with the spin-out activity. We consider employment in terms of four metrics:

- **Gross employment:** the total headcount across all spin-outs over a defined period, excluding any consideration of additionality effects
- **Maximum employment to date**: amongst young businesses in particular, employment levels can fluctuate given the susceptibility to market conditions. In some cases, employment may have peaked prior to 2015/16. This metric therefore sums the highest employment figures achieved by each portfolio firm to date.
- **Current employment**: this reflects the position of the portfolio as it stands currently (based on figures for 2015/16).
- **Forecast employment**: the anticipated employment across the portfolio at 2018/19.

3.5 Between 2002/03 and 2015/16, the total maximum employment in gross terms across the spin-out portfolio was 224 FTEs. Gross employment at 2015/16, however, was 133 FTEs across. This observed fall can largely be explained by the failure or winding down of half of the spin-out portfolio.

3.6 More generally, the trajectory of employment is reflective of both a firm's performance and its maturity in relation to its growth model. For most Ploughshare spin-outs, small numbers of highly-skilled technologists will initially lead both product and firm development. Once firms near production, in-house full-time capacity will normally be needed, meaning that job numbers can escalate rapidly. Gross employment is expected to reach 150 FTEs by 2018/19, a rise on current levels. Most notably, staff levels for one of the spin-outs are forecast to treble over this period, demonstrating how quickly the employment figures across the portfolio may change going forward.

3.7 In this context, the 'direct' additional impact on employment (i.e. resulting from the expenditure and operation of the spin-out) is presented in Table 3-1. The fact that these figures are similar to the 'gross' figures shown above is reflective of the high levels of additionality from Ploughshare's activities. Table 3-2 presents the estimates including 'indirect' effects on employment (i.e. including multiplier effects resulting from expenditure and operation within the spin- outs' supply chains) as well as the direct effects.

Table 3-1: Additional Direct Impact on Employment

Annual Employment Metric	Total (FTE)
Maximum employment to date	202
Current (2015/16)	122
Forecast by 2018/2019	146

Source: SQW analysis of Ploughshare data

Table 3-2: Additional Direct and Indirect Impact

Annual Employment Metric	Total
Maximum employment to date	321
Current (2015/16)	194
Forecast by 2018/2019	240

Source: SQW analysis of Ploughshare data

Contribution to export sales

3.8 To date (2002/03 to 2015/16), the spin-out portfolio has generated in gross terms, exports worth £66 million, with a further £141 million forecast from 2016/17 to 2018/19.

3.9 In terms of gross export values to date, the vast majority (nearly 90%) is accounted for by one spin-out, with two others together accounting for most of the remaining 10%. The noticeable jump in export values between 2015/16 and 2018/19 is due to some significant projected increases in exports for certain spin-outs. These sizable export values will contribute to the government's wider rebalancing objectives which include improving the net trade balance.

3.10 Once more, Table 3-3 shows the direct additional impact on exports.[9] 'To date' figures are similar to the 'gross' ones, reflecting high levels of additionality. However, for forecast export values there is a greater difference between the 'gross' and 'additional direct' impact figures, which is largely explained because of the lower levels of additionality associated with SARA[10].

Table 3-3: Additional Direct Impact on Exports

Export Value Metric	Total
To date (2002/03 to 2015/16)	£65,524,000
Forecast (2016/17 to 2018/19)	£87,482,000

Source: SQW analysis of Ploughshare data

GVA contribution

3.11 As with employment, we consider GVA contribution against different metrics: the contribution of portfolio firms to GVA to date (covering the period 2002/03 to 2015/16); and their contribution to forecast GVA (covering the period 2016/17 to 2018/19). In both cases,

[9] Multiplier effects are not appropriate here and are thus excluded from the assessment of export sales.
[10] This is due to the substantial differences between the knowledge required to develop SARA's product offering and the original IP taken from Dstl in order to set up SALT – although sales remain royalty-bearing. Consultation evidence indicated that the contribution of the original IP was "relatively low" with significant other investment required, and so the additionality associated with Ploughshare is modest.

we consider three parts to this: gross impact; additional direct impact; and additional direct + indirect impact (please re-visit Table 2-1 for a detailed explanation on these).

3.12 Over the period 2002/03 to 2015/16, the spin-out portfolio generated GVA worth an estimated £56 million, an average of £4 million per year. The biggest contributors over this time have been P2i and Enigma[11]. Forecast gross GVA for the period 2016/17 to 2018/19 is estimated at around £50 million, an average of £17 million per year. This per year increase in GVA (compared to the 'to date' figures) is reflective of the expected maturity of some of the live spin-outs that, and in one case an anticipated rapid expansion. However, the failure/winding down of one or two of the other spin-outs mean that forecasts are slightly lower than may have been anticipated in the previous 2015 assessment.

3.13 'Additional direct' and 'additional direct and indirect' impacts are presented in Table 3-4 and Table 3-5. In headline terms, this shows an additional direct and indirect GVA effect of around £80million cumulatively to date, with a forecast effect, including both direct and indirect impacts, of just over £40million for 2016/17 to 2018/19.

Table 3-4: Additional Direct Impact on GVA

GVA Metric	Total
To date (2002/03 to 2015/16)	£50,571,000
Forecast (2016/17 to 2018/19)	£25,714,000

Source: SQW analysis of Ploughshare data

Table 3-5: Additional Direct and Indirect Impact on GVA

GVA Metric	Total
To date (2002/03 to 2015/16)	£80,912,000
Forecast (2016/17 to 2018/19)	£42,505,000

Source: SQW analysis of Ploughshare data

3.14 The case study below, on P2i, illustrates the economic contribution that spin-outs through Dstl/Ploughshare can have. The last assessment highlighted the contribution of this company to the economy, and the updated assessment has reaffirmed this.

[11] This reflects in particular its employment of R&D staff.

P2i

Established as a Dstl spin-out in 2004, 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.

As P2i has evolved, it has entered new markets, most notably in the waterproofing of consumer electronics. This was initially focused on protecting hearing aids, but in recent years P2i has concentrated on smart phone protection. Whilst its markets are global it continues to have a significant presence in the UK, in particular in relation to R&D. Around 80 employees are based in the UK, and this is forecast to grow. As such, P2i's contribution to the economic assessment is significant in terms of employment, GVA and exports.

Ploughshare played a key role, particularly in the early stages of market development for P2i. Though this relationship diminished over time as the spin-out matured, this was regarded as a natural part of the business' development, culminating in Ploughshare exiting from its shareholding in 2015.

Assessment of the benefits of licensee activity

3.15 Our approach to presenting the impact of licensee activity follows a similar structure to that of the spin-outs with the same metrics being captured for employment, export and GVA effects.

3.16 This sub-section presents our estimates for impact across the whole licensee portfolio. Our detailed analysis was based on firm-level analysis of 25 of the most prominent and active licensees. Consequently, when assessing the maximum employment to date, GVA to date, and exports to date, we have presented *grossed up* economic contribution figures to help account for the full impact. To do this, we examined the income contribution to Ploughshare of these 25 firms to date as a proportion of the total income received by Ploughshare from the fuller set of licensees presented in Annex B. We then scaled up the economic contribution of these 25 firms accordingly to estimate the total impact across the entire licensee portfolio.

3.17 In assessing current employment and forecast benefits, grossing up is not required, working, because the firms that have not been subject to detailed analysis are largely inactive.

Employment

3.18 Gross employment in 2015/16 stood at 215 FTE (i.e. approximately 9 per firm). This figure is lower than 23 FTE per firm seen with the spin-outs. This is explained by the fact that a large proportion of licensee activity remains focussed on R&D rather than production and sales. As such, employment activity is characterised by small, focussed activity. Of the licensee firms covered in detail, BBI Detection, AmSafe Bridport, Thales, Raptor and Tata account for over half of the FTEs.

3.19 As shown in Table 3-6 and Table 3-7, our estimates of 'additional' employment in 2015/16 is lower than the gross effect. This reflects the fact that in many cases, licensee firms were already doing some relevant activity anyway but saw the licence deal as a way of accelerating progress. The tables also show that the forecast employment figures for 2018/19 are noticeably lower than the maximum peak employment for the period 2002/03 to 2015/16. This reflects two issues:

- Many licensees do not expect large increases in employment in the immediate future with activity remaining relatively constant going forward.
- Many of the licensees examined in the period 2002/03 to 2015/16 are now inactive and therefore will not generate any future employment.

Table 3-6: Additional Direct Impact on Employment

Annual Employment Metric	Total
Maximum employment to date	148
Current (2015/16)	103
Forecast by 2018/19	113

Source: SQW analysis of Ploughshare data

Table 3-7: Additional Direct and Indirect Impact

Annual Employment Metric	Total
Maximum employment to date	264
Current (2015/16)	185
Forecast by 2018/19	199

Source: SQW analysis of Ploughshare data

Contribution to export sales

3.20 Gross export values to date have been low, reflecting the fact that most of the licensees have either not yet reached the point of sales, or have focussed on domestic markets. Indeed, of the 25 firms examined in detail, only three reported export sales between 2002/03 and 2015/16 and one of these accounted for nearly all of the total exports. In gross terms, for the whole licensee portfolio exports between 2002/03 and 2015/16 totalled £16 million (£1.1 million per year). Between 2016/17 and 2018/19, gross exports are expected to rise substantially to £99 million (£33 million per year) across the licence activity. A large part of this increase is expected to come from Thales, which is forecasting sales from 2017 onwards, and from BBI Detection.

3.21 As shown in Table 3-8, the additional direct impacts (both 'to date' and forecast) are lower than the corresponding gross figures. As per employment, this is illustrative of the fact that Ploughshare's additionality for licensees is lower than that for spin-outs.

Table 3-8: Additional Direct Impact on Exports

Export Value Metric	Total
To date (2002/03 to 2015/16)	£9,059,000
Forecast (2016/17 to 2018/19)	£60,144,000

Source: SQW analysis of Ploughshare data

GVA contribution

3.22 Over the period 2002/03 to 2015/16, gross GVA across the licensee portfolio totalled £31 million with Thales and Morgan Composites contributing together around one-half of this. GVA for 2016/17 to 2018/19 is forecast to be a further £55 million. This is accounted for by a small number of licensees that are forecasting sizeable increases in sales over the next few years.

3.23 Table 3-9 and Table 3-10 present the 'additional direct' impacts and 'additional direct and indirect' impacts respectively. In headline terms, with the inclusion of multiplier effects (i.e. using the direct and indirect figures), the GVA contribution to date from the licensees is estimated at just under £37 million, and the forecast contribution for 2016/17 to 2018/19 is over £60 million.

Table 3-9: Additional Direct Impact on GVA

GVA Metric	Total
To date (2002/03 to 2015/16)	£19,661,000
Forecast (2016/17 to 2018/19)	£32,711,000

Source: SQW analysis of Ploughshare data

Table 3-10: Additional Direct and Indirect Impact on GVA

GVA Metric	Total
To date (2002/03 to 2015/16)	£36,667,000
Forecast (2016/17 to 2018/19)	£64,309,000

Source: SQW analysis of Ploughshare data

3.24 The case study for AmSafe Bridport provides an example of a licensee that is expected to generate substantial GVA. Activity related to its licence, which has enabled them to develop Tarian ®, an armour system for vehicles, has created around 20 full-time equivalent jobs in the UK. At the time of the last assessment, AmSafe was on the cusp of generating significant sales, and since then has secured a number of contracts. It is now generating a surplus from activity related to the licence and the forecast economic contribution appears to be now more certain.

AmSafe Bridport

Founded in 1979, AmSafe Bridport designs and manufactures engineered textile solutions for global aerospace and defence markets. In 2010, they introduced Tarian®, a Rocket Propelled Grenade (RPG) net armour system for armoured vehicles following a licence deal with Ploughshare.

According to the firm, the licence deal has been central to getting Tarian to market. AmSafe Bridport needed to be able to test effectively their technology and ensure that it met the needs of the market.

At the time of the 2015 study, AmSafe Bridport believed it was on the cusp of generating significant sales. Since then, the company has signed a major contract with the Danish government to provide RPG protection for a period of seven years. It has also signed notable contracts with countries in Europe, the Middle East, Asia, north Africa, and with the UK's MoD.

Currently, activity related to Tarian generates approximately 20 FTE jobs in the UK and is now beginning to create a surplus for AmSafe Bridport. The firm's future prospects are also positive, and Tarian sales are expected to grow year-on-year from under £7 million in 2015/16 towards £15 million in 2018/19.

In terms of our economic assessment, it is estimated that the licensing of the technology by Ploughshare will have contributed around £10 million to UK GVA (cumulatively) by 2018/19.

Total economic impact

3.25 Table 3-11 below brings together the previous spin-out and licensee analysis and shows the total impact generated. As shown, our study has found significant additional direct and indirect impact on employment, exports and GVA that are attributable to Ploughshare's commercialisation activities.

3.26 A high proportion of the additional economic impact to date has come from the spin-outs which have contributed c. 70% of the GVA and c. 60% of the maximum employment to date. Nevertheless, the licensees are expected to play a much more significant role in the future: according to our estimates the licensees will generate nearly 60% of forecast GVA. Moreover, to date Ploughshare's economic impact has largely been dominated by a few key spin-outs and licensees. Going forward, however, a slightly greater number of firms are expected to contribute to the economic contribution of Ploughshare.

Table 3-11: Summary of impact indicators for spin-outs and licensees combined

Indicator	Additional Direct Impact	Additional Direct + Indirect Impact
GVA to date (2002/03 to 2015/16)	£70,231,775	£117,578,731
Future GVA (2015/16 to 2018/19)	£58,424,926	£106,814,267
Maximum employment to date (2002/03 to 2015/16)	351	585
Current employment (2015/16)	225	379
Future employment (at 2018/19)	258	439
Exports to date (2002/03 to 2015/16)	£74,583,052	-
Future exports (2016/17 to 2018/19)	£147,625,773	-

Source: SQW analysis of Ploughshare data

3.27 In Table 3-12, we present a summary of the results for the economic assessment under this new updated 2017 assessment alongside those from the previous 2015 assessment. The results of this updated assessment highlight the progression that a number of spin-outs and licensees have made, with the impacts 'to date' now higher. Notably, the net additional GVA to date has moved on from £65million (to 2013/14 – estimated in the previous assessment in 2015) to £118million (to 2015/16), which is encouraging.

3.28 The net additional forecasts are slightly lower in this updated assessment. This reflects a few key factors:

- Some of the forecasts from the previous assessment have translated into actual impacts to date.
- The previous assessment had a slightly longer timeframe for forecasts (four years rather than three).
- There have been some significant changes in the fortunes of different companies within the spin-out and licensee portfolio. Notably, one spin-out, which was forecasting significant growth as part of the previous assessment, is now winding down, whereas another spin-out is now expecting slightly higher levels of growth. There are similar changes in the expected growth of different licensees. These changes are to be expected, and reflect the different development paths of businesses, in particular in markets for innovative technologies that can be unpredictable and/or risky. The net balance, however, has meant that forecasts have shifted down slightly.

3.29 Due to challenges in disentangling R&D investments for licensees, we only have data in both assessment periods for investment for the spin-outs. As reported earlier, the 12 spin-outs have attracted at least £140 million of public and private investment to date. This is a slight increase from the £130 million reported in the 2015 assessment.

Table 3-12: Comparing the previous 2015 assessment with the new 2017 assessment

Indicator	Total additional impact (new assessment)	Total additional impact (previous assessment)
Employment to date (max)	585	547
Current employment (i.e. at 15/16 for new and 13/14 for previous assessment)	379	286
Employment forecast (i.e. at 18/19 for new and 17/18 for previous assessment)	439	516
GVA to date (i.e. to 15/16 for new and to 13/14 for previous assessment)	117,579,000	64,718,000
GVA forecast (i.e. 16/17 to 18/19 for new and 14/15 to 17/18 for previous assessment)	106,814,000	125,636,000
Total GVA	224,393,000	190,354,000
Export to date (i.e. to 15/16 for new and to 13/14 for previous assessment)	74,583,000	43,503,000
Export forecasts (i.e. 16/17 to 18/19 for new and 14/15 to 17/18 for previous assessment)	147,626,000	179,070,000

4. Benefiting defence and civilian markets

4.1 This section examines the wider benefits associated with the types of technologies that Ploughshare has helped commercialise, covering both defence and civilian markets. It draws on information gathered through interviews with individual spin-outs and licensees, and discussions with Ploughshare account managers. The assessment includes benefits that are already happening as well as those where there is the potential for impacts in the future. These future potential effects reflect the various stages of market readiness of different technologies.

Benefits to the defence market

4.2 Technologies commercialised through Ploughshare have brought about two important benefits to UK defence and security: improvements to the country's defence and security capabilities, and development of the UK supply chain.

UK based defence capabilities

4.3 In several instances, Ploughshare has helped instigate activity, which has enabled UK firms to develop technologies that MoD would ordinarily have had to source form abroad. Aside from helping to retain economic benefits in the UK, this is also important from a strategic defence perspective insofar as it helps provide the UK with independent defence capabilities. In addition, the application of technologies helps the UK to combat various challenges to national and international security.

4.4 The two case study boxes below provide examples of the commercialisation of technology that provides UK-based capabilities. Both companies identified supply (or have supplied) the MoD as well as other countries, and so contribute to Ploughshare's objectives relating to economic benefits and ensuring that the UK has defence capabilities. The first example is ESROE, a spin-out company, which provides electronic warfare software, and the second example is Morgan Composites and Defence Systems, which has licenced technology from Ploughshare to provide specialist ceramic technology in vehicle armour systems.

ESROE

ESROE is an electronics company that specialises in electronic surveillance and support software solutions. It was created in 2010 as a Dstl spin-out to commercialise electronic warfare software developed by the MoD.

The software provides real-time identification of radar signals and is used across armoured vehicles, large warships and surveillance aircraft. Others are now also using the ESROE software to provide real-time protection of major strategic assets. The vast majority of ESROE's sales are outside the UK though there is also a small amount of UK-based sales each year helping to contribute to UK defence.

According to the firm, ESROE's future prospects are strong. Market awareness of the software is improving and the firm believes it is on the cusp of seeing major sales. ESROE is also looking to take the technology into new areas, including much smaller units, which can be carried by individual soldiers.

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 Ploughshare over the last decade for the use of specialist ceramic technology in vehicle armour systems. Ceramic-based armour is generally lighter than more traditional steel armour and offers additional survivability benefits, making it particularly effective in many vehicle applications.

In 2008/09, Morgan Advanced Materials sold its armour systems to the UK government to help service operations in Afghanistan. In order to fulfil this contract, Morgan Advanced Materials employed around 200 staff. The firm also expects to generate future sales to north American allies.

The ceramic armour technology is now regarded as a tried and tested technology for the type of warfare associated with Iraq and Afghanistan. Although there will still be some residual demand for this technology over the coming years, many nations are now updating their fleets and are looking for lower cost and more modern armour ceramic/composite protection schemes instead. Morgan Advanced Materials is also developing these newer technologies. However, should there be a need for ceramic armoured protection (e.g. due to new conflicts) before fleets are updated, then Morgan Advanced Materials will remain well placed to service this potential demand.

4.5 Other companies have commercialised technologies in the defence area. For example, Amsafe Bridport has developed the Tarian® armour system for vehicles as a result of a licence deal

with Ploughshare. It has contracts in various countries, including with the MoD. Importantly in terms of UK-based defence-related capabilities, around 85% of its suppliers are UK-based. In addition, there are other companies that have or are expected to contribute to UK defence capabilities, including those providing various detection and testing technologies.

Civilian and commercial markets

4.6 In addition, Ploughshare-facilitated activity has also generated benefits for civilian and commercial markets.

4.7 There are a number of companies operating within the health and life sciences sphere. For example, Prokarium (see case study box below) has a licence with Ploughshare that they are using to help with work on vaccines for a range of diseases. Other firms, such as Pharmathene, Recipharm and Selective Antibodies, all hold licences that is supporting research and development work in the field of health and life sciences. In all of these cases, and as noted in the box below on Prokarium, work is still in development with the potential to have an impact in the future. This reflects in part the long development times associated with the sector.

Prokarium

Prokarium is a biopharmaceutical firm that develops vaccines based on synthetic biology. Vaccines are administered orally and use bacteria to encourage the body to stimulate an immune response.

The firm holds a licence with Ploughshare for the ORT-VAC technology (Operator-Repressor Titration for Vaccines) which helps stablise vaccine plasmids inside the bacteria used.

Prokarium is currently working on six vaccines for diseases including asthma, chlamydia and C. difficile. Four of their vaccines currently use the ORT-VAC technology.

The firm's vaccines have the potential to transform the administering of vaccines, ensuring that they are more effective and can be delivered more efficiently. The vaccines are more stable than those currently on the market, ensuring they have a longer shelf life. Being oral vaccines, they can also be self-administered, making it easier to implement larger scale vaccination programmes. Additionally, Prokarium's vaccines better mimic the source of most infections (namely in the air or through food) in contrast to injections which only really mimic insect bites, enabling a more effective response. Prokarium can also engineer the bacteria in the vaccines to cover multiple strains of the same disease.

4.8 Some of the technologies that have been licenced have applications in markets that are related to defence, e.g. in surveillance and security. Examples are provided as follows:

- BBI's licence arrangement with Ploughshare has given them access to technology relating to the detection of bio threats and explosives. BBI's IMASS device can provide detection capabilities relating to identifying biological and chemical threats with benefits to, for example, improving airport security.

- Claresys, a spin-out company, has world-leading camera lens technology for covert surveillance thanks to the technology endowed to it through Ploughshare. This enables improvements in the effectiveness of camera lenses as well as addressing issues of detectability. The company supplies a niche market to support special forces and law enforcement.

4.9 Other technologies can have dual use between defence and other sectors. For example, ASV Global (see case study box below) is a relatively recent licensee, signing a deal with Ploughshare last year. The licence gives the firm access to technology required for self-driving boats and the ability to develop this outside of the defence sector. Whilst in the short-term it is expected that the firm's software will benefit the defence sector, in the longer-term there is potential to have broader use, including in the marine sector.

ASV Global

Founded in 2010, ASV Global is a supplier of unmanned and autonomous marine systems and works across a range of sectors including military, science and offshore energy.

In September 2016, ASV Global signed a licence deal with Ploughshare for access to technology concerning the autonomy architecture and software needed for self-driving boats. More specifically, the licence gives ASV Global rights to develop the product for non-MoD markets.

In the short-term, ASV Global envisages most software sales to come from military and defence markets. However, in the longer term they see it having much broader uses. For instance, they expect to gain commercial clients including in the oil and gas sector, and with universities and the wider scientific research community. There is also potential to develop the technology as a driver aid to enable autotomized loading and unloading, something which is hoped will mitigate risks of piracy.

According to the firm, the technology could have a wider impact on the civilian shipping market. Increased use of autonomous systems will reduce the number of crew required on boats, helping to make shipping operations more efficient.

4.10 Finally, some technologies have a wide range of applications. For example, the Multiplexed Binary Offset Carrier (MBOC), which will be the standard used in global navigation satellite systems, will have an impact in a range of different sectors and markets (see case study box below).

MBOC

MBOC is a signal modulation solution that provides the means to receive and unscramble signals from satellites. MBOC will be the standard used in Global Positioning System III (GPS III) in the USA and the complementary but separate Galileo system in Europe. The decision to use MBOC (rather than other solutions) partly related to its superior performance on aspects such as the degree of accuracy and quality. Effectively, any product or application that uses GPS III or Galileo satellite signals, from satellite receivers to mobile phones, will automatically utilise the MBOC technology. Its importance to consumer phone markets, navigation for transport sectors and the general public, logistics, and a range of other emerging applications will therefore be significant.

The financial benefits to Ploughshare have been limited because of the agreements made with the USA government and the European Commission, which reflected diplomatic considerations (see below). Access to the technology contained in the MBOC patents has therefore been provided in the USA and Europe at sums that do not reflect their full market or economic value.

In order to consider the benefits of the development of MBOC, it is therefore necessary to assess the wider benefits. There are three aspects to this: **descriptive analysis of the potential applications** in different sectors; the benefits through **diplomacy** such as fostering relationships with the USA; and the **economic benefits** through assumptions of royalties that theoretically could have been obtained.

In terms of the potential applications, the breadth of those that require MBOC is extensive, and it is estimated that over 10% of the UK's non-financial business economy is supported in some way by global navigation satellite system to which MBOC will contribute[12]. The use of GPS in automotive products and Smartphone products are perhaps the most familiar, along with the increasing use in cameras (enabling geotagging) and portable devices such as fitness equipment for runners and cyclists. In addition, there is specialist use in a range of other product lines:

- The greater accuracy in location can enhance the use of machines in precision agriculture, supporting UK industrial priorities around the development of the agri-tech sector where there is growing use of robotics and sensors.
- The application of GPS in logistics and tracking is expected to grow in the future, as this enables the tracking of fleet vehicles and the goods that they carry. Amongst other applications, this has huge potential in supply chain management and is a key part of supporting improvements in the competitiveness of manufacturing as part of Industry 4.0. Again, this supports the development of this priority sector as part of UK industrial strategy.
- Applications in navigation and tracking are also being used in a range of transport-related applications, including aviation, rail (such as in tracking

[12] London Economics (2016) *The Size & Health of the UK Space Industry,* Report to the UK Space Agency. This reports that 11.7% of the non-financial business economy is supported in some way by GNSS.

rolling stock) and marine (e.g. for 'driverless boats' and tracking fishing trawlers), and in the development of services relating to other societal challenges and opportunities, for instance around future/smart cities, and assisted living. These are also key innovation priorities for the UK.

As the examples above show, the improvements in satellite signals, that MBOC is contributing to, can help encourage innovation in new types of application. This is an important feature of the wider benefits, because it will assist in establishing the conditions that can prompt innovation in a range of other areas, from the internet of things to connected and autonomous vehicles to a set of currently undeveloped applications.

The financial benefits to Ploughshare have been limited because of the international and Government-to-Government agreements reached, particularly with the USA and the European Commission. The process of reaching agreements involved leading representatives from military, political and scientific organisations on both sides of the Atlantic. The negotiations were highly sensitive. The result provided significant diplomatic benefits for the UK and its partners, including a basis for even deeper space co-operation by the UK and USA across a range of civil and defence-related challenges and opportunities.

It is difficult to value the potential economic benefits of MBOC, as there is value to those developing and selling products and services, the extra value to users of these products and services that is not reflected in the market prices that they pay (i.e. the consumer surplus), and the potential wider benefits to society. It also needs to reflect the attribution to MBOC specifically (versus other contributory factors) for the developments of these products and services. Nevertheless, based only on the potential UK royalty fees for high-end receivers that have been forgone, our analysis suggests that the estimates of the economic benefits would run into the tens of millions of pounds. If global royalty fees were considered, the benefits are much more significant.

Summary

4.11 As outlined in this section, technologies spun-out or licenced by Ploughshare can have applications in a range of sectors. These include defence (and so developing UK-based defence capabilities); areas allied to defence such as surveillance and security; industrial sectors such as marine, oil and gas, and aerospace; and health and life sciences. In most of these cases, technologies that have been licenced or endowed in spin-outs have started to make positive contributions to these sectors. For certain examples, the developments are at the forefront and so will require time, e.g. in the case of unmanned boats, or the timescales of development are very long, notably in the case of health and life sciences where technologies relating to treatments are yet to reach the market.

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 derived from these activities. This has drawn on evidence provided in in-depth interviews with a selection of scientists representing a range of research areas and technology types.

Background to consultees

5.2 As part of the study, we conducted detailed consultations with four Dstl staff who had roles such as 'Principal Scientist', 'Senior Engineer' and 'Researcher'. All of those interviewed had extensive experience of the research related to the specific spin-out or licensee, with three consultees with 8-10 years' experience on their projects and one with about 20 years' experience – though this includes some periods of project inactivity. More widely, those interviewed had substantial experience in their careers, ranging from 20 – 30 years' experience on projects at various levels of technological readiness.

5.3 Despite this depth of experience, for each of the consultees, their project with Ploughshare represented their first time explicitly participating in the commercialisation process. For some consultees, their involvement with licensees or spin-outs was relatively indirect, while, for others, engagement with licensees or spin-outs was much more detailed and engaged.

5.4 Whilst, on the whole, we were able to conduct open and detailed consultations with the consultees, on certain aspects there was a reluctance to discuss the details of their project due to the confidential and militarily sensitive nature of their work. Despite the absence of some project-specific information as a result, consultees were still able to provide valuable contributions regarding the process of commercialisation and their personal/professional development that resulted from the process.

Benefits to researchers

5.5 At the most general level, all consultees identified personal, professional and institutional benefits stemming from their involvement in the commercialisation process. Three of consultees explicitly identified the fresh perspective provided by collaborating with private-sector businesses as beneficial. This was due to the increased number of experts working on the technology and/or because of the added sense of purpose resulting from the commercial imperatives of the spin-out or licensee.

5.6 Professionally, consultees said that commercialisation had allowed them to develop a better understanding of the R&D process and how the requirements and priorities of this process developed as R&D transitioned from public sector to private sector-led development. One consultee also noted that they had actively expanded their networks as a direct result of the process (see case study box below), especially amongst business and academic partners, two others said that they already had good relationships with their collaborators.

Scientist A

Scientist A is a Principal Scientist with 20 years' experience working on MoD research, with a particular focus on identifying and categorising biological airborne particulate matter.

With funding from the EU INTERACT programme in 2010 , Scientist A was part of the team at Ploughshare co-ordinating the commercialisation project and taking an MoD prototype in to commercial development. As a result of this process, Scientist A worked closely with one licensee to develop the technology and was able to refine the process and broaden the commercial market and scope for the technology.

Engagement in the commercialisation process strengthened Scientist A's network in academic and commercial research – collaborating with colleagues at these organisations to publish papers and develop PhD programmes.

Reflecting on the process, Scientist A said that Ploughshare played an important role taking care of the initial market research and managing the relationship between scientists and commercial partners. Scientist A was able to dedicate more time to the technical elements of the project and was particularly pleased to see that there were now active users of the research – and that the research was not simply 'a report filed away on a shelf somewhere'.

From an institutional perspective, Scientist A said that Ploughshare projects allowed technology to be developed, refined and progressed at arms-length from the MoD even when direct funding was unavailable for the project. This meant that, rather than have the technology lie dormant, the technology was kept active should Dstl or MoD reprioritise it in the future.

5.7 Though not framed specifically as a negative issue, two consultees said that they had not received the career progression and commensurate increase in their remuneration they had expected because of engaging in commercialisation. Specifically, these consultees said that, while there were important additional benefits of taking part in commercialisation, they did not think that taking part in the process had obviously or directly improved their employment or progression opportunities. In part, this aligns with the findings from the 2015 assessment, for which Dstl researchers commented that the primary reward was the satisfaction of seeing a technology concept taken to market. The financial benefits, whilst important to have and noted as being essential to keep, were seen as a secondary element to the motivation for being involved in commercialisation.

Benefits to Dstl and developing the defence sector

5.8 In terms of developing the technology, a number of consultees said that – in relation to MoD budget reviews – commercialisation allowed technology to be developed and refined even when it was no longer Dstl priority. Consultees who identified this benefit said this was beneficial for the technology and the spin-out/license companies, but also for Dstl itself – as it meant that, rather than simply "leave the technology gathering dust on a shelf", the technology was progressed and then potentially returned to Dstl in a more advanced form at later.

5.9 This links back to personal benefits. On this subject, one consultee added that – while perhaps not institutionally important – it was personally satisfying to see research/technology progressed and developed even when it was not being directly pursued by Dstl.

5.10 Some consultees said they thought supply chains had been improved by the commercialisation process, with one consultee saying that licensed firms were able to trade technology back to the MoD and others. Furthermore, this consultee added that, by broadening the technology and the stakeholders using it, the market for components had been strengthened and was becoming more refined in terms of technological effectiveness. Another consultee indicated that the process had broadened perceptions about the market applications of their project's technology. In doing so, this had allowed more companies to use the technology in their industry.

Future engagement

5.11 A number of consultees highlighted the time-consuming nature of engaging in the commercialisation process – saying that it was quite strenuous when regarded as additional to their normal workflow. This is not to say that commercialisation was thus seen as a burden, but rather there was a sense that, as one consultee put it, "you get out [of commercialisation] what you put in". Nevertheless, all consultees said they would be willing to engage in the commercialisation process again in future, as it had provided numerous, varied insights and benefits.

5.12 However, three consultees said the process only made sense for reasonably concrete, serious and large projects, with one saying they felt that, while they had benefited from the process, they could have benefited further had they been able to engage more – though this was ultimately not possible due to budget constraints. This observation was made particularly forcefully with regards to projects with an international dimension.

Scientist B

While all consultees said they benefitted from participating in the commercialisation process, it is worth highlighting the challenge of ensuring military and institutional processes align with the commercialisation requirements of civilian markets.

Specifically, one consultee discussed the significant challenges faced by their project, which, while commercially viable and at the cutting edge of technology, was almost entirely dependent on the formal acceptance of a standard within a large multilateral organisation.

As a result of delays to the acceptance process, the commercialised project was temporarily shelved and saw elements of its technology overtaken by rival systems. Combined with the relatively small market that was relevant to the project, this led to serious difficulties finding customers for the technology and incurred frustrating financial and opportunity costs for those engaged.

Key issues going forward

5.13 Taken as a whole, the consultees' evidence provides a broadly positive account of participating in the commercialisation process, albeit not without some challenges and critical observations. Summarising some of the key issues identified above, this section highlights considerations that could to be borne in mind to ensure effective engagement of researchers in future.

5.14 **Time and resourcing** – Three consultees said that participation in the commercialisation process was more time-consuming than they had expected. While this was not seen as a problem, and none of the consultees suggested they would not have participated had they known it would take up more time, more information could provide researchers with a better sense of proportionality between the benefits and the amount of time required to get the most out of participation.

5.15 **Relationship to progression and reward** – Two consultees discussed the relationship between participation in the commercialisation process and anticipated progression and increased remuneration, with neither identifying any tangible benefits. Though both regarded the issue as a secondary concern, they nevertheless thought participation would advance their careers. In future, any relationship between participation, progression and financial benefits could be made more explicit to provide researchers with greater clarity about the opportunities.

5.16 **Promoting wider benefits of technology** – With the exception of one consultee, whose project was restricted to a specific military application, all remaining consultees highlighted the importance of engaging with external experts as a means of broadening the application of their project's technology. In addition to sharing knowledge and capabilities to the benefit of civilian markets and the broader economy, this approach also benefits the MoD, as it enables technology to be progressed and refined even when it is not actively being pursued.

6. Conclusions

6.1 The main findings from the study are summarised as follows, covering the economic contribution and the wider benefits to markets and Dstl researchers.

Economic contribution of Ploughshare's activities

6.2 The analysis undertaken for this updated assessment indicates that Ploughshare's commercialisation activities have led to significant economic impacts. When the direct and indirect effects are combined, we estimate that Ploughshare's/Dstl's commercialisation activities have contributed to:

- the creation of around 585 net additional jobs to date (at peak levels), with nearly 440 jobs in the spin-outs and licensees supported forecast to exist in 2018/19
- the generation of £75million in net additional exports between 2002/03 and 2015/16, with another £148million of exports forecast for the period 2016/17 to 2018/19
- net additional GVA worth nearly £118million to date (2002/03 to 2015/16) with future GVA forecast to be £107million (over the period 2016/17 to 2018/19) – i.e. resulting in a total GVA effect of nearly £225million.

6.3 In addition, Dstl has developed technology that is integral to the progression and application of global positioning systems. This has and will continue to deliver significant economic and wider benefits in addition to those set out in the bullet points above.

6.4 The results of this updated assessment highlight the progression that a number of spin-outs and licensees have made, with the impacts 'to date' now higher than under the previous 2015 assessment. Notably, the net additional GVA to date has moved on from £65million (to 2013/14 – estimated in the previous assessment in 2015) to £118million (to 2015/16 in this new assessment). Whilst expected, this is positive, in particular the size of the increase. The net additional forecasts are slightly lower in this updated assessment than under the previous assessment. This reflects three key factors:

- Some of the forecasts from the previous assessment have translated into actual impacts to date – hence the increase in the 'to date' figures.
- The previous assessment had a slightly longer timeframe for forecasts (four years rather than the three used in the current assessment).
- There have been some significant changes in the fortunes of different companies within the spin-out and licensee portfolio. Notably, one spin-out, which was forecasting significant growth as part of the previous assessment, is now winding down, whereas another spin-out is now expecting slightly higher levels of growth. There are similar changes in the expected growth of different licensees. These changes are to be expected, and reflect the different development paths of businesses,

in particular in markets for innovative technologies that can be unpredictable and/or risky. The net balance, however, has meant that forecasts have shifted down slightly.

Wider benefits

…To the MoD and wider defence

6.5 The commercialisation of research through Ploughshare has led to the development of a range of new defence technologies that have been used by the MoD and governments of allied countries. These include applications for vehicle armour, electronic warfare software, and chemical and bio threat detection. As well as the development of useable products and services for the MoD, there are further benefits relating to the defence sector:

- UK defence capabilities have been enhanced as a result of the commercialisation opportunities through Ploughshare in UK-based companies – which is beneficial from a strategic defence perspective. Illustrative of this is the development of one of the vehicle armour products, for which 85% of the supply chain is UK-based.
- Defence-related technologies such as bio threat detection and surveillance have applications that are relevant for domestic security and the emergency services as well as military uses.
- The development of technologies that have a defence element (e.g. the role of MBOC in global positioning systems) have been instrumental in gaining significant diplomatic benefits.

…To civilian and commercial markets

6.6 The analysis has found notable applications in non-defence markets. Some examples are as follows:

- There are a number of companies operating within the health and life sciences sphere, for instance working on vaccines for a range of diseases, and diagnostic tools. These may have impacts for healthcare in the future, though for many of these work is still ongoing, reflecting the development timeframes for such applications.
- Detection technology that has been developed for the military in identifying mines has been used in applications for the oil and gas sector to facilitate underwater dredging. It is also in development for use in civilian aerospace.
- MBOC will help improve the precision of applications that draw on global positioning systems. This has a range of applications, including in precision agriculture, supply chain management, the marine sector, and in emerging areas such as smart cities and autonomous vehicles.

…To Dstl researchers

6.7 All four of the Dstl scientists interviewed as part of the study identified personal, professional and institutional benefits stemming from their involvement in the commercialisation process. In particular, these benefits included:

- an added sense of purpose and the technical challenge associated with translating research into a commercial setting
- the fresh perspective offered through working with the private sector, which have improved the understanding of the R&D process as it moves from the research lab to commercialisation
- in some cases expansion of professional networks
- more widely, the opportunity for technology to be developed and refined even when it was no longer a priority for Dstl – this was noted as obviously having benefits for the spin-outs/licensees, but then subsequently it has the potential for later benefits for Dstl itself if the technology is returned in a more advanced form subsequently.

Annex A: Detailed methodology

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

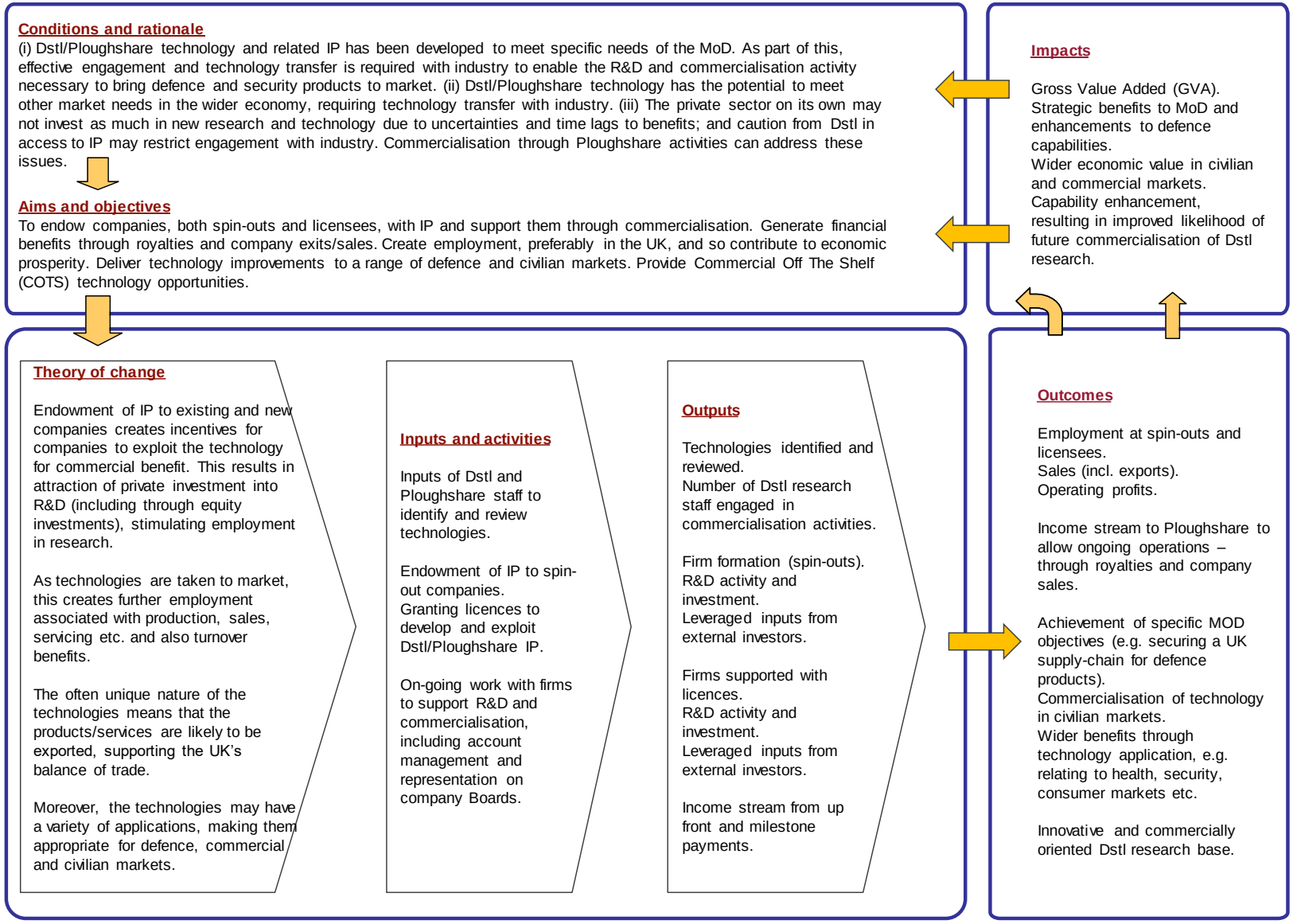
The routes to impact from Ploughshare's commercialisation activities

A.2 In assessing the benefits of Ploughshare's commercialisation 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 12 new companies to form via this route (including one spin-out from a spin-out).
- 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.
- 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, setting out how these generate outputs, outcomes and impact, as well as the underlying rationale and objectives for its work.

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



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 and estimating Gross Value Added (GVA). The last sub-section examines how we have assessed the wider benefits to society and the research base.

Measures of economic benefit

A.5 Spin-outs and licensees were at different stages of development, with some activity in pre-sales stages, and other activity at various stages of market maturity. To reflect this variation, we have considered a basket of indicators to assess Ploughshare's economic contribution. 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[13]. An estimate of GVA is provided as part of the assessment, in line with Department of Business, Innovation and Skills (BIS) guidance[14], 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[15].

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	Data held by Ploughshare on company investments Interviews 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	Interviews with Ploughshare staff, Dstl staff and researchers, 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, with on-going companies implying 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 and interviews with spin-outs and licensees
Value & proportion of sales that are exports	Injection to circular flow of income to the UK economy	Company account data and interviews with spin-outs and licensees
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

[13] Scottish Enterprise (2008), *Additionality and Economic Impact Assessment Guidance Note*, Scottish Enterprise, Glasgow
[14] Department for Business, Innovation and Skills (2011) *Guidance on Evaluating the Impact of Interventions on Business*, BIS, London
[15] 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[16] recommended 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 here. There are several factors underpinning this judgement:

- In the case of spin-outs, they have been formed in order to commercialise IP endowed to them by Ploughshare. Conceptually, therefore, there is no group of 'spin-outs' that attempted to obtain Dstl IP but failed to do so or other technologies which could form a well-matched comparison group.
- 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, 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 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 We have tested additionality with companies themselves and a selection of Ploughshare staff. This qualitative insight has informed a judgement on the levels of additionality associated with each spin-out and licence[17]. The levels of additionality have been used to estimate 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. employment, value of exports and GVA) to Ploughshare versus external support and/or funds provided through other sources. Evaluation practice indicates a need 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

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

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.

Leakage and displacement effects

A.11 We have considered leakage in a UK context, i.e. leakage exists if any activity (e.g. employment, purchasing of good and services) takes place overseas. For spin-outs and active licensees, we have obtained this information from the companies themselves or from Ploughshare account managers – either as an estimate of the percentage of activity overseas (with the application of a leakage assumption) or through specific data on the numbers of employees based in the UK and overseas (with these numbers incorporated into our economic modelling).

A.12 This report assesses displacement effects 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%). The evidence to inform the judgement on displacement has been obtained from companies themselves or from Ploughshare account managers.

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.13 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:

- Basic pharmaceutical products and pharmaceutical preparations 1.4
- Computer, electronic and optical products 1.7
- Other transport equipment 2.1
- Scientific research and development activities 1.7

- Weapons and ammunition 1.8.

A.14 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 were asked to take part in the study. Nevertheless, where possible, we have used the consultation process to learn about the purchasing behaviour of firms. We have used these to justify (or challenge) the use of multiplier effects in undertaking the economic impact assessment.

Assessment of GVA

A.15 We have undertaken the GVA assessment in stages to provide a structured analysis that is clear and transparent.

Spin-outs

A.16 The first stage 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[18] [19]. 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.17 The GVA estimates are presented in different ways, in line with other recent approaches[20], as follows:

- cumulative to date
- projected cumulative.

Duration of benefits

A.18 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.

[18] Scottish Enterprise (2008), *Additionality and Economic Impact Assessment Guidance Note*, Scottish Enterprise, Glasgow
[19] 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.
[20] 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.

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 have allowed a maximum of up to 10 years persistence effect for interventions supporting businesses. Therefore, we have considered persistence effects up to around 15 years, which ought to be appropriate given the age of the spin-out companies and aligns with patent lifecyles of 16 years. Making projections beyond three years is challenging, and so in practice the benefits have been assessed up to 2018/19, which, for those companies still active falls within the persistence effect of 15 years. For future assessments, it may be necessary to exclude future benefits for some of the older spin-outs and licensees. For example, P2i was established in 2004, and so based on 15 years of benefits it may be advisable for 2018/19 to be the final year for the inclusion of benefits attributable to Ploughshare.

A.19 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.

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 one notable way. 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.

A.21 The duration of benefits are 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 have been presented as follows:

- cumulative to date
- projected cumulative.

Grossing up for licensees

A.23 For the economic assessment of the spin-out activity we have been able to incorporate data on effectively all relevant spin-outs – for those that have not been included there was very limited economic activity.

A.24 For licensees, however, there were ten that were not included directly in the analysis, because they were inactive and/or had been inactive for a long time. In order to take account of this, we have grossed up the data on licensees for the purpose of the economic assessment. The process for estimating this grossing up has drawn on the data we have from Ploughshare on income received to date from licensees:

- Based on Ploughshare data, the income to date related to the deals that have been used to inform the assessment is estimated at 93% of the income from all licensing.
- In order to account for the missing 7%, therefore, we gross up by multiplying the estimates of GVA, employment and exports by 1.08.
- Note that this has been applied to the 'to date' impacts but not the forecast impacts – because those licensees that have not informed the economic assessment are inactive.

Optimism bias

A.25 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.26 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.27 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.28 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.29 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.

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

Company	Status
Acolyte Biomedica	Sold (exited), but then became inactive
Alaska	Inactive
Claresys	Live
Enigma	Live
ESROE	Live
Leading Light Scientific	Sold (exited) as part of Acolyte deal
P2i	Sold (exited) and still live
ProKyma	Live, but low level of activity
Remo	Sold (exited), though company went into liquidation
SALT	Live
SARA	Live ('daughter' company of SALT)
Sherwood	Incorporated, but never got going

Table B-2: Portfolio licensees and associated technology

Company	Dstl Technology
Intellectual Ventures	Parallel Computing
AB Precision Ltd	IED Disrupter
AB Precision Ltd	Projector Equip
Atkins Ltd	MALPAS
Atkins Ltd	TANKILL
BIRAL	Particle Analysis
BIRAL	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
Thales	RESM
Morgan (ex NP Aerospace)	Ceramic Armour
Morgan (ex NP Aerospace)	Vehicular Armour

Company	Dstl Technology
Tata UK Ltd	SBS
Amsafe Bridport Ltd	Tarian Armour Net
Amsafe Incorporated	Tarian Armour Net
Du Pont	BABT Test Rig
Ketech Defence ltd	V/G Converter
APMG	CD CAT
Raptor	Filter
3SDL	CESMO
ASV	Advanced USV Capability
European Commission	MBOC
Lonza Rocklands	AK Assay
3M	Luciferase
3M (ex Biotrace)	Cyclone
3M (ex Biotrace)	Continuous Flow + AK
Celsis Internation Plc	AK Assay
Archimedes	Chitosan Encap
Defyrus Inc	Alpha Virus (VEEV)
BBI Solutions	Ebola Diag
BBI Detection Ltd	Antibodies + LFD Device
Pharmathene UK Ltd	Anthrax Vaccine
Pharmathene UK Ltd	Plague Vaccine
Lipoxen Tech Ltd / Xenetic	Liposome Technology
Recipharm Cobra	Bacillus Expression
Selective Antibodies Ltd	Explosive Antibodies - Option
DMT	WIBS - Licence
DetectionTek	WIBS - Licence
Cangene	Antibody Fragments
Prokarium	OrtVac

Annex C: Detailed analysis

C.1 This annex provides 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.

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

Indicator	Gross Impact
Spin-outs	
GVA to Date (2002/03 to 2015/16)	£56,585,000
Future GVA (2016/17 to 2018/19)	£51,997,000
Maximum employment to date (2002/03 to 2015/16)	224
Current employment (2015/16)	133
Future employment (at 2018/19)	150
Exports to date (2002/03 to 2015/16)	£66,113,000
Future exports (2016/17 to 2018/19)	£141,563,000
Licensees	
GVA to Date (2002/03 to 2015/16)	£31,656,000
Future GVA (2016/17 to 2018/19)	£54,972,000
Maximum employment to date (2002/03 to 2015/16)	232
Current employment (2015/16)	155
Future employment (at 2018/19)	162
Exports to date (2002/03 to 2015/16)	£16,784,000
Future exports (2016/17 to 2018/19)	£99,314,000
TOTAL	
GVA to Date (2002/03 to 2015/16)	£88,241,000
Future GVA (2016/17 to 2018/19)	£106,969,000
Maximum employment to date (2002/03 to 2015/16)	456
Current employment (2015/16)	288
Future employment (at 2018/19)	312
Exports to date (2002/03 to 2015/16)	£82,897,000
Future exports (2016/17 to 2018/19)	£240,877,000

Source: SQW analysis of Ploughshare Data

Table C-2: Licensees – summary of impact indicators

Indicator	Additional Direct Impact	Additional Direct + Indirect Impact
GVA to Date (2002/03 to 2015/16)	£18,235,000	£34,008,000
Future GVA (2016/17 to 2018/19)	£32,711,280	£64,309,000
Maximum employment to date (2002/03 to 2015/16)	137	244
Current employment (2015/16)	103	185
Future employment (at 2018/19)	112	199
Exports to date (2002/03 to 2015/16)	£8,402,000	-
Future exports (2016/17 to 2018/19)	£60,144,000	-

Source: SQW analysis of Ploughshare data

Annex D: List of consultees

D.1 We have consulted the following as part of the study. We are grateful for the time and help they have provided. We are also grateful for the time and support provided by: Steve Callister in helping to steer the work; Gordon Scott, Jim Ashe, Kirsty Hewitson and Noel Botha in providing details of the individual firms that Ploughshare has worked with; and to Clare Booth, Maureen Levey and Andrea Linscer for assisting with data.

Table D-1: List of consultees

Name	Organisation
Jim Ashe	Ploughshare
Noel Botha	Ploughshare
Steve Callister	Ploughshare
Kirsty Hewitson	Ploughshare
Gordon Scott	Ploughshare
Ian Campbell	Dstl
Graham Farnsworth	Dstl
Virginia Foote	Dstl
Chris Harris	Dstl
Tony Pratt	Dstl
Warren Tam	Dstl
Jon Roe	ESROE
Andy McLeod	Claresys
Carl Tiltman	SALT and SARA Ltd
Ady Moores	P2i
Richard Pharro	APMG
Richard Daltry	ASV
Ted Fjällman	Prokarium
Fiona Marshall	BBI Detection
Matt Chuter	AmSafe Bridport
Robert McAllister	DMT
John Lovett	Detection Tek
Matt May	3SDL
Phil Ventress	Thales
John Reeve	Morgan Composites
Hugh Ballatine-Dykes	Ex-CEO, Alaska