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Principles and Practices for the
Application of Systems Engineering to
Heterogeneous Research
Partnerships

by

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Doctoral Thesis

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ABSTRACT

A heterogeneous research partnership (HRP) is one in which industry, academia and government collaborate to conduct research, typically of national importance. Whilst most HRPs complete their planned duration and deliver their agreed tasks, it is not uncommon for participants to be left feeling somewhat dissatisfied, suggesting that the requirements which are being met are incomplete. There is an opportunity to improve the success of HRPs by establishing principles and practices for the application of systems engineering in their development.

The thesis reviews literature drawn from a broad body of work covering three main areas: the context of HRPs themselves, systems engineering and related disciplines, and research methodology. The research adopts an interpretive approach, initially applying Soft Systems Methodology in a pilot case study and subsequently conducting a qualitative analysis of sixteen HRP case studies in order to develop and refine generic models which are relevant to HRPs. Drawing from the commentary of interviewees, published sources and other evidence, major themes across the case studies are integrated in order to develop ten principles and ten practices for the application of systems engineering to HRPs.

The importance of consistency between the research context, systems approach and research methodology is emphasised, and the thesis highlights a significant philosophical challenge facing system of systems research as the discipline seeks to use a range of hard and soft systems approaches which are fundamentally rooted in different paradigms.

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GLOSSARY

Although primarily a list of acronyms used, the glossary also contains a number of terms which are used within this document to have specific meanings. Such terms are presented ‘thus’ below.

<u>Acronym or Term</u>	<u>Definition</u>
CATWOE	Customers, Actors, Transformation, Weltanschauung, Owners, Environment
CFD	Computational Fluid Dynamics
CiK	Contribution in Kind
CM	Conceptual Model
CMMI	Capability Maturity Model Integration®
‘Context’	HRPs are the context for this research
CSER	Conference on Systems Engineering Research
CSP	Critical Systems Practice
‘Customer’	Within the case studies, the primary funding body
D&D	Design and Development
DIS	Defence Industrial Strategy
‘Discipline’	Field of study such as systems engineering, physics, art etc.
DoD	Department of Defense
‘Domain’	Area of application such as defence or aerospace
Dstl	Defence Science and Technology Laboratories
DTI	Department of Trade & Industry
DTS	Defence Technology Strategy
EIA	Electronic Industries Alliance
EngD	Engineering Doctorate

<u>Acronym or Term</u>	<u>Definition</u>
'Environment'	The situation in industry academia and government within which HRP's are created
EPSRC	Engineering & Physical Sciences Research Council
HRP	Heterogeneous Research Partnership
IEC	International Electrotechnical Commission
INCOSE	International Council on Systems Engineering
IPR	Intellectual Property Rights
IRA	Irish Republican Army
ISO	International Standards Organisation
IT	Information Technology
'Lifecycle'	The progression of an HRP from creation to termination, whether natural or 'engineered'
KM	Knowledge Management
NASA	National Aeronautics and Space Administration
OR	Operations Research
'Sector'	Industry, Academia or Government
HRP	Heterogeneous Research Partnership
IEEE	Institute of Electrical and Electronic Engineers
MoD	Ministry of Defence
NASA	National Aeronautics and Space Administration
PhD	Doctor of Philosophy
QAA	Quality Assurance Authority
QFD	Quality Function Deployment
QR	Quality Related
R&D	Research and Development
RAE	Research Assessment Exercise

<u>Acronym or Term</u>	<u>Definition</u>
RD	Root Definition
SE	Systems Engineering
SEDC	Systems Engineering Doctorate Centre
SG	Steering Group
SME	Small and Medium-sized Enterprise
SoS	System of Systems
SOSM	System of Systems Methodologies
SRL	System Readiness Level
SSE	System of Systems Engineering
SSM	Soft Systems Methodology
SyE	Systems Engineering
TRL	Technology Readiness Level
TSB	Technology Strategy Board
UAS	Unmanned Air System

1 RESEARCH NEED: POSITIONING THE RESEARCH

1.1 Introduction

The title “Principles and Practices for the Application of Systems Engineering to Heterogeneous Research Partnerships” will, it is hoped, raise a number of questions in the reader’s mind. Academic researchers and students may be interested in the contribution to systems engineering research, whilst those from industry or government may wonder whether the research will add any value in practice. Both are likely to ponder what ‘heterogeneous research partnerships’ actually are. Were the title to apply to a PhD thesis or company report, then to satisfy one or other interest would be adequate. For an Engineering Doctorate, however, both groups of readers should be satisfied. By the end of Chapter Ten, it is hoped that this will be the case - and that the reader will have also become very familiar with the operation of heterogeneous research partnerships.

This thesis represents a journey through the largely uncharted territory of systems engineering research. There are no maps or well-trodden paths to follow and each pioneer of systems engineering research must be willing to explore, to take wrong turns and to find their own way. The journey starts here in Chapter One, where the systems challenge to be addressed is positioned in the context of broader systems problems: specifically, within the class of problems associated with the extension of systems engineering into the domain of Systems of Systems.

1.2 Systems of Systems

1.2.1 Generic Systems of Systems Challenges

‘System of Systems’ (SoS) is a term given to large, complex systems where the component subsystems can operate as independent systems in their own right (or indeed as part of other SoS), such that the interdependence and

interconnectivity of component parts is not easily understood or engineered. Maier's definition notes that the component systems possess two additional properties which distinguish them from the components of a mere system: the operational and managerial independence of the components (Maier 1998). Four different types of SoS are identified: Virtual, Collaborative, Acknowledged and Directed (Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering 2008).

According to the International Council on Systems Engineering (INCOSE) (Fossnes, Forsberg et al. 2007), the development of a SoS is influenced by the following characteristic challenges:

- System elements operate independently
- System elements have different life cycles
- The initial requirements are likely to be ambiguous
- Complexity is a major issue
- Management can overshadow engineering
- Fuzzy boundaries cause confusion
- SoS engineering is never finished.

Some of these challenges relate to aspects of project management and the coordination of independent projects aimed at delivering different parts of the system of systems at different times. Some relate to the sheer scale and duration of the undertaking and the fact that requirements may be unknown and/or change. Some relate to the technical difficulties associated with a very large scale undertaking.

They do not, however, address a critical aspect of systems of systems, and that is the interaction of people. In noting that system elements *operate*

independently, they imply some degree of free will for each element – and few system elements operate entirely without human intervention in some form. However, they fail to recognise, at least explicitly, that this therefore implies some form of interoperation between humans. A number of possible reasons might be cited for this.

- INCOSE's focus is on systems *engineering*, and therefore although organisational structures and relationships may be engineered, it might be considered that *engineering* is an inappropriate process for *human relationships*.
- Although systems engineering processes exist for a number of human factors aspects of system development, such as ergonomics and cognition, they focus on aspects of individual or group capability to undertake a particular task rather than the social aspects of interaction.
- Although systems engineering can be considered a very broad discipline which stretches far beyond technical topics, the theories and techniques which address these social aspects sit within disciplines such as social and management sciences, and not in engineering.
- Expertise in the discipline has yet to advance to the point where it can offer solutions to this form of complex human relationship in the context of a broader, technical system of systems.

1.2.2 Current SoS Approaches: Drawbacks & Limitations

By focusing on the technical and project management aspects of systems of systems, current approaches do not tackle the challenges associated with the social interaction between individuals from different backgrounds, often with conflicting aims or priorities, who are expected to cooperate in order to achieve the system of systems purpose. Without this essential element, good management of deadlines and technical compatibility will still fail to deliver.

In practice, management methods may be used to alleviate the problem – perhaps by selecting operators with certain backgrounds, or providing additional cultural training. Indeed, these may be essential elements of effective operation, but should therefore be developed as part of the system of systems itself, and not as operational ‘fixes’. There is a clear need for the enhancement of current methods for engineering systems of systems to ensure that their development encompasses the social factors inherent in their operation.

1.3 Research Focus: Heterogeneous Research Partnerships

In identifying a suitable area for study, the aim was to find a suitable set of data sources within a specific, limited context, which would be both valuable to the understanding of that context in its own right, but also relevant to the broader systems of systems challenge. Thus the research should be able to offer solid principles, concepts and ideas for this limited context, but also potentially highlight where these may be applicable to broader SoS problems.

In order to do this, it was first necessary to identify a relevant context in which greater understanding was sought. The problem area chosen is that of Heterogeneous Research Partnerships (HRPs) operating within the defence environment. These are arrangements by which individuals and organisations from industry, academia and government sectors work together in order to realise defence-related research. These HRPs exhibit, to a greater or lesser extent, all of the characteristics of systems of systems identified above.

For the purpose of this study, the HRPs are also chosen for:

- Conducting research in systems engineering or a closely related field within the defence and/or aerospace domain
- Involving, at a minimum, 2 groups from different organisations; but preferably multiple parties from each of the three sectors.

Using US Department of Defense terminology, HRP's would be considered to be Acknowledged Systems of Systems (Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering 2008). However, unlike conventional SoS in the defence domain, HRP's do not tend to involve significant equipment assets. In fact, their operation relies predominantly on the enterprises engaged within the HRP. This emphasis facilitates a focus on the study of the social aspects of interaction, without becoming overwhelmed by technical complexity of equipment. Although a single enterprise would not necessarily be considered a SoS since it would not typically meet Maier's criteria of operational and managerial independence (Martin, Davidz 2007), this shortfall is clearly not true for the partners within an HRP. In effect, an HRP might also be called enterprise of enterprises. The organization and management of such collaborative relationships, and in particular their organizational dynamics, are "under-researched" (Perkmann, Walsh 2007).

1.4 The Broader Environment: Research for Defence

1.4.1 Introduction

The conduct of pure and applied research is critical to the sustainment of defence capability, not only in the creation of new technologies, but also in the development of processes by which those technologies can be brought into service. Prior to 2001, the majority of defence research was undertaken within the Ministry of Defence itself, typically within the part of the organisation which is now split into the Defence Science and Technology Laboratories (Dstl) and Qinetiq. However, following the part-privatisation of Qinetiq there has been an increasing trend towards placing defence research with other providers, and competing work in order to seek best value for the taxpayer. In keeping with broader government policies, the MoD does not fund 'basic' research (*Research and Development Handbook. 2007*), but accesses a broad range of research capabilities in both academia and industry (Defence Equipment & Support 2008), and supports programmes of

academic research which may be pulled through into industry for use on defence equipment programmes. Relationships and interfaces within the MoD itself and between the MoD and industry are recognised as key to long term partnering and to ensuring that new technologies are exploited in defence solutions (*BLUEPRINT: The Future Operating Model*. 2008). Through Dstl, it actively seeks scientific and technological collaboration with industry, academia and government bodies in the UK and overseas (*Dstl: For when it really matters*. 2006). However, the complexity of how the MoD seeks to manage these relationships is illustrated by their own R&D Handbook which goes to enormous effort to detail roles and responsibilities but remains in draft form almost four years after initial publication (*Research and Development Handbook*. 2007).

However, in this more open environment it is recognised that “although MoD clearly expresses intentions, requirements and objectives for research spending, the response of the supplier network in terms of what they bid and deliver is modified by MoD commercial practices (e.g. competition) and their own set of values and objectives, weighted by the value of the ‘MoD £’ in combination with other research income streams. In some cases, satisfying MoD’s needs will not be the dominant driver of supplier behaviours”(Oxenham 2010).

The 2003 Lambert Review of business-university collaboration “highlighted the importance of encouraging closer links between industry and the research base”(HM Treasury, DTI 2006), and this was reinforced in 2006 in the MoD’s Defence Technology Strategy (Ministry of Defence 2006). However, in conducting collaborative research programmes industry, academia and government face a number of challenges (Brown 2007a): system of systems context and the change of pace; identification and communication of critical research areas; management approaches at all levels; funding; scarcity of qualified resources and security considerations. Each of these is now described in more detail in order to highlight the scope of the challenges faced.

1.4.2 SoS context and the change of pace.

The environment in which the challenge of multi-enterprise research management exists is, in itself, a complex system. From an international defence perspective, the relative certainties of the Cold War are little more than a distant memory, rekindled only when seeking to solve today's asymmetric warfare challenges with equipment designed for that bygone era. Although in the UK the threat of terrorism is not new, the nature of the threat is quite different to that of the Provisional Irish Republican Army (IRA), predominantly in the 1970s & 80s. With notable exceptions, the IRA threat was an armed struggle against the police and military – a conflict seated in political decisions of the 16th century, but with a clear aim that could be addressed through modern political process. Not so the global asymmetric warfare of the 21st century - apparently driven by idealism, far from susceptible to national or international political processes; and constantly evolving at a rapid pace.

Against this international backdrop, the UK retains its ambitions as a world military power in a way which is increasingly in conflict with the views of both the Treasury and the voting public. Investment in hospitals and schools wins votes. The 'War on Terror' and expensive new military materiel do not. The MoD and its contractors are called to account on cost overruns for complex development programmes which span years and even decades: the requirement is to do more for less, at the forefront of technology and without the significant technical and programmatic risks becoming reality. Thus all military projects are required to be delivered 'on time and to cost', whilst being able to deal with threats that were not envisaged at the time the programme was conceived and the contract let. After years of squeezing more into less, the politically sensitive need to take very difficult decisions in order to create a realistic and affordable equipment programme was inevitable (House of Commons Defence Committee 2008).

In this environment, research - which by its very nature may actually 'prove' that an idea doesn't work rather than the converse - provides an even greater challenge. The added complication of doing research to meet some future requirement which has yet to be fully defined, and developing technologies for which the ultimate commercial viability is also indeterminate can place this research in direct conflict with the demands of its environment. Rapid technology change and the world-wide-web give potential aggressors access to a range of new technologies at a pace not experienced before, and in stark contrast to traditional 10-20 year procurement cycles for major defence equipment. The need for agility in defence procurement has become very real and new, flexible approaches to technology planning are required which reflect an understanding - not of what the future will be - but of what it will be 'like' (Pang 2006).

Since the end of the cold war, the western defence industry has been driven by "industry-led cooperation under the pressure of globalisation toward trans-national industrial consolidation". At the same time, Governments on both sides of the Atlantic have failed to match this trend, remaining "behind the curve" in failing to remove bureaucratic and regulatory obstacles (Schmitt 2002). At the November 2002 European Security Forum in Brussels, the chairman Klaus Becher noted that "The overwhelming size of the US defence market and the fragmentation of markets in Europe add aggravating structural dimensions to the difficult business prospects in this sector after years of shrinking or stagnating defence spending in Europe that increasingly leaves European players without the necessary critical mass...", and that "... properly coordinated and strategically targeted R & D programmes would be important to halt the demise of European defence industries" (Becher 2002). Nevertheless, almost a decade on, the challenges remain. UK defence industry has become characterised by shrinking budgets for both R&D and equipment programmes, and by trans-European and transatlantic collaboration, mergers and acquisitions in an attempt to maintain a sustainable business, avoid the feast-and-famine associated with large

contracts and extended procurement cycles, and provide an acceptable return for the notorious short-termism of the financial markets.

The academic environment also faces change. The number of UK students studying Physics at “A” level, for example, has halved in the past 20 years (Science and Technology Committee 2006). Science, technology and engineering are “unattractive” to the current generation of students, resulting in the closure of a string of UK university departments in recent years, notably in the physical sciences. The teaching facilities required for these subjects are typically more expensive than those for the humanities and social sciences, although a variable course fee structure compensates universities for some of those costs. With the introduction of tuition fees paid by the students themselves, advanced technical courses lasting 4 years or more are now not only ‘unattractive’, but also more expensive to study, leading to rising levels of student debt. The UK trend is, however, compensated by the large and growing body of overseas students who pay higher fees and act as a lucrative source of income for universities under financial pressure. Collaborations between western universities, particularly in the US and UK, and pre-eminent institutions in India and the Far East are becoming more popular, further reinforcing the globalisation of the academic system, and often with Government support (HM Treasury, DTI 2006).

Whilst UK government has struggled to take an integrated approach to science and innovation, some countries such as Finland “... are increasingly considering science and innovation as an ‘ecosystem’, and are developing holistic strategies to drive forward a commercialisation agenda”(HM Treasury, DTI 2006).

1.4.3 Identification and communication of critical research needs

The Defence Industrial Strategy (DIS) (Secretary of State for Defence 2005) and Defence Technology Strategy (DTS) (Ministry of Defence 2006), published by the UK Government, go some way to identify the technology

areas of national importance but, unsurprisingly for unclassified documents, suggest the technology areas rather than the critical technologies per se. The generic question is “How to identify which research is critical to the delivery of a particular capability in perhaps 20 years time?” given only a vague concept of that capability today and many different ways in which it might be achieved. The identification of exploitable research paths relies on the successful integration of scientific expertise – whether in industry, academia or government – with industrial expertise to identify both those technologies which are, in themselves, exploitable and secondary technologies which may be necessary for exploitation. For companies who integrate large, complex systems, the balance between developing technology internally, buying it in and partnering with others is paramount when developing technical capability and requires “a bird’s eye view of what’s on offer from supplier companies and institutions around the world”(Jenkins 2007).

Government control of some of the critical technology areas has changed significantly in the past 20 years, with the value of commercial research, particularly in the IT sector, far outstripping government-funded work. The smaller scale and lower profitability of government & military markets is such that technology advances in this area will inevitably be made in the civil sector, removing Governmental influence on both the identification and exploitation of such critical technologies. The challenge then becomes one of adopting or adapting such technologies for government and defence use, and dealing with the significant security issues which commercial IT products bring.

Communication of identified research needs provides another challenge. Research areas will typically have their own “language” with which to express technical concepts. However, these do not always readily translate between technical domains, or between the government customer and industrial & academic research providers. At the System of Systems level, the range of research required to develop a future capability is likely to cross a number of

technical domains. Achieving complementary research results will provide both a temporal and physical integration challenge, and the lack of common concepts and terminology can make a difficult task virtually impossible. This is further complicated by the fact that the UK funding system has “traditionally channelled research along specific disciplinary ‘silos’” in a way which “may unintentionally give preference to work in established fields” without reference back to industry or government needs (HM Treasury, DTI 2006). In the light of this, technology roadmapping is seen as an important tool which should “improve the common understanding of all MoD and industry stakeholders”, by providing the “ability to share an overarching view of the project or problem, quickly & accurately”(Ministry of Defence 2006), although this does not address the further step of translating that view into academic terms.

1.4.4 Management approaches at all levels

Research – as with any innovative endeavour – is not an activity which lends itself particularly well to the rigours of management. That is not to say that work cannot be planned and objectives set, but that the outcomes cannot be predicted. To a product developer, a negative outcome to critical research can spell the end of a programme, and yet it is a risk that cannot readily be managed.

Increasingly, defence-related research of national importance is undertaken by a consortium of industry and academia. Such consortia may either be ad hoc – formed to address a particular technology need and funding opportunity – or enduring, such as relationships between major companies and selected academic institutions. Often these programmes can have multiple funding sources, involving “Contribution in Kind (CiK) ” (e.g. manpower, research facilities, modelling capabilities) from the companies involved. Even the smallest of these companies may well be involved in several different consortia, conducting related research and providing CiK for a number of different contracts and “collaborative R&D partnerships among

asymmetric partners are becoming increasingly common”(Carney, Strong et al. 2007). The effective management of intellectual property rights and contractual obligations across this complex web is a challenge for all involved and formal partnership agreements are sometimes needed. “These partnerships must be meaningful, tough and contractually binding”(Lord Drayson 2006).

The drivers for partnership are mixed. “Some of the most interesting scientific advances occur ... on the boundaries between publicly and privately funded R&D”(HM Treasury, DTI 2006), and certainly attempting to develop all the technologies needed by a company or even country “in-house” can be very inefficient (Stevens, Brook et al. 1998). However, 40% of respondents in one survey felt that collaboration “made product development more costly, more complicated, less efficient, more time consuming and more difficult to control and manage”(Carney, Strong et al. 2007). Another survey noted that over a quarter of companies reported their “least successful innovation activities” as being with universities, with three quarters feeling that academics did not understand business needs. Nevertheless, collaboration “has a lot to offer, but a different approach is probably required to ensure that companies maximise their returns”(Confederation of British Industry 2005). This clearly reflects a conflict between the need for “invention, product innovation and technology” to be as close to production as possible, whilst gaining effective access to the “brilliant ideas” of university-based research scientists (Stevens, Brook et al. 1998).

In this context, the protection of Intellectual Property Rights (IPR) by an organisation or individual appears to make sound business sense. However, such protection can be in direct conflict with maximising exploitation – graphically illustrated by the success of open standards in computing and the entertainment industry. In general however, the ownership and use of IPR is seen as a particular barrier to business-university collaboration (Santoro, Greenish 2006). Universities wish to publish the results of their research as a measure of status and the means by which staff further their careers, but

industry would rather keep potentially profit-making results private. “Negotiating a position between these two objectives is extremely time consuming” (Santoro, Greenish 2006) and trust remains a key issue, without which “collaborations will not bring value and the painstaking work on clarifying agreements will be wasted”(Carney, Strong et al. 2007).

The importance of exploitation is still a subject for debate. Research for its own sake, simply adding to the knowledge base, may be acceptable from an academic perspective, but the same cannot be said of industry or government. Yet both industry and government continue to suffer from the problem of taking research from their own research establishments and exploiting it on equipment programmes. The inefficiency of this process is a key driver for change in management approaches. The challenges are even greater where research is conducted in academia, further extending both the physical and intellectual distances that must be covered for exploitation to succeed. A lengthy PhD thesis is not the most valuable tool to aid exploitation: computer-based modelling & simulation, graphical representations, presentations etc are all more likely to assist in a wider take-up of the work. However, a Powerpoint presentation is not a replacement for rigorous analysis and these exploitation aids will generally be in addition to, rather than to replace, the thesis. This needs to be accounted for in both the planning and funding of the work.

The ongoing assessment of the quality of an individual piece of research, and the way in which it is developing to aid subsequent exploitation, provides another management challenge. Some academic researchers in particular resist “interference” and will expect to be left undisturbed for the duration of the research contract (perhaps up to 3 years), typically providing an annual report. From an industrial perspective, finding out that research hit a problem and was redirected 12 months ago is not acceptable. Approaches which demand a monthly report, whilst partially successful, can sometimes be met with a rather superficial overview which still does not highlight technical difficulties. Obtaining better information generally requires a significant

investment in time to develop a close working relationship between research manager and research provider, and the establishment of equality of power and influence in both interpersonal and group relationships. Simply adopting good processes for dealing with stakeholders is no guarantee of the effectiveness of the relationship (Elias, Cavana et al. 2002).

1.4.5 Funding

Inevitably, in conducting research of national importance there will be the question of “who is going to pay?” The fact that it is nationally-important research might suggest the taxpayer, but even this is not straightforward. Government research, funded by the taxpayer, comes in a number of different forms, and is handled through different departments or ministries and the UK Research Councils such as the Engineering & Physical Sciences Research Council (EPSRC). European Union-funded programmes are funded by European taxpayers – some of them, of course, in the UK. Each body is faced with funding requests which far outweigh the funds they have available and prioritisation is necessary. Such prioritisation tends to follow topics which are felt to be important in each area, and these can shift between the different funding bodies. Thus funding requests also travel between the funding bodies until funding is obtained, and long-term research may be funded by the taxpayer through a number of different bodies over time. Each funding body has its own rules regarding which costs can legitimately be claimed, and so knowing how and where to obtain funds can be the factor which makes or breaks critical research. Nevertheless, the scarcity of Research Council spending on industry-led research stands as another barrier to industry-university collaboration (Santoro, Greenish 2006), in spite of their stated aim to work closely with all these parties in order to “play a strategic role in fostering effective knowledge transfer” and drive innovation (Esler 2007).

Non-project-specific research funding of UK universities is largely driven by the Research Assessment Exercise (RAE) through “quality-related”(QR)

block grants. Whilst research quality has risen significantly since the RAE was introduced (HM Treasury, DTI 2006), it has tended to drive behavioural patterns on publishing and staff recruitment, and involves a silo-driven peer review process which fails to appreciate interdisciplinary research. Further, although it is supposed to encourage industrial relevance by rewarding “excellent user-focused research in the same way it rewards excellent curiosity-driven research ... it is not at all clear that this has occurred in practice”(HM Treasury, DTI 2006). This is reflected in the fact that among the eighteen categories of ‘indicators of peer esteem and national and international recognition’ taken into consideration in the 2008 RAE, only four relate to industry, the first of which appears twelfth on the list (Hughes, Madden et al. 2006). Metrics used to assess the value of university knowledge transfer activities also “place insufficient emphasis on the value of these activities to business”(Confederation of British Industry 2005). Once again this is at odds with the Research Councils’ intent to “engender a culture in the research base in which collaborations and exploitation are encouraged, valued and rewarded”(Esler 2007). The fact that working with industry is potentially ‘less beneficial’ to peer review and therefore academic funding makes universities reluctant to engage in industrial projects (Santoro, Greenish 2006) and inevitably offers a further challenge for collaboration.

The Government might argue that industry, as the ultimate beneficiaries of the research, should bear at least part of the research costs (Anderson 2006). In a highly competitive environment, however, industry would argue that the risk associated with such investment is too great. Not only is there risk associated with the research itself, but even successful research does not guarantee product sales and profitability. At a time when friendly nations are seeking greater interoperability between their armed forces, a failure to obtain sales in the home market can completely destroy the potential market elsewhere in the world. Increased industry funding is therefore reliant on better government – industry cooperation and trust in this area, providing greater certainty of a return on the research investment. This approach, together with the important support role of public expenditure and

procurement policy (Hughes 2006), is self-reinforcing: “ironically, guaranteed long-term funding by MoD is more likely to attract industry investment (and academia’s commitment) for this very reason”(Carney, Strong et al. 2007). There is evidence that universities are better suited to long-term investigations of a more fundamental character than short-term developments (O’Reilly, Broers 2005), and that “the best industry-university collaborations tend to be based around long-term relationships rather than individual research contracts”(Santoro, Greenish 2006). The role of government as an early adopter and procurer of new ideas and technologies is seen as critical to support such innovative partnerships: whilst no department fares particularly well in this, MoD is amongst those judged ‘better than average’(Confederation of British Industry 2005).

1.4.6 Scarcity of qualified resources

By its very nature, research of national importance draws upon relatively scarce skills, at both scientific and engineering levels. The scientific expertise at the forefront of such technologies is far from being a commodity and may only exist within a small handful of universities, and/or government and corporate research establishments – typically within a small team comprising a highly knowledgeable and experienced (and therefore “mature”) researcher, leading a group of more junior staff. However, “university expertise is embodied in individuals and therefore is not stationary”(Santoro, Greenish 2006). In spite of attempts to develop the junior staff, the retirement or departure for other reasons of the group leader can have disastrous results for the overall capability of the team, often leading to disbandment and the redistribution of the other staff. Even in cases where this does not happen, the external perception that the loss of the leader has eliminated key skills can be enough to prevent future work from being placed with the team and thus guarantee the team’s demise. The most positive outcome might be the transfer of the remaining group of skilled individuals to another similarly skilled team, but this is not straightforward. Barriers to mobility vary between industry, academia and government, and also with the

age of those affected. The geographical scatter of the teams and ultimately details such as pension arrangements can be deciding factors which prevent skilled individuals from moving.

Whilst the scientific knowledge of critical technologies may well be led within academia or government laboratories, skills for their exploitation and engineering sit almost invariably in industry. In addition to many problems similar to those in the scientific base, industry teams face an additional threat in the form of a lack of engineering contracts. Whilst the scientific base can be sustained by the injection of sufficient funds to support scientific research, the industrial base cannot. So, for example, improved aircraft sensor technologies might be developed in the laboratory but the expertise in sensor engineering comes only with their application on a new or modified aircraft – with many-fold increases in costs associated with development, manufacturing, test, training, maintenance and so on. Thus the industrial capability cannot sensibly be sustained simply by funding – retaining engineering expertise also requires ‘something to engineer’.

MoD procurement staff are also under pressure: not from a lack of programmes to engineer, but from cost-cutting measures designed to redirect funding to front-line forces. Such moves are in conflict with the need to maintain a highly-skilled workforce and can mean that even when staff are so busy they have insufficient time to attend training courses, their numbers are subject to further substantial reductions (House of Commons Defence Committee 2008).

In identifying appropriate resources to conduct a piece of research, judging the qualification of the resources provides another challenge. In industry, obtaining government contracts generally requires external certification of the quality management system to standards such as ISO 9001:2000. Academia, on the other hand, applies no such formal standards. Instead, government research funding levels are determined based on the outcome of the formal Research Assessment Exercise (RAE) which is held periodically to

establish the relative research quality of different universities conducting research in similar areas. The assessment is based on a number of criteria including the numbers of doctoral students supervised and of papers published in peer-reviewed journals, per head of academic staff. Whilst this provides an indication of technical quality it does not adequately address the issue of key interest to industry and government: effective exploitation. From their viewpoint the ability, willingness and indeed success of academic staff in ensuring that their work is usefully applied is a key criterion. Not all academic staff share this view, however – which may explain why it is largely missing from the current assessment approach. There remains a question of “how the different incentive structures for academic researchers and industry staff can be aligned to produce mutually beneficial results” (Perkmann, Walsh 2007).

“On an individual level, scientists need to choose who to collaborate with and in what form, not have it imposed. The diversity of participants is also important and arenas and systems for social interaction and networking are required”(Carney, Strong et al. 2007).

1.4.7 Security considerations

Fundamental to the national importance of the defence-related research are the interrelated issues of sovereignty and security, and this is “an occasional barrier to communication” within research partnerships (Carney, Strong et al. 2007). The Defence Industrial Strategy (DIS) and Defence Technology Strategy (DTS) effectively identify the technology areas where the UK wishes, for reasons of national security, to retain a national capability. Fundamentally, this means not being reliant on another nation for the supply and maintenance of key defence equipment at a time of conflict, independent of whether that nation is a coalition partner. It also means that the UK can retain control of the supply of that technology through export regulation, preventing it from being sold to potential aggressors. The export regulation of other nations, especially with regard to US export of technology to the UK,

remains an issue (Adams 2002) for which satisfactory resolution has yet to be demonstrated.

Globalisation of both industry and academia further complicate the security picture. None of the major defence industrial players have a footprint in only one country, and technology leakage within companies but across national boundaries remains a risk. In academia, a large and growing proportion of doctoral students are not UK nationals, and this trend is reflected among many western nations including the USA. Most students return home on completion of their studies, and the internet provides global access to the science and technology base. Thus academic research in UK universities cannot, in most cases, be considered to be national resource, but rather a contribution to the international knowledge base.

1.5 Generic HRP description

1.5.1 Aims

HRPs aim to draw upon the research management and delivery capabilities of industry, academia and government, coupled with funding sources in industry and government to deliver nationally-important research with the potential to be exploited commercially and for national benefit.

HRPs are established to address the need for research outputs in complex disciplines and domains where no one organisation or sector has the need, the knowledge and the funding to deliver the solution. Typically, knowledge of both the need and potential solutions is spread between many individuals and organisations; meanwhile funding may only be available to certain types of organisation. Such pressures within the industry, academic and government sectors were reviewed in detail in Chapter 1. Cooperation within and between the sectors is the only way to deliver the requirements within the constraints faced.

1.5.2 Characteristics

Perceptions of HRP at this stage are based on the author's own experiences of working in and with such partnerships over more than ten years. It is this experience, coupled with that of systems engineering, which motivated the research.

For the purpose of this research, HRPs involve:

- At least two organisations from two different sectors, but typically many more
 - Government organisations may be within the MoD, industry-related departments, research-funding bodies such as the Technology Strategy Board (TSB) or Engineering and Physical Sciences Research Council (EPSRC), or regional such as the Regional Development Agencies.
 - Industry typically involves large companies, their partners and competitors, as well as Small and Medium-sized Enterprises (SMEs).
 - Academia involves UK universities, typically with a strong research reputation and with good ratings in recent government assessments
- A scale of research which requires the involvement of perhaps 10 to 100 or more people on at least a part time basis, providing not only research outputs but also technical leadership, project management, commercial and administrative support.
- A multi-year duration, typically 5 to 10 years with a minimum commitment of 2 years.

These characteristics imply that those involved cannot operate as one small team of known composition, nor can the research requirements and the

relationship between them be explicitly detailed within a straightforward contract. Complexity and uncertainty are implicit.

1.5.3 Measures of Success

Measures of success vary to some extent between HRP. Some measures will be public and explicit, typically declared on websites or in publications. Others will be internal to the HRP, or perhaps even just to one partner. It is the author's view that, in general, HRP may be judged to be 'successful' by industry and government funding agencies when:

- The research which is undertaken is judged by peer review or other comparison to be of national standard.
- Research is delivered largely in line with the original expectation.
- Viable routes to exploitation are identified.
- The research community is stable and relationships are good.

For HRP to be judged 'highly successful' by these bodies:

- The research which is undertaken is judged by peer review to be of international standard.
- Research is delivered in line with the original expectation, or evolves as needs evolve, so that the benefit is at least as great as was envisaged at the outset.
- Exploitation of the research can be demonstrated.
- The community engaged within the research cooperates to become self-sustaining, identifying ongoing research directions and securing funding to pursue them.

1.5.4 Familiar Challenges

In the author's experience, typical problems faced by HRPs include:

- A sense of 'acceptable' rather than exemplary outcomes
- Research outputs which are not in a form which can be used by industry and government
- Tension between the desire to protect intellectual property and the desire for academic publication
- 'Good' outcomes which are still not exploited
- A sense that the same work could have been performed 'in-house' by industry or government, more effectively and at lower cost.

1.6 Conclusion

HRPs are an attempt to deliver cost-effective, leading-edge research in a complex and changing environment. They face a range of challenges and in order to be successful there is a need to work towards an agreed vision based on trust and confidentiality. "Partnership cannot be based on words. It must be based on actions and a commitment to shared values"(Lord Drayson 2006).

2 RESEARCH REQUIREMENTS

2.1 Introduction

Having identified the generic issues associated with SoS in Chapter 1, and outlined the characteristics of HRPs as one instantiation of SoS, Chapter 2 now identifies the aim of this research and the requirements it seeks to satisfy, which come from several sources:

- The research aim is driven by an immediate technical problem which the industrial sponsor seeks to solve.
- The research itself must conform to the requirements for doctoral research established by the UK Quality Assurance Agency for Higher Education (QAA).
- The research must also conform to the framework of complex challenges established by the Systems Engineering Doctorate Centre (SEDC).

Taking these as the fundamental research requirements, further requirements can also be derived which help to define what the research itself needs to do: in systems terms, its required functionality.

2.2 Research Aim

During the initial stages of the research it was agreed with the sponsor that the specific aim of this research was

“to develop and validate guidance for those involved in establishing and operating HRPs to enhance their effectiveness by choosing and using the systems techniques which reflect the needs of their partnership, underpin the establishment and maintenance of shared understanding, and support the delivery of envisaged benefits through life.”

2.2.1 Implied Research Questions

This research aim implies a number of questions which the research will need to address:

- What are the needs of these partnerships? Can generic needs be identified?
- What is the nature of HRPs such that appropriate systems techniques can be selected?
- What systems techniques are available to enhance the effectiveness of HRPs?
- What is the lifecycle of an HRP? Are different systems techniques more appropriate at different times?
- Although primarily taking the UK as the sampling base, are there any indications that this learning might also be applicable in other countries?

2.3 Generic Doctoral Requirements

According to the QAA descriptor for a higher education qualification at level 8 (Doctoral degree) (The Quality Assurance Agency for Higher Education 2008)

“Doctoral degrees are awarded to students who have demonstrated:

- the creation and interpretation of new knowledge, through original research or other advanced scholarship, of a quality to satisfy peer review, extend the forefront of the discipline, and merit publication
- a systematic acquisition and understanding of a substantial body of knowledge which is at the forefront of an academic discipline or area of professional practice

- the general ability to conceptualise, design and implement a project for the generation of new knowledge, applications or understanding at the forefront of the discipline, and to adjust the project design in the light of unforeseen problems
- a detailed understanding of applicable techniques for research and advanced academic enquiry.”

2.4 SEDC Requirements

According to the SEDC website (Systems Engineering Doctorate Centre), its

“Research projects, developed with industry partners, will address current and future challenges in Systems Engineering associated with:

1. Exploiting Systems of Systems
2. Managing Systems complexity
3. Maximising system performance, capacity and capability of affordable systems
4. Understanding humans in the system.”

The implication here is that research projects will address one or more of these challenges but not that they are expected to address all four.

Whilst research project outlines are agreed by the SEDC, the detail is largely driven by the industrial sponsor, ensuring applicability of the research to the company. This can, in some cases, create tension between industrial needs and the accepted bounds of research. It is the research engineer’s responsibility to manage that tension and ensure that both industrial and academic needs are met. In so doing the research engineer is able to practice the skills of a systems engineer in managing the trade-off between conflicting requirements.

2.5 Derived Requirements

Further requirements have been derived based on these explicit requirements and the author's knowledge and experience: from the taught elements of the EngD programme and wider reading, from more than 20 years industrial experience and from observation of the international systems engineering research community.

2.5.1 Business Usability

In order to meet the needs of industry, the output has to not only be in academic form, but also in a form which is useful to the business. Whilst an "executive summary" or abridged report may go some way to meet that need, they are still unlikely to be read by the majority of the target audience. In order to be genuinely valuable to the business, the research output must include material in a form which is familiar to the business and usable in a way which is consistent with its normal operations.

2.5.2 Challenges in Systems Engineering

According to the SEDC requirements, the research should address current and future challenges in systems engineering. The research must therefore encompass aspects of systems engineering, either through the research focus on systems engineering itself, the novel application of systems engineering to a new area, or its use as an overarching model for research which addresses novelty in another technical area.

Systems engineering is both systemic (considering not only the parts but also the whole and their relation to it) and systematic (following a structured approach), and these aspects should therefore be evident whatever the focus of the research.

2.5.3 Challenging the Boundaries of the Discipline

In order to extend the boundaries of the discipline, it is necessary to identify where these are. However, systems engineering means different things to different people and therefore the boundaries are not easily defined.

For the purpose of this research it is necessary to identify assumed boundaries (at least for the context in question) and areas where these might overlap adjacent disciplines. This is addressed in Chapter Four.

2.5.4 Research Techniques

In order to meet the requirement for a detailed understanding of applicable research techniques, the research must include an exploration of this topic area. However, it is known that systems engineering is a relatively new and therefore immature discipline, particularly in terms of its research. It is therefore likely to be necessary to undertake research beyond the immediate subject matter to satisfy the research aim, into research techniques themselves. This is expected to go beyond literature review to contribute to the development of the body of knowledge on systems engineering research, and therefore provide both methodological and substantive contributions to knowledge.

2.5.5 Meriting Publication

Even when the intent is to submit by thesis rather than by publication, it is important to demonstrate that the research is of a quality and substance worthy of publication.

2.6 Functional Identification

These requirements imply certain functionality in the research: that is, what the research needs to do. Taking the fundamental and derived requirements, the following functions can be identified as shown in Table 2.1.

Table 2.1 Research Functions

No.	Research Requirement	Research Function
1	What are the needs of these partnerships? Can generic needs be identified?	Understand HRP context and operation
2	What is the nature of HRPs such that appropriate systems techniques can be selected?	Link HRP context and operation to systems techniques
3	What systems techniques are available to enhance the effectiveness of HRPs?	Understand potential systems techniques
4	What is the lifecycle of an HRP? Are different systems techniques more appropriate at different times?	Understand HRP lifecycle and link to systems techniques
5	Are there any indications that this learning might also be applicable beyond the UK?	Design research to give initial insight beyond UK
6	Creation and interpretation of new knowledge	Create / interpret new knowledge
7	Extend the forefront of the discipline,	Extend the SE discipline
8	A systematic acquisition and understanding of a substantial body of knowledge	Systematically acquire / understand knowledge
9	Conceptualise, design and implement a project	Design research
10	A detailed understanding of applicable techniques for research	Understand research techniques
11	Exploiting systems of systems	Propose SE techniques for SoS
12	Understanding humans in the system	Propose SE techniques for humans in the system
13	Business usability	Match research output to business need
14	Challenges in systems engineering	Apply SE to research design and content
15	Challenging the boundaries of the discipline	Understand boundaries of SE discipline
16	Research techniques	Understand research techniques
17	Merit publication	Publish research

In order to satisfy all the major stakeholders, it is necessary to take a holistic approach which goes beyond the research aim to address these broader, largely implicit, research ‘functions’. These functions – and the architecture of the research necessary to deliver them - will be considered further in Chapter Three.

2.7 Preliminary Literature Review

2.7.1 HRPs: what do we already know about them?

HRPs (specifically) are not an area that has been well covered in the academic literature, either in the UK or elsewhere.

Exceptions to this include two papers addressing extant HRPs based in the UK which have also been used as case studies here. The first describes the complex systems engineering exercise involved in developing the HRP, noting that the different objectives and constraints of a wide range of stakeholders had to be reconciled into legal, technical and organizational frameworks to provide identity and coherence “without compromising the potential contribution of the parent organizations”. However, other than noting the role of organizational structures and the formation of working groups, the approach taken to achieve this reconciliation is not described (Jackson, Siemieniuch et al. 2003).

The other takes an interpretive case study approach to explore the role of intellectual capital in what is described as a “virtual centre of excellence”. Drawing upon resource-based theory, they examine the interplay between social and structural capital and the role of each in developing enterprise intelligence. They emphasise the importance of “broad based relationship building” using activities which “cut across, bridge or blur boundaries” to create social coherence’ around which the organization can adapt through time, whilst recognising the coordination burden and impact on short-term efficiency that this creates.(Dixon, Brown et al. 2007)

Looking further afield, Berumen et al proposed a systems approach to enhance the effectiveness of a Research and Development (R&D) Centre in Mexico (Berumen, Toledo et al. 2009). Although recognising that the competitiveness of R&D activities was dependent on a “joint and sustained effort” between government, R&D centres, universities and industry, the paper did not address differences in need or perspective between these stakeholders, but focused on the application of systems theory to initiate and manage innovation. It assumed that systems engineering would enable the elimination of communication barriers and enable cooperation and collaboration towards a common objective and strategic vision. In going on to consider the role of systems engineering in design and development, they suggested that although in general “the more detailed the requirements the better”, this is not necessarily true for innovation activities. They note that in this case “systems analysis is an attempt to apply the scientific method to important strategic issues, even when those problems are not particularly suited to scientific method and would never have been selected for the application of scientific method by a truly academic researcher”.

In a fourth study, Elias et al suggest that applying the concept of participatory design to the entire innovation system, potential customers and partners can be integrated into R&D activities in order to build overlapping communities of practice (Elias, Cavana et al. 2002), although they do not address differences in stakeholder needs and objectives and how these might be addressed.

Although not in openly-published literature, the author identified another study based on stakeholder interviews, in which practice in HRP was reviewed from the Government perspective (Carney, Strong et al. 2007). This identified that:

- there was reasonable consistency in the generic factors contributing to effective collaborative research, such as the influence of personality. The behaviours of individual actors were “repeatedly cited” as being highly influential.

- management and organisation was another significant factor: complex management structures were not favoured, but those which were strong and tightly run were seen as most beneficial.
- there were marked differences between stakeholder perspectives (e.g. customer/supplier and academia/industry) over perceptions of issues such as risk.
- in spite of “close relations” between them, individuals had not lost their core identity, nor had the liaisons become “full-blown partnerships”. Individuals needed to be appropriately expert to be taken seriously, and too many participants diluted the benefits.
- there was a concern that some work lacked relevance to the government customer, or duplicated work already done internally. In part, this was attributed to commercial or defence security concerns which prevented the sharing of relevant information.
- complexities in contracting resulted in staffing problems which delayed the start of the research.
- most stakeholders felt that they provided good “value for money” compared to conducting such research in-house, but recognised that such additional value was largely intangible.

The study’s recommendations included:

- selecting majority partners with existing networks and a good reputation
- establishing HRPs with a minimum of 3 years funding to aid recruitment and investment
- exercising care in developing IPR agreements, using existing models to minimise the cost and effort of negotiations whilst ensuring that the government’s needs were met.

2.8 Initial Research Approach

Drawing from the 1973 work of Rittel and Webber, John describes ‘Wicked Problems’ in which requirements are volatile, constraints keep changing, stakeholders can’t agree and the target is constantly moving. Such problems run counter to the systems engineer’s traditional desire to understand the problem, gather and synthesize data, and develop a solution. He notes that in these situations “one cannot understand the problem without knowing about its context... one cannot meaningfully search for information without the orientation of a solution concept... one cannot first understand, then solve” (John 2006).

Such is the challenge of this research area. There is insufficient information in published literature to characterise the problem and design an appropriate research solution and thus an evolutionary approach has been adopted. This employs one possible methodology by means of a pilot study in order to further explore the problem context and application of systems engineering, and to test the appropriateness of the methodology itself.

3 INITIAL FIELD DATA COLLECTION AND PILOT STUDY

3.1 Introduction

Having explored the context of HRPs in Chapter One and taken an initial review of the literature in Chapter Two, it was apparent that some initial field work was required. This comprised two major elements: field data collection on several HRPs to which the author had direct access in order to both better understand the problem space, and to identify where literature from other domains or disciplines might be relevant; and the conduct of a more in-depth study on one of them in order to start to develop relevant models and explore a potential research methodology.

3.2 Initial Study Methodology

3.2.1 Field data collection

During the early stages of this research, the author had direct access to four of the HRP case studies subsequently selected for the main research. Such access ranged from attendance at strategic and operational meetings, workshops and conferences, to access to the working documentation of the HRP covering areas such as strategy, management planning and review, technical direction and working with external customers and contacts. The author's position at the time meant that the access in several cases was as a participant-observer, involved to a greater or lesser extent in each of the HRPs, but without specific management responsibilities.

Detailed field notes were taken and copies of documentation collected, although no analysis was done at this stage. Nevertheless, the observation inevitably influenced the author's perception of themes and issues for the HRPs in question, as well as establishing a network of contacts for the main study.

3.2.2 Philosophical position

A primary challenge within this research design was in establishing the philosophical position from which the research would be conducted. Those funding the research (the industrial sponsor and EPSRC) both typically fund research undertaken from a positivist or realist, natural science perspective. Both the industrial supervisor and researcher are qualified as engineers, and therefore also come from a realist background. And yet, fundamentally, the real need underlying this research did not lend itself to such an approach.

From the outset, it was clear that the different sectors (industry, academia and government), and indeed individuals within those sectors, had different views on HRPs. This is true both in terms of what the objectives should be and how they should be achieved, and in terms of the perceptions of actual operation. Carney had made it clear that in his study, interactions between individuals were key (Carney, Strong et al. 2007). HRPs do not operate in a machine-like manner following prescribed processes, but rather rely on those interactions in order to deliver outcomes through a complex social system.

It was therefore clear that a realist stance would be unlikely to adequately reveal the richness of data relevant to the research questions and that some form of interpretive approach was appropriate, but also that such an approach must be tuned to the needs of the customer. This meant that the analysis and presentation of results would need to go beyond comparative observations of different HRPs, their participants and their use of systems engineering, to produce some form of characterisation and actionable recommendations.

It became apparent that a pilot study was appropriate which:

- Examined one HRP (which would become known as Case Study A)
- Utilised a systems engineering approach
- Employed a recognisable research methodology.

The aim of the pilot would be to test the approach (both in terms of the systems engineering and the research approach) and to act as a start point for either more in depth research in the same HRP, or similar research across a number of HRPs.

3.3 Pilot Study

3.3.1 Pilot Study Methodology: influential literature

Nothing in the rather sparse existing literature on HRPs provided a basis on which to select an appropriate research methodology for this pilot study. Nor did the traditional processes of systems engineering itself: the HRP studied had no obvious single customer, no clear user need or complete set of requirements against which its implementation could be verified and validated.

In this situation, it was noted that an interpretive systems methodology “should always be chosen initially as the dominant methodology”(p374) since such interventions tend to proceed more smoothly than those governed by functionalist or emancipatory rationales (Jackson 1997). One authoritative source provided a way forward: Peter Checkland’s “Systems Thinking, Systems Practice”. The battered copy of the original 1981 publication, obtained originally from the university library, was a revelation. Reprinted almost annually since that original edition, and known around the world, the authority of the work speaks for itself: it should be a compulsory text for all students of systems engineering. Not only did it explain the soft systems methodology which would be perfect for the pilot study, but it opened up a deeper understanding and a deeper questioning of systems, both hard and soft: of science and of practice, of thinking and of reality. It was a revelation that would underpin the research going forward.

Post-1999 reprints of Checkland’s book include a new retrospective chapter which, rather than changing the original text, adds reflections of soft systems

research and practice over 30 years. It allows the reader an insight into not only the evolution of his Soft Systems Methodology (SSM), but also how it has been used and misused, represented and misrepresented (Checkland 1981). What emerges is a clear impression that SSM is not a collection of tools, nor a prescriptive method which when 'applied correctly' will give the 'right answer'. SSM demands rigour and self-discipline in its use, through an approach such as action research.

3.3.2 Action Research

With its foundations generally attributed to Kurt Lewin and others working in the 1940s (Cooke, Wolfram Cox 2005), action research involves:

- Systematically collecting research data about an ongoing system relative to some objective, need, or goal of the system
- Feeding these data back to the system and conducting a collaborative diagnosis of the data
- Taking action based on the diagnosis, and
- Evaluating the results of the action (Ramirez, Bartunek 2005)

"Instead of beginning in the conventional fashion with a review of literature, the specification of hypotheses, and the finding of a target organization to test out our design, we start by discovering the problems existing in the organization"(Foote Whyte, Greenwood et al. 1991). The goals of Action Research are practice-focused: understanding, improving, contributing to knowledge and critically improving the practitioners' ability to understand and improve their own practice (Robinson 2005). The value of action research is determined by "the extent to which the methods and findings make possible improvements in practice", and not by its contribution to generalisable knowledge (Corey 2005).

Although it may be any of them, it is not *necessarily* a technical, critical, liberal or emancipatory endeavour (Robinson 2005). Argyris and Schon argue that in many cases "particular problems cannot be resolved unless one

also addresses the question of why the relevant practitioners have so far been unable to resolve the problem” (Argyris, Schon 1991). In settings containing ‘multiple realities’ (i.e. where different constituencies have divergent perceptions of apparently ‘shared’ events), action research interventions are likely to surface differences in the values held by stakeholders (Ramirez, Bartunek 2005).

It is suggested that for applied social research in industry or agriculture, “participatory action research offers a more effective strategy for the interdisciplinary applied research projects”, than using technical specialists as passive informants (Foote Whyte 1991). In addition, “...participatory action research can have a far greater role than the conventional professional expert role of the consultant in stimulating and guiding major organizational change” and can not only “achieve results of current benefit to the organizations but can lead to a rethinking and restructuring of relations so that the impact of the process can carry far into the future” (Foote Whyte, Greenwood et al. 1991).

Action research interventions are likely to lead to the use of political behaviours and turnover of participants (Ramirez, Bartunek 2005). This may be in direct conflict with the need, “particularly at crucial points in their initiation and development” for the “development of effective, indeed, intimate, relationships with harassed and troubled individuals, usually men or women in key positions”. Under these conditions, whilst the anxiety and uncertainty aroused by the need to seek external help must be recognised, the participatory role of the researcher makes self-discipline essential: in order to be effective they must be seen to be neutral by both sides and ensure that their motivations in terms of interests, needs and attitudes do not interfere with the success of the research. Above all, however tempting it may be, the engagement should not lead to the researcher taking over the problem (Wilson 2005).

3.3.3 Study description

The Pilot Study was conducted over a four-month period between September – December 2007. The aim was to gather and analyse data relating to the case study, in order to identify areas where a systems approach might resolve difficulties and further enhance areas of strength.

An Action Research approach was used to explore the different perspectives of the HRP stakeholders. Critically, this was not an independent investigation into the operation of the HRP, but rather an integrated approach aimed at engaging key stakeholders in enhancing their shared understanding of the partnership, and supporting joint action planning to further develop the HRP.

3.3.4 Research methodology

SSM was taken as the basis of the research methodology. The four activities of his “second decade” SSM deployment were used as a framework (Checkland, Scholes 1990):

- finding out about the situation,
- formulating relevant models,
- debating the situation using the models,
- taking action

Figure 3.1 details the process followed for the first three of these activities, as described below.

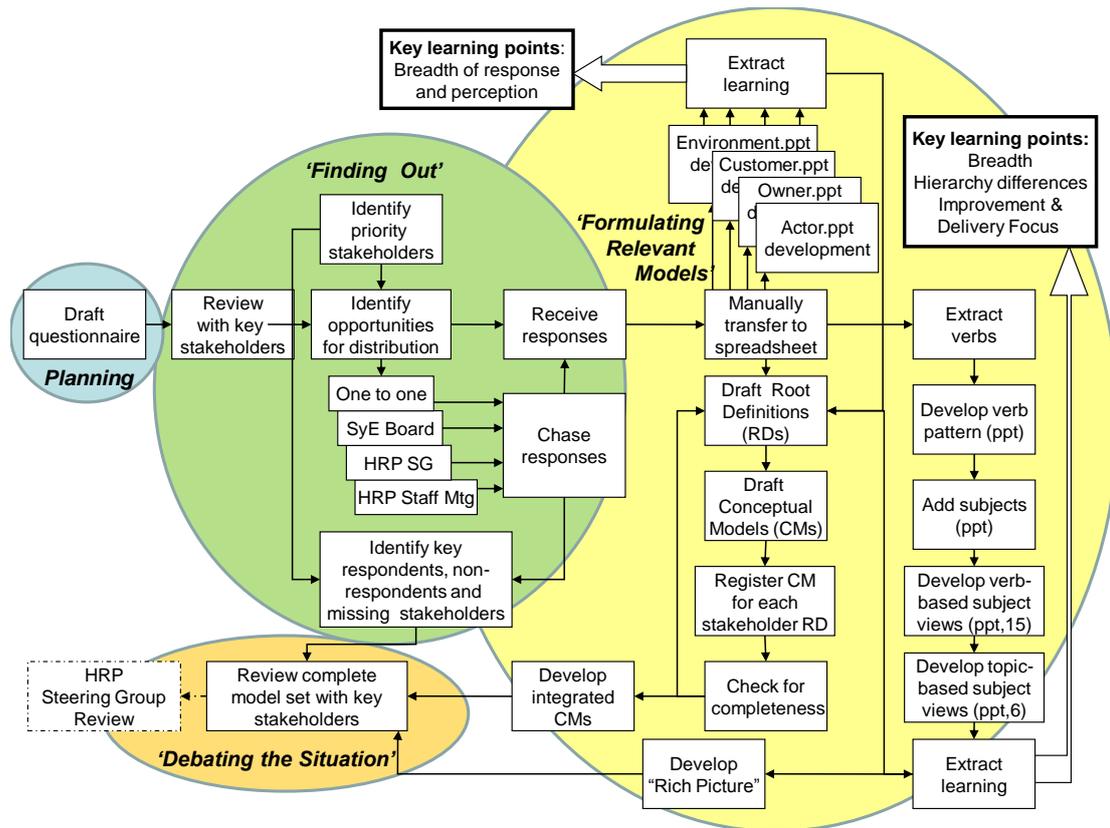


Figure 3.1 Pilot Study Process

3.3.4.1 Finding Out

The stakeholder group was both hierarchically & culturally diverse, and geographically dispersed. A questionnaire was therefore used to capture initial views in an asynchronous way, to ensure that the full breadth of perspectives would be represented in the data set. The raw data was then used to inform the development of potentially useful models for subsequent stakeholder review and action planning.

The study involved more than 60 of the HRP’s stakeholders. These stakeholders were drawn from both academia and industry, and included members of the Steering and Management Groups, participants, key customers and industrial technology champions. 60% were from the industrial partner, 30% from the academic partner and 10% from elsewhere including government bodies.

The questionnaire was used to gather one or more structured definitions from the stakeholders, each describing their view of a purpose of the HRP, using the form “WHAT – HOW – WHY”. Beyond the provision of an unrelated example, no guidance was given as to the scope or level of required responses, in order to avoid artificially constraining the different ways in which the stakeholders viewed the HRP. Respondents were encouraged to provide as many separate definitions as they felt necessary to fully describe their perspective, rather than creating one bland and all-encompassing statement. This resulted in an average of 3-4 responses per respondent. Each stakeholder was also asked to complete two supporting information forms, giving details of the nature and duration of their relationship with the HRP. This information was not used in any explicit way (for example in a quantitative analysis), but enabled the context of their responses to be understood to assist interpretation of the data as part of the qualitative analysis.

Throughout the data collection exercise, the emphasis was on the *quality* of interaction with the stakeholders. Nearly 90% received at least an outline face-to-face explanation of the aims of the research and the methodology being used, taking opportunities as these arose through team briefings, management meetings and so on. Detailed explanations were given on request to around 10% of stakeholders. Due dates for responses were negotiated on an individual basis to take account of work pressures and other priorities, and this resulted in just under 23% of stakeholders providing their response by the agreed date; a further 25% needing one reminder and additional time, and the remaining respondents requiring a further reminder.

Response rates for the questionnaire were very high, averaging 56% overall as illustrated in Figure 3.2. Although the responses were clearly dominated by the higher number of industrial stakeholders and their higher response rate, no weighting was given to ‘repeated’ responses. Thus whilst a better balance of inputs would have been desirable, the inclusive rather than reductionist approach to analysis meant that the larger number of responses

gave the industrial partner's needs no greater weight than that of the academic partner, and in fact served to include the views of the diverse range of industrial stakeholders (from different businesses, sectors and job roles) which was not such a characteristic of the academic population.

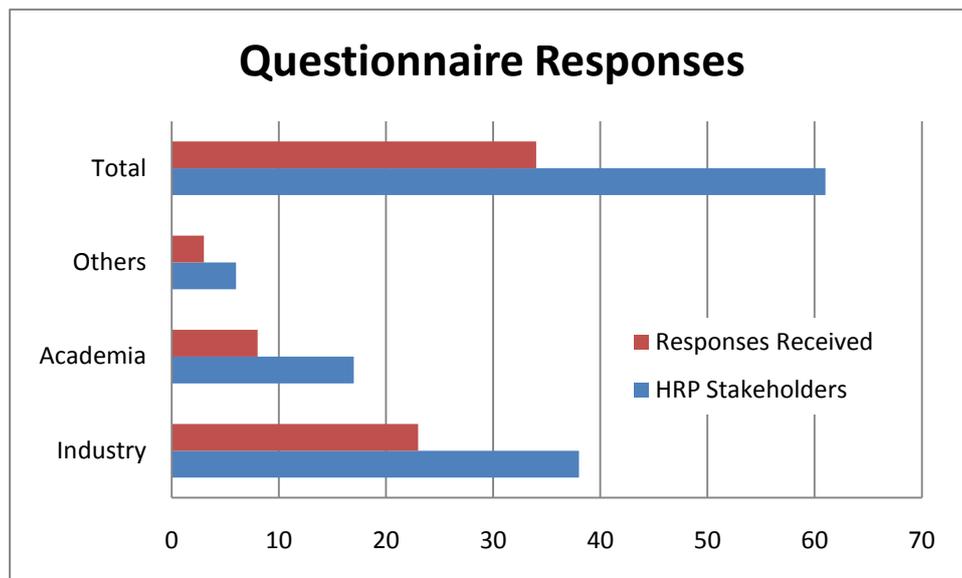


Figure 3.2 Questionnaire Responses

Questionnaires were made available in both hard and soft copy to suit the different needs of those who preferred to complete them by hand, and those who preferred electronic submission. In general, although not exclusively, remote respondents tended to favour electronic submission whilst those based locally favoured hard copy. A total of 132 structured definitions of the HRP's purpose were provided.

3.3.4.2 Formulating Relevant Models

Modelling was focused in two areas: the creation of an integrated set of conceptual models to reflect all the perceived aims of the HRP, and development of a "Rich Picture" to reflect the organisation and context based on the nature of stakeholders' relationships with the HRP.

Figure 3.3 shows the first step in the development of the conceptual model. Verbs used by stakeholders to describe the purpose of the HRP were grouped to show related themes. As groupings were established, it became

clear that these could be loosely related to a two-dimensional matrix, reflecting whether the aim was internally or externally facing (i.e. the focus was the HRP itself, or its relationship with others), and whether it was input-related (such as winning a contract) or output-related (delivering the results).

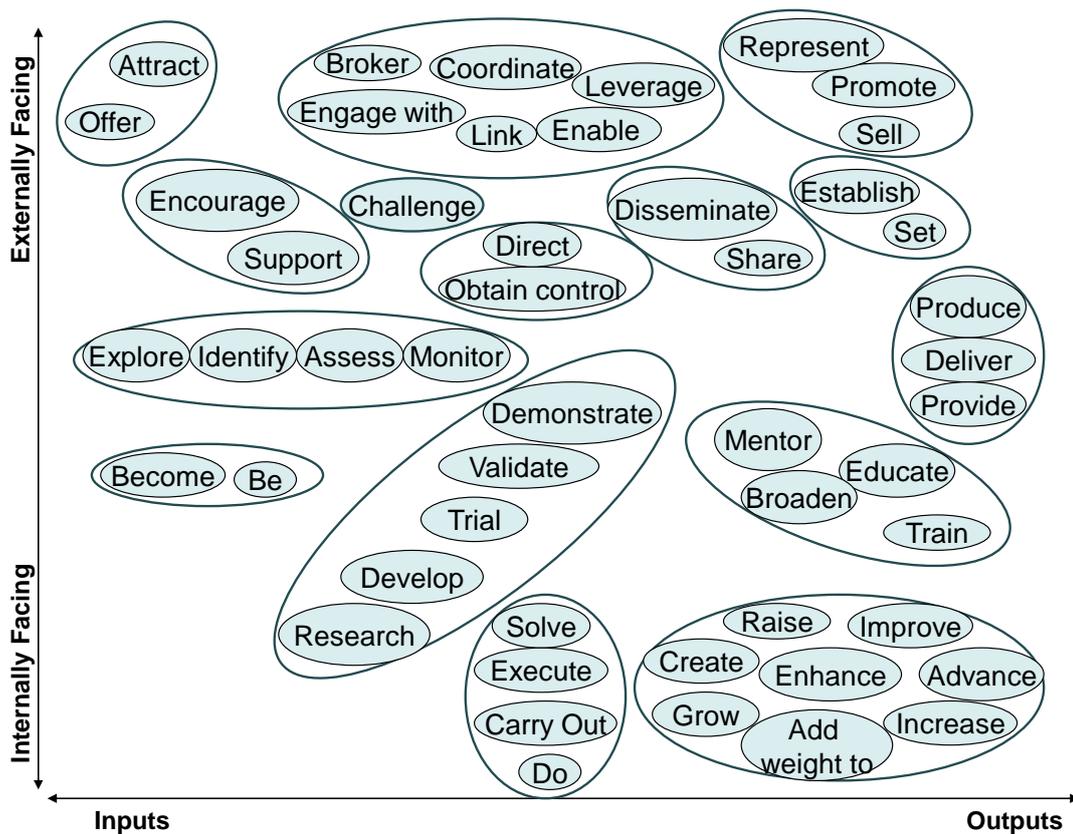


Figure 3.3 HRP Purpose: Verbs Used

Next, the objects associated with each verb were identified, as per the example in Figure 3.4. This helped to clarify the extent to which the use of the same or similar verbs actually reflected similar objectives, and was necessarily a manual process which required an understanding of context to correctly interpret the respondent’s intent.

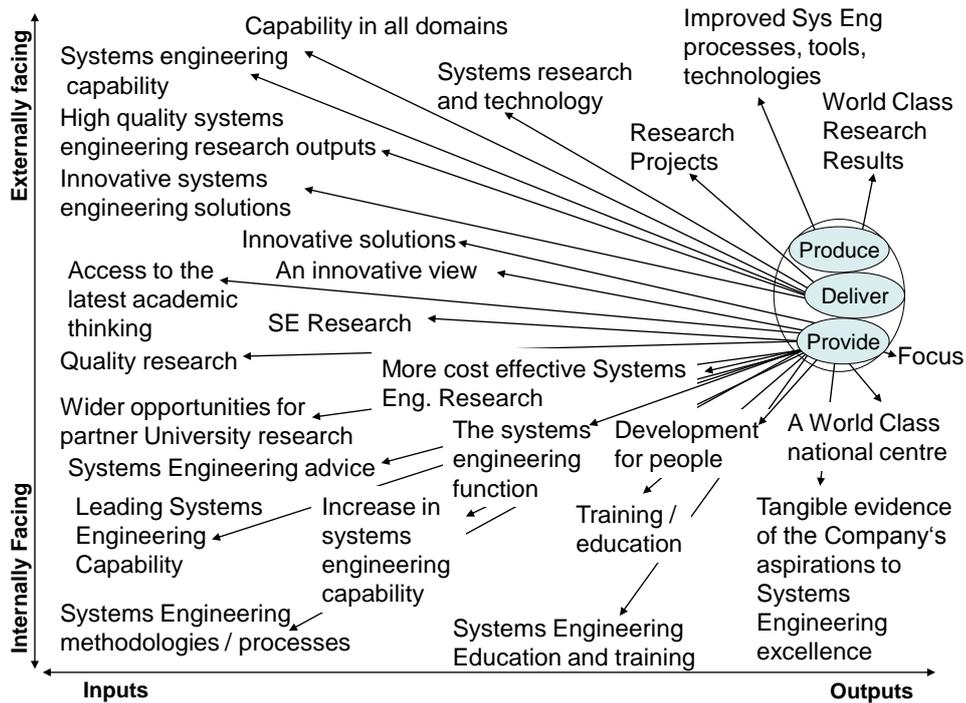


Figure 3.4 HRP Purpose: Example

Several common themes arose across a range of verbs: training & education, innovation, outreach, partnership, products and world leadership. Each of these were identified and mapped separately, see Figures 3.5 – 3.10.

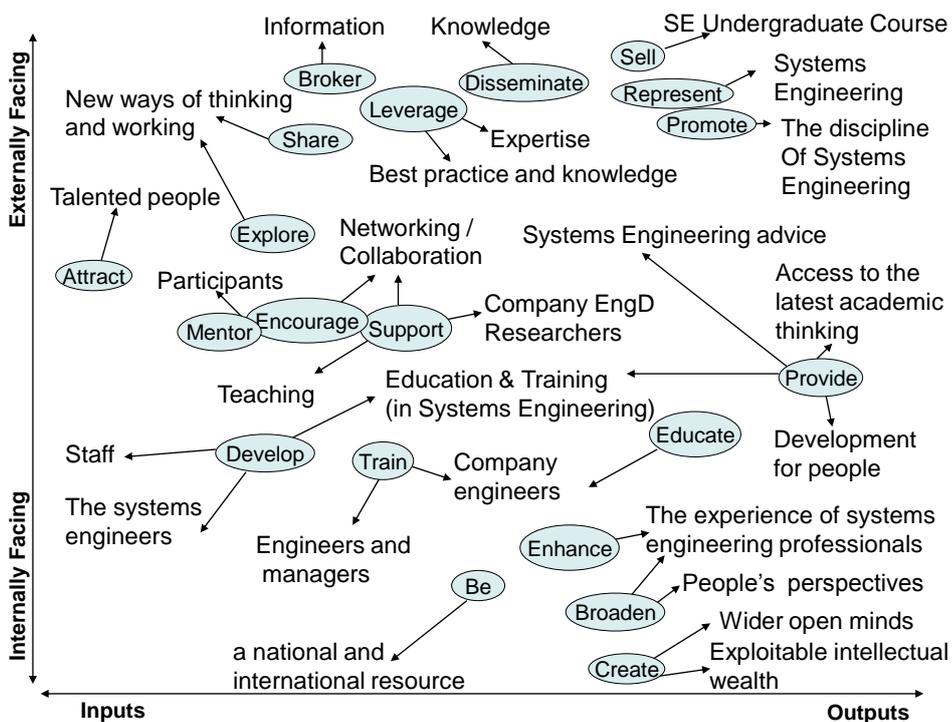


Figure 3.5 HRP Purpose: Training & Education

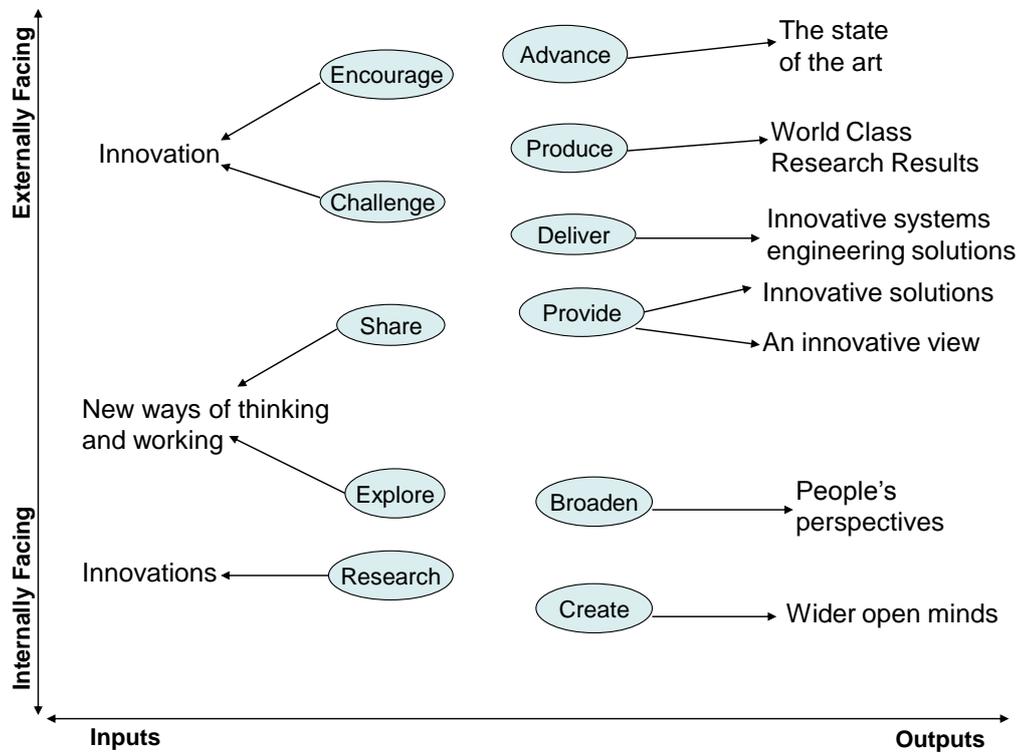


Figure 3.6 HRP Purpose: Innovation

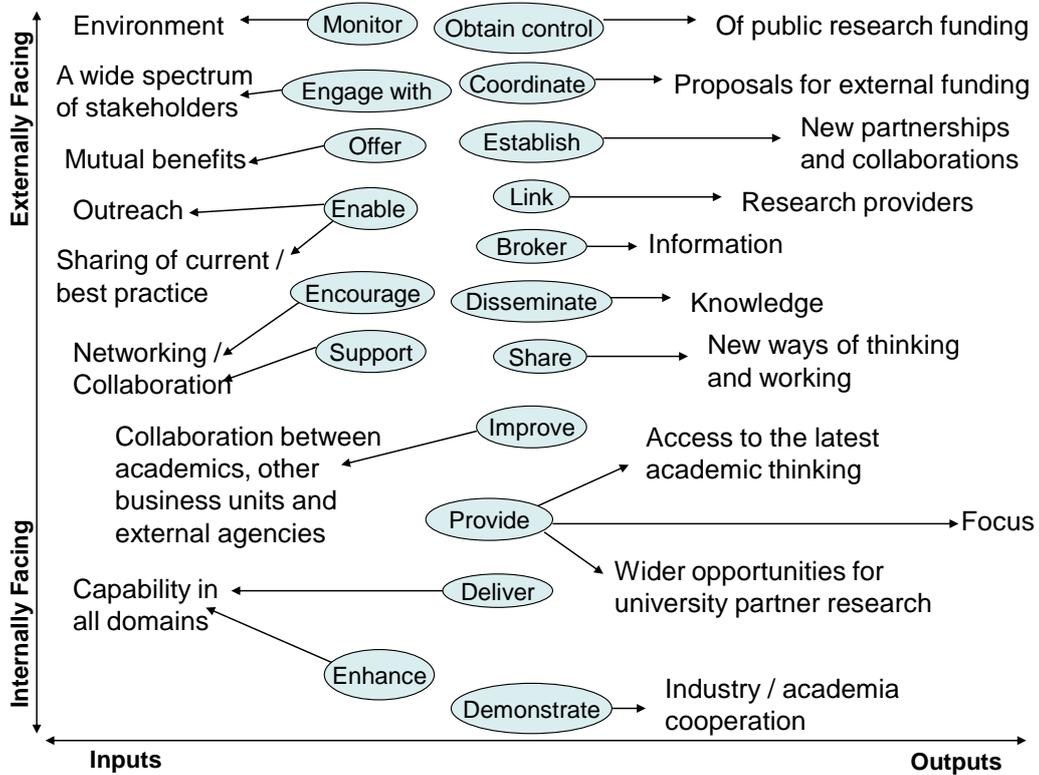


Figure 3.7 HRP Purpose: Outreach

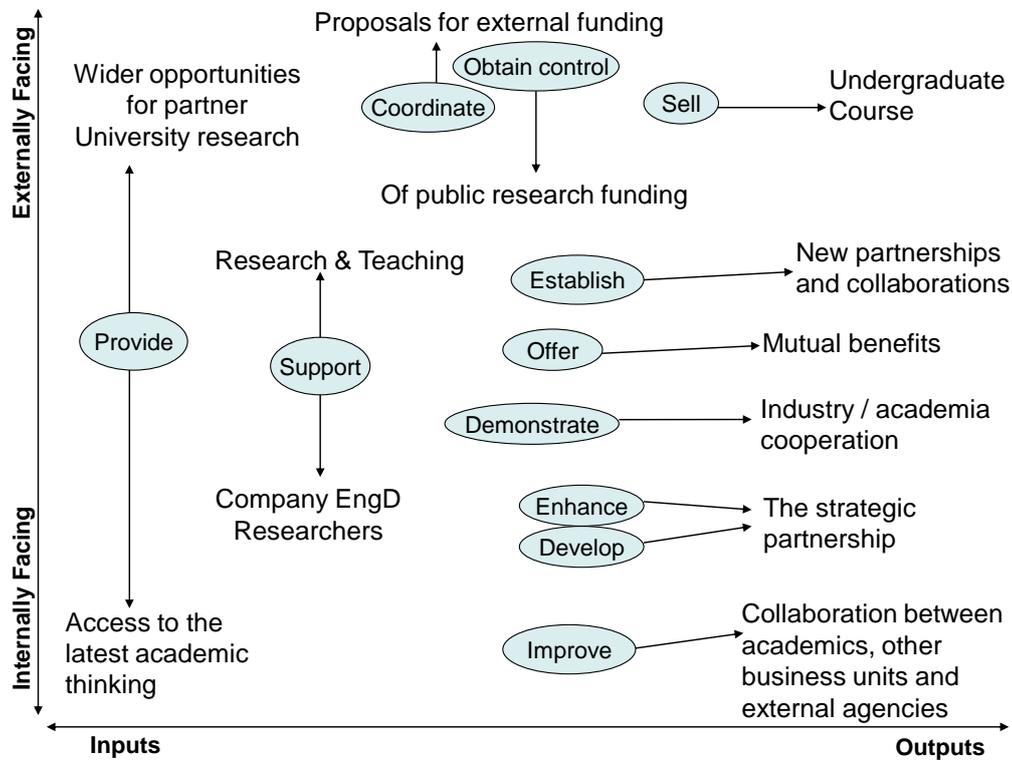


Figure 3.8 HRP Purpose: Partnership

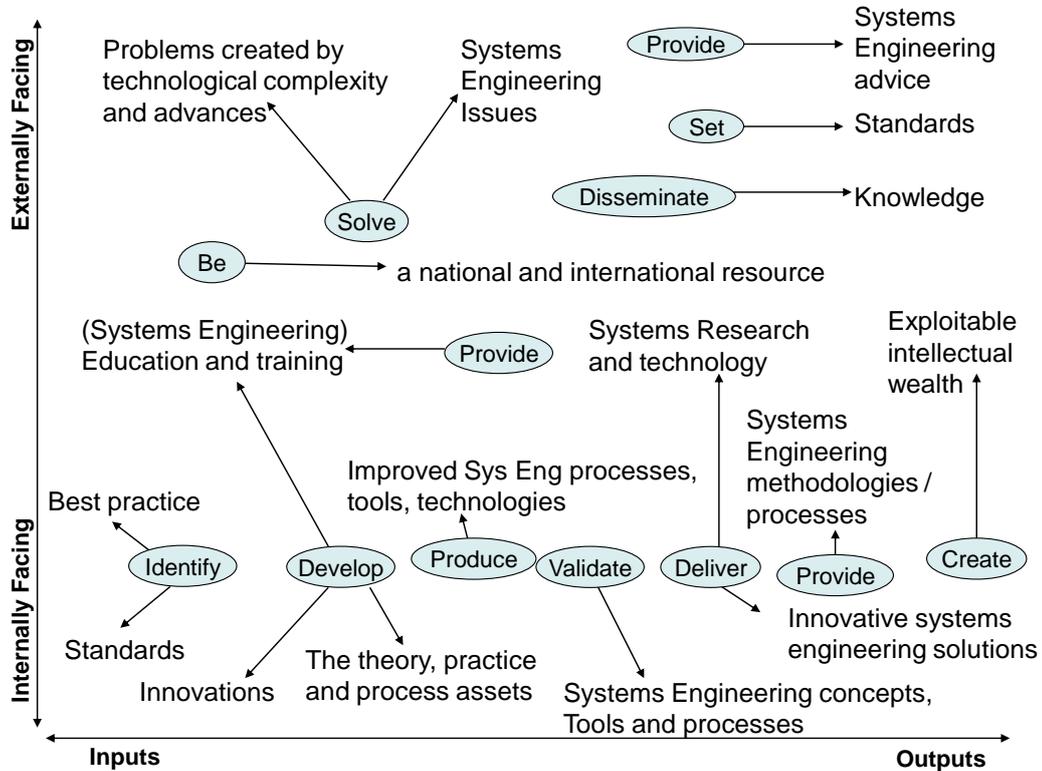


Figure 3.9 HRP Purpose: Products

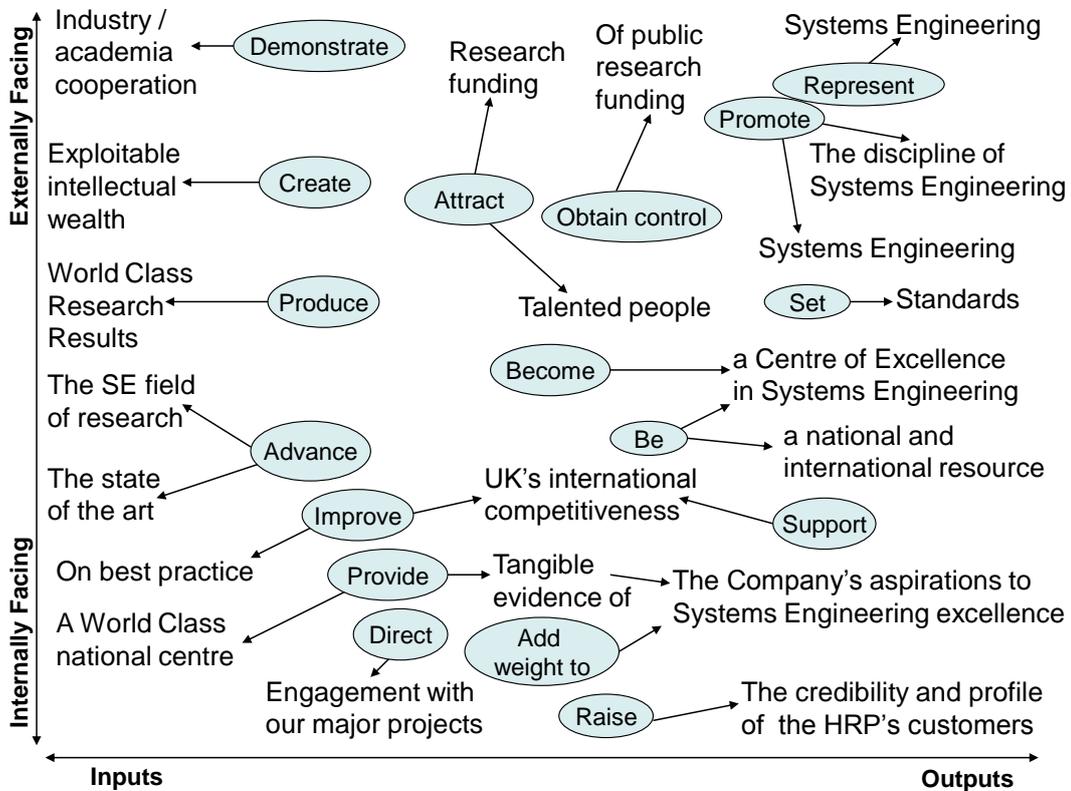


Figure 3.10 HRP Purpose: World Leadership

This process of exploring the verbs used, whilst not producing a definitive model in itself, enabled the author to become sufficiently familiar with the data to derive a set of nineteen structured definitions which fully encompassed the scope of the original 132. Fig. 3.11 and Table 3.1 provide an illustrative example of the simple top level model and supporting description based on Checkland’s CATWOE mnemonic (Customers, Actors, the Transformation, Weltanschauung, Owners and Environment) which were developed to support communication and shared understanding of meaning. The complete set is included at Appendix One.

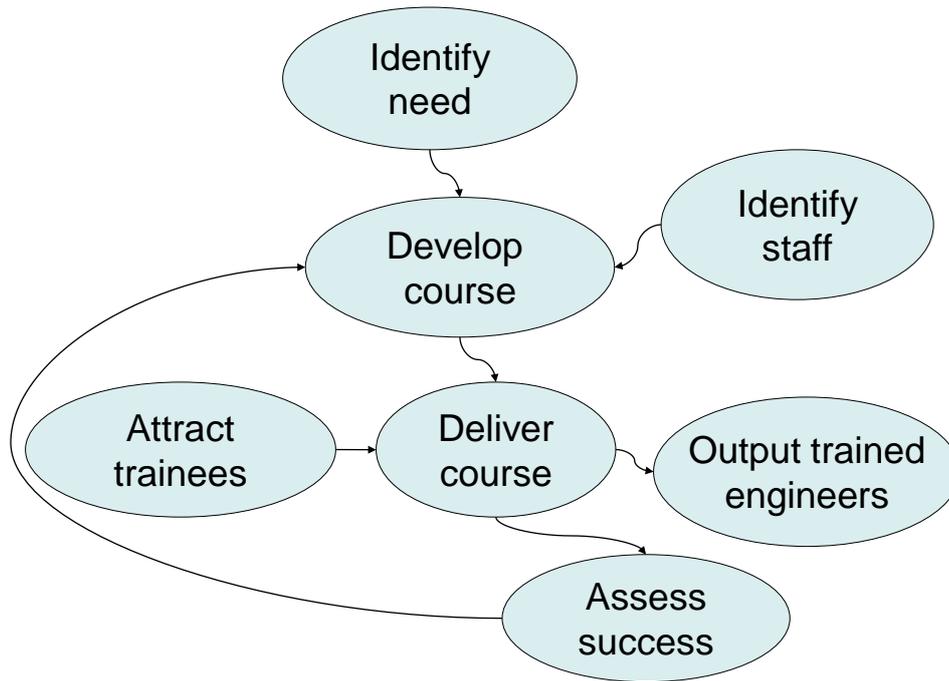


Figure 3.11 Conceptual Model: Educate and train systems engineers

Table 3.1 Root Definition: Educate and train systems engineers

Owned by (Owner)	Operated by (Actors)	To ... (Transformation)	For (Customer)	Worldview, Environment (W, E)
University department	Academic and administrative staff	Educate and train systems engineers By Developing, promoting and running profitable education and training programmes in systems engineering	Industry and commerce in the UK	In order to grow the systems engineering resource to meet society's needs

The 19 definitions differed broadly in both scope and the level at which they applied, reflecting different stakeholder perspectives and priorities. In order to make them more easily understood as a complete set, a hierarchy was introduced. Fig. 3.12 shows the hierarchy and indicates how the underpinning objectives relating to, for example, resource provision and basic operations can be seen to contribute to the strategic objectives and underlying values of the HRP.

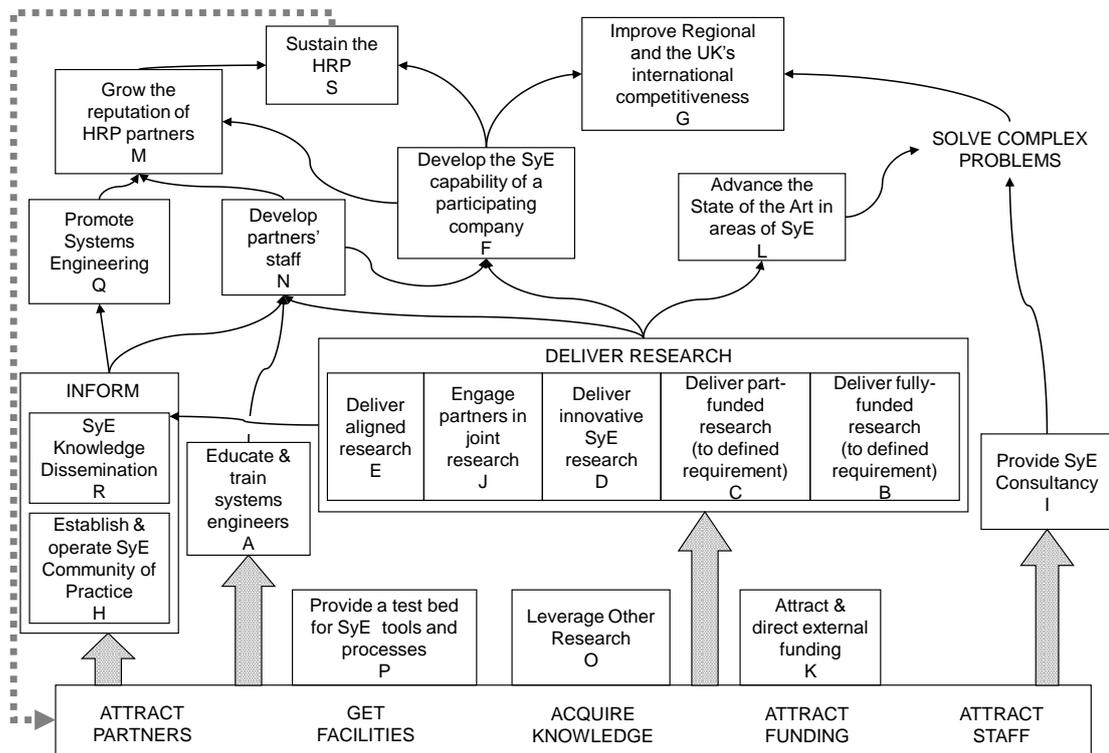


Figure 3.12 Hierarchical Conceptual Model

The second key model developed to support the HRP management in understanding the ‘situation of interest’ was a ‘Rich Picture’. The first step in this was to collate stakeholder responses to Checkland’s ‘CATWOE’ mnemonic: Customers, Actors, the Transformation, Weltanschauung, Owners and Environment. This immediately demonstrated that there was enormous breadth in perception, in particular regarding the HRP’s Customer(s) and Owner(s). The HRP was seen to have many purposes (illustrated by the nineteen conceptual models), often with different stakeholders for each. Based on this and the author’s own background

knowledge, a first draft ‘rich picture’ was constructed, and over a period of some six weeks this was reviewed and evolved in conjunction with eight key stakeholders: three from industry, three from academia and two from the HRP leadership. The final version of the model is shown in Figure 3.13. It illustrates the resources, activities and outputs of the HRP, and how these interact with, and are influenced by, the partners. Whilst the ‘clip-art’-based model does not fully meet Checkland’s preference for hand-drawn models to reflect uncertainty and transience, it responds to the cultural expectations of the target audience: in the 21st century, neither engineers, researchers nor senior managers in academia and industry relate readily to hand-drawn graphics.

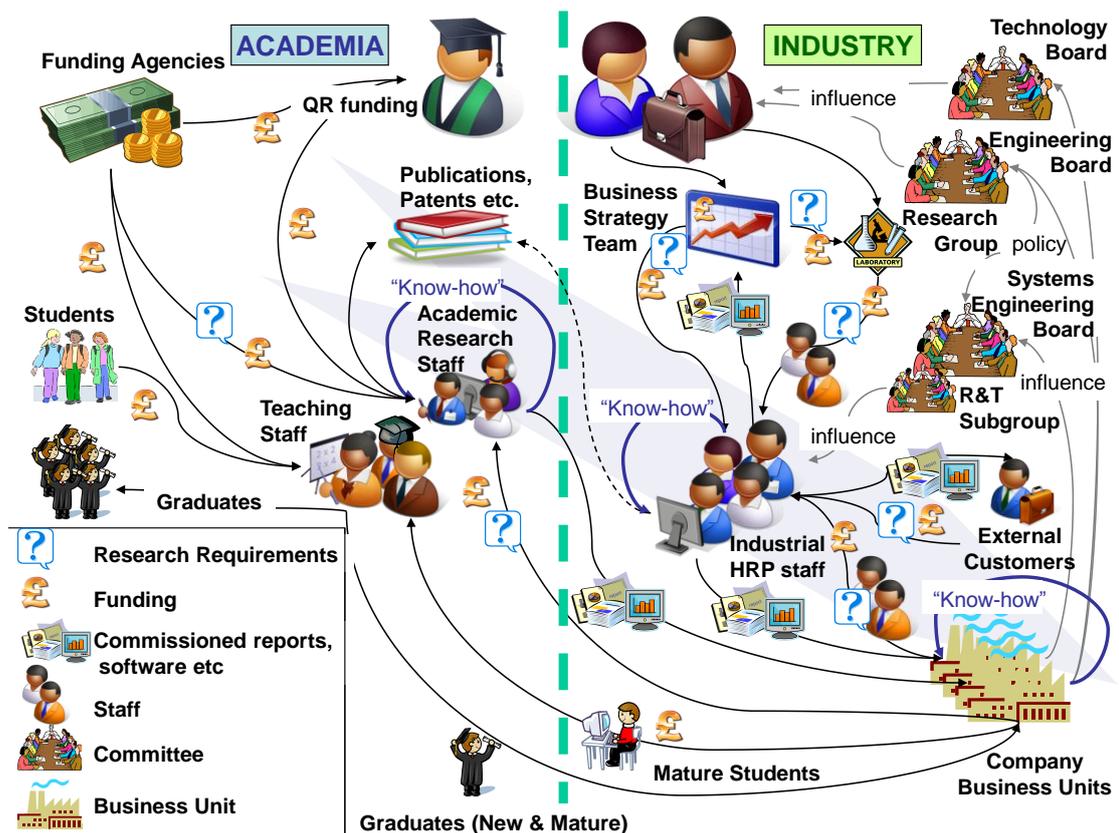


Figure 3.13 HRP “Rich Picture”

For the purpose of the analysis, it is important to note that the HRP was established as a partnership, rather than a separate legal entity such as a Joint Venture. Control of both strategy and operation was therefore

exercised through joint steering and management groups as illustrated in Figure 3.14, resulting in the part-time engagement of a broad body of stakeholders from both partners.

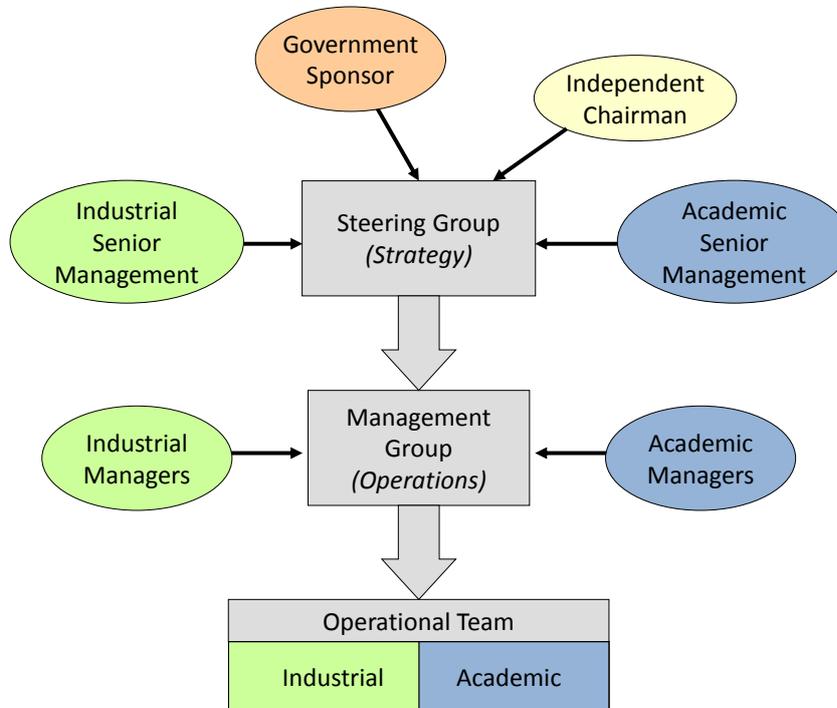


Figure 3.14 HRP Management Structure

It is notable that the formation of the HRP in this way enabled the boundary between each partner and the HRP to remain fuzzy, whilst the central division between the organisations was not. In effect, each half of the HRP acted as an open system with its parent organisation, with the attendant benefits of facilitating the resource flow into the HRP and broader access to resources, and drawbacks associated with lack of control (Dixon, Brown et al. 2007). In contrast, all the flows between the academic and industrial partner inevitably crossed a contractual boundary. This demanded that the partner interfaces were adequately defined, drawing on both hard systems concepts such as timing, format and technology standards as well as reflecting cultural norms. The impact on the HRP boundaries, interfaces and ways of working were identified as worthy of further study.

3.3.4.3 Debating the Situation

Throughout the model development process, opportunities were sought for review with key stakeholders, both academic and industrial. This was a critical part of the methodology, both ensuring that the validity of the models was explored and tested, and sustaining the stakeholder engagement as an essential element of the Action Research process. Recognising the risk that the lower number of responses might result in critical omissions from an academic perspective, this review and debate included a number of one-to-one interviews with the ‘missing’ key academic stakeholders in which draft models were reviewed and updated. This provided slightly more balance in the representation of responses between academia and industry, as illustrated in Figure 3.15

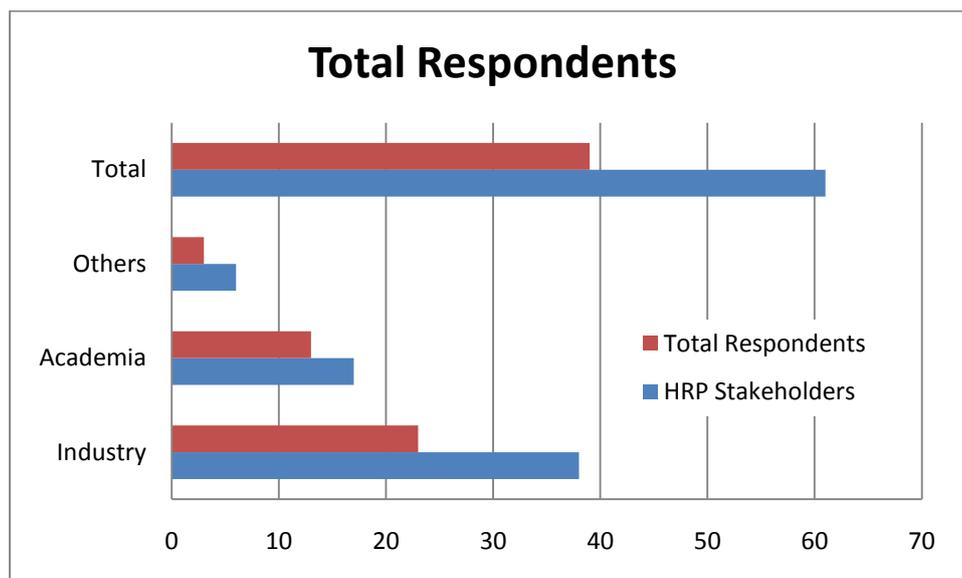


Figure 3.15 Questionnaire Responses

The original intent was for the author to lead further debate and analysis of the models within the strategic and operational management groups of the HRP. This would have enabled the different parties involved to develop a shared understanding of the key issues, reduce misunderstandings and differences in perception, and identify areas where there was opportunity for significant benefits. However, for a number of reasons, the opportunities for this did not materialise. In effect, this brought the Action Research activities

to an end before any actions which were traceable to the SSM process could be initiated.

3.3.5 Pilot Outcomes

In spite of the high level of support for developing the models and debating the situation on a one-to-one basis, the HRP participants were reluctant to engage en mass in a discussion of the models and what insights into the HRP they might provide. Various reasons were given or became apparent, including 'other priorities', the maturity and sensitivity of the relationship between the HRP partners, and contractual angst. Twelve months later, an independent review of the HRP's objectives unsurprisingly indicated that a number of issues were unresolved. At this point HRP leaders "backed away from" using SSM (Darbyshire 2008) and material from this study was not used.

This outcome is consistent with the view that SSM has "a limited domain of applicability. In particular, the kind of open, participative debate that is essential for the success of the soft systems approach, and can be the only justification for the recommendations that emerge, is impossible to obtain in problem situations where there is fundamental conflict between interest groups that have access to unequal power resources"(Jackson 1997, p358). In such situations, it is suggested that the SSM researcher either has to walk away or abandon their philosophical principles and accept that the proposed changes will emerge from limited debate and distorted communications. In this case the decision was made to step back, regroup, and seek an alternative approach better suited to the problem domain.

3.4 Evolution of Methodology

3.4.1 Learning from pilot and early field data collection

Evidence from the pilot study indicated that the action research approach was ineffective with this HRP, and was likely to face similar problems if used for other HRPs. The application of SSM in this context

- was time consuming and complex, because the problem was also complex
- highlighted a set of issues such as the concept of a lifecycle, which may be common to other similar partnerships
- exposed issues which were considered sensitive within the partnership and therefore which could not easily be openly discussed.

Participation in the meetings of the other HRPs illustrated that political issues were common and even objectives which were ostensibly 'shared' could be an uneasy compromise. Individuals and their relationships were highly influential in the direction and dynamics of the partnerships. Although some systems approaches were used, neither the pilot study nor the field data from the other three HRPs showed any significant evidence of the consistent and rigorous application of a systems engineering approach through the life of the HRP.

3.4.2 Three areas of study

In undertaking and subsequently reflecting upon the pilot study, it became clear that three key areas of study had emerged, as illustrated in Figure 3.16.

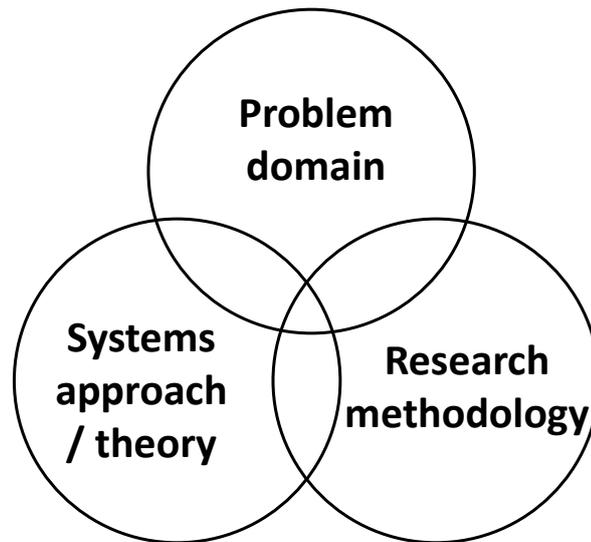


Figure 3.16 Three Key Areas of Study

These were the systems engineering approach that was adopted, the research methodology that was used, and the problem domain itself. It was apparent that each had its own body of knowledge and characteristics which was largely independent, but that any effective research ‘solution’ needed to integrate the three. Thus the systems theory and approach adopted should be consistent with the problem domain and context; the research methodology should be philosophically and practically consistent with the systems theory and the research output should be relevant and useful in the problem domain. Checkland’s use of action research to apply his SSM to deliver practical benefits to organisations is an example of this internal consistency which clearly produces results: however, it is conjectured that this principle applies much more broadly and indeed may benefit all systems engineering research (Valerdi, Brown et al. 2010).

3.4.3 Research Architecture

Three core ‘sub-systems’ of this research have now been identified: research context, systems approach and research methodology. Each of these is a distinct area where both background research and foreground data collection and analysis is required to ensure that the research addresses all the requirements. The functions identified in Chapter Two above, can then be

allocated to the three primary architectural areas for the research as shown in Table 3.2:

Table 3.2 Allocation of Research Functions

Research Function	Allocation		
	Context	Systems Approach	Research Methodology
Understand HRP context and operation	✓		
Link HRP context and operation to systems techniques	✓	✓	
Understand HRP lifecycle and link to systems techniques	✓	✓	
Create / interpret new knowledge	✓	✓	✓
Systematically acquire / understand knowledge	✓	✓	✓
Understand boundaries of SE discipline		✓	
Extend the SE discipline		✓	
Identify potential systems techniques		✓	
Develop SE techniques for SoS		✓	
Develop SE techniques for humans in the system		✓	
Apply SE to research design and content		✓	✓
Design research			✓
Design research to give initial insight beyond UK			✓
Understand research techniques			✓
Match research output to business need	✓		✓

3.4.4 Way forward

If continued, action research would have enabled actionable recommendations to be developed on the HRP in Case Study A, and would have supported the immediate implementation of actions, and their ongoing review and refinement. Although these actions would not be applicable to other HRPs, localised benefit within this case study could be expected. However, since the openness of the approach was in conflict with the HRP's norms and the ways of working within and between the partner organisations, it became clear that the significant political influences made it difficult for SSM to be carried through to 'action'. As a result, it was determined that an action research approach was unlikely to be effective in this context: not only within this HRP, but also in others like it.

The way forward was therefore determined to:

- Extend the literature review into the two functional areas (systems approach and research methodology) not yet addressed.
- Maximise the value of the pilot study by using it to identify concepts and subsequently develop models which may then be used to inform further research.
- Collect data from other case studies based on these ideas.

4 LITERATURE REVIEW

4.1 Introduction

4.1.1 Aims of this Chapter

The problem domain, systems engineering approach and research methodology have been identified as the three key themes or subsystems of this research. The literature review in Chapter One explored the problem domain by examining the context of HRPs in some detail: Chapter Three then looked at the limited amount of literature on HRPs themselves and touched on literature relating to Action Research in order to undertake the pilot study, which itself provided a better understanding of the application of systems engineering research to HRPs. In particular, it identified a number of issues associated with both applying systems engineering and conducting research in this environment. Chapter Four concludes the journey through the relevant extant literature by examining these two elements in greater breadth and depth in order to “develop sharper and more insightful questions” (Yin 2003) and support the development of both substantive models and a methodology for the main study. Based on the pilot study, some initial conclusions on the relevance and applicability of the literature are drawn.

4.2 Systems Engineering and adjacent theories

Many definitions of systems engineering exist, and these range from a narrow process description to the ‘exceedingly broad’, encompassing everything where it is possible to take a systems perspective in order to improve understanding. For the purpose of this literature review, the usual bounds of systems engineering have been ‘stretched’ in two ways: first, by extending backwards through the early ‘pre-engineering’ phases of the

system lifecycle, and second, by extending downwards from practice-based systems engineering into its science-based underpinnings.

No single view exists of 'relevant adjacent theories within the system lifecycle', but the representation developed by Arnold in his consideration of systems competencies is useful in this respect, using overlapping normal distribution curves to indicate in a stylised way the overlapping roles of business management, project management, systems engineering and specialist engineering disciplines (Arnold 2000). Specialist engineering is considered to be less relevant in the context of HRP development and has not been addressed within this literature review. For business management and project management, no attempt has been made to conduct an exhaustive review of these disciplines, but rather to focus on the identification of work in these areas which is relevant to systems engineering and in particular its application to HRPs. Perspectives which are addressed include technology management, project management, knowledge management and management science.

4.2.1 Process-based approaches from traditional SE

4.2.1.1 Introduction

Traditional systems engineering in aerospace and defence is predominantly process-based, aiming to provide assurance through consistency of approach. In most implementations, such as standards and corporate processes, the focus is on the systematic nature of the approach.

No attempt has been made to provide an exhaustive review of traditional systems engineering literature: there is a wealth of sources ranging from journal papers, conference proceedings, textbooks, standards, teaching material and so on. Cataloguing this body of knowledge is a major undertaking, and the subject of an international project due to deliver version 1.0 in 2012 (Systems Engineering Body of Knowledge 2011). A detailed examination of the material is not relevant to this research: across this body

of knowledge, principles remain largely the same, even where nomenclature may vary and nuances are introduced. The traditional systems engineering approach starts with the assumption that requirements can be elicited and used as the basis for system design. Whilst this approach is sound and proven for physical, electromechanical engineered systems, difficulties arise with complex systems where humans play a significant role.

Authoritative texts, which are representative of the substantial body of knowledge addressing the traditional systems engineering approach, include an international standard, two handbooks and a maturity model.

4.2.1.2 ISO/IEC 15288:2008

Widely adopted as the international standard for systems engineering processes, ISO/IEC 15288: 2008 is a generic process description for systems engineering. It identifies four process groups to support systems engineering: technical processes, project processes, agreement processes and organizational project-enabling processes (formerly known as enterprise processes in ISO/IEC 15288:2002 (*ISO/IEC 15288: 2002(E), Systems Engineering – System life cycle processes*. 2002)). The definitions and processes are intended to be applicable to the development of products and services across a wide range of application domains (*ISO/IEC 15288: 2008, Systems and software engineering – System life cycle processes*. 2008).

4.2.1.3 INCOSE Handbook

Currently issued as version 3.2, the INCOSE Systems Engineering Handbook provides “a description of key process activities performed by systems engineers”. Originally based on US-based standards, the material was fundamentally revised and reorganised in 2006 to align with ISO/IEC15288:2002, and again updated in January 2010 to bring it in line with the 2008 revision of that standard. Recognised globally as a guide to the implementation of ISO/IEC 15288, it is also the stand-alone reference

text for the INCOSE Certified Systems Engineering Professional examination (Krueger, Walden et al. 2010).

4.2.1.4 NASA Systems Engineering Handbook

First published in 1995 and significantly updated in 2007, the NASA Handbook became an early reference text for systems engineers worldwide. It describes systems engineering as a “methodical, disciplined approach for design, realisation, technical management, operations and retirement of a system” (*NASA Systems Engineering Handbook*. 2007). Within that system it includes elements such as people, facilities, policies and documents within the definition of all the things that are required to produce “system level results”. Moving away from the overly-simplistic ‘V’ model, it revolves around the concept, which is attributed to Jerry Lake, of an SE ‘engine’ which drives the process of successful systems engineering on a project (Forkosh 2010).

4.2.1.5 Capability Maturity Model Integration (CMMI®)

CMMI® is a process improvement approach which both acts as a point of reference for appraising current processes and helps to integrate traditionally separate organizational functions (Software Engineering Institute 2011b). Of the three model variants, the Development model is used most frequently in organizations applying systems engineering to product development. The model provides a collection of development best practices covering the lifecycle of products and services from conception through to delivery and maintenance (Software Engineering Institute 2011a) in a highly structured format. Each of the 22 process areas represents a cluster of related practices which collectively satisfy a set of goals to enable improvement in that area (Software Engineering Institute 2010).

CMMI® certification is frequently required of industry by government acquisition organisations. In effect, it demonstrates that the organisation not only has appropriate processes in place, but operates them with a high level of understanding and control. Whilst it is not suggested that HRPs should

seek such certification, these broad concepts may help to ensure that the HRP has all necessary processes in place, and has ways to understand and control critical functions.

4.2.1.6 The role of Systems Thinking

Whilst much of the emphasis of traditional systems engineering is on the systematic approach to product development, the second key element – systems thinking – should not be overlooked. It is this merger of systemic and systematic practices that lies at the heart of exemplary systems engineering.

Although evident among the early systems thought leaders, the balance of the approach moved in favour of process through the adoption of process-based standards such as IEEE1220 and EIA632, particularly in the USA. In the past 20 years however, there has been a gradual resurgence in the role of systems thinking in systems engineering, driven by a number of factors:

- Growth in international systems engineering participation from countries where the systemic aspects are culturally more important
- The recognition of problem classes which defy simple process application and demand that a more holistic approach is taken. This is true in a number of domains including military planning and defence system acquisition (Tibbitt 2008).
- Increasing activity in the advancement of systems engineering in areas other than 'process improvement'.
- The publication of seminal works on systems engineering application in management domains, such as *Systems Thinking*, *Systems Practice*, referred to earlier, (Checkland 1981) and *The Fifth Discipline* (Senge 1990).

Some of Senge's 'laws of systems engineering' are more focused on management problem solving than organisational design and operation.

However, key systemic issues from the perspective of HRP design are the need for the organisation to be self-sufficient and not rely on outside agencies for support, and the need to recognise the system boundary (which is unlikely to coincide with existing organisational boundaries)(Senge 1990).

Other authors have developed techniques such as Systemigrams (Boardman, Sherman et al. 1996) and the Rigorous Soft Method (Hitchins *undated*) to depict complex situations in a structured way to assist with understanding and analysis. More recently, the creation of the Conceptagon offers a way to balance our thinking about systems around seven triples:

- Boundary (Interior/Exterior)
- Harmony (Variety/Parsimony)
- Relationships (Wholes/Parts)
- Emergence (Hierarchy/Openness)
- Transformations (Inputs/Outputs)
- Function (Structure/Process)
- Communication (Command/Control) (Boardman 2010)

This return to an emphasis on the systemic is starting to be seen in other 'main stream' systems engineering publications. Originally released in 2005 in the UK and published internationally in 2010, the INCOSE UK Systems Engineering Competency Framework explicitly recognises the role of systems thinking in systems engineering, and whilst still heavily focused on the process aspects, also notes the need for an understanding of three overarching areas:

- Systems concepts – the application of the fundamental concepts of systems thinking, including understanding the system context, boundaries, interfaces and lifecycle.

- Super-system capability issues – an appreciation of the role the system plays in the “super-system” of which it is part.
- Enterprise and technology environment – understanding the definition, development and production of systems within an enterprise and technological environment. (INCOSE UK Systems Engineering Competencies Working Group 2010).

4.2.2 Theories and Approaches from Systems Science

Although systemic approaches are becoming re-established in systems engineering, it is nevertheless a pragmatic, practitioner-based discipline. From a research perspective, and in the growing number of areas of application which resist the successful implementation of simple process, there is much that can be learned from the domain of systems science which has evolved independently of systems engineering, and remains focused on the scientific integrity of the system concepts under investigation. This is not to suggest that systems science and systems engineering are independent: on the contrary systems engineering is founded on the principles of systems science. Nevertheless, for the purpose of this literature review the two *bodies of knowledge* are largely independent and have therefore been treated separately.

The ‘System of Systems Methodologies’ (SOSM) (a system of methodologies which are systems-based, and not to be confused with methodologies for SoS) is a valuable framework for understanding the applicability of systems approaches, developed by Jackson and Keys in 1984 (Jackson, Keys 1984) and subsequently extended by Jackson in later work (Jackson 2003). It considers systems as either simple or complex, and the participants with interest in the problem as unitary, pluralist or coercive, reflecting the degree of difference in their values, beliefs and interests and their subsequent ability to agree objectives. Using this framework, Jackson classified the suitability of systems approaches as follows:

- Simple/Unitary: Hard systems thinking, such as systems engineering, systems analysis and operations research.
- Complex/Unitary: System Dynamics (Forrester, Senge), Organizational Cybernetics (Beer), Complexity Theory (Stacey)
- Simple & Complex/Pluralist: Strategic Assumption Surfacing and Testing (Churchman, Mason, Mitroff), Interactive Planning (Ackoff), Soft Systems Methodology (Checkland)
- Simple/Coercive: Critical Systems Heuristics (Ulrich), Team Syntegrity (Beer)
- Complex/Coercive: Postmodern Systems Thinking (Taket & White)

Jackson reviews each approach in detail, addressing its history and theoretical underpinnings as well as its field of applicability before drawing together the key principles into the creative holistic framework of Critical Systems Practice (Jackson 2003). This framework presents generic functionalist, interpretive, emancipatory and postmodern methodologies which enable the user to draw upon the broad body of systems work in a way which is appropriately tailored to the systems problem at hand.

4.2.3 Technology Management

HRPs exist to conduct research within an environment intended to facilitate exploitation. As such, they can be an integral part of the technology management strategy of the organisations involved. Although it is unlikely that an HRP will have a technology management strategy independent of the partners, and equally unlikely that the partners will share the same technology management strategy (since they typically occupy different positions in the supply chain), the HRP can contribute to the technology management strategy of multiple partners simultaneously.

Roadmapping is recognised by Government and Industry as an important methodology and tool to promote technology development to meet future capability needs (Future Business Group 2006). The approach is very flexible and has a wide range of uses including product planning, service/capability planning, strategic planning, long-range planning, knowledge asset planning, programme planning, process planning and integration planning (Phaal, Farrukh et al. 2001). By enabling better communication, visibility and alignment of programmes it enables better decision making and helps deliver effective technology exploitation, acquisition and insertion. Enhanced communications are particularly noticeable across disparate teams and organisational boundaries (Future Business Group 2006), and across functional boundaries within an organisation (Phaal, Farrukh et al. 2001).

4.2.4 Project Management

HRPs are in effect projects. They have a (funding) start point, a (funded) duration and expected deliverables. However, whilst projects are typically centred around the core concepts of timescale, cost and quality, these concepts are less apparent in the fundamental characteristics of HRPs.

As with systems engineering, a large authoritative body of knowledge exists for project management, the essential core of which is captured within the Project Management Institute's Body of Knowledge (Project Management Institute (PMI) 2000). A review of this literature is similarly outside the scope of this research. In drawing upon this wider body of both academic and practitioner texts, Maylor notes that the main task of project management is to resolve conflict, working with fuzzy lines of authority, in order to achieve the project goals (Maylor 2005). However, although he presents processes and case studies for the four stages of project definition, project process design, project delivery and subsequent process development, the specific approaches to conflict resolution are unclear. The 7-S framework, originally promoted by McKinsey and Co., is offered as a way to identify and classify

the issues that need to be considered: strategy, structure, systems, staff, skills, style/culture and stakeholders.

Project management and systems engineering are essential and complementary methodologies for a successful project. Although the focus is different (cost/schedule and technical respectively), they share similar processes, tools, techniques and competencies (Brown 2007c). However, a fundamental tenet of project management is the assumption that the goals can be defined and agreed: the process is then one of overseeing change and managing individual stakeholders in order to achieve those goals. In contrast, evidence from the pilot study suggests that HRPs cannot be effectively managed unless the stakeholder needs are integrated. Whilst some project processes (such as human resource management and cost management) will be effective in supporting HRP establishment and operation, this effectiveness is likely to be limited in areas of uncertainty and conflict.

4.2.5 Management Science

A broad review of management science literature has not been conducted. However, management science themes which are applicable to HRPs include strategic management, leadership and motivation, change management and organisational design. These bodies of knowledge offer theoretical principles which may inform the design, implementation and operation of HRPs and enable a systems approach to be derived which benefits from earlier work in these disciplines.

4.2.5.1 Strategic Management

Maitlis and Lawrence conducted an intensive, inductive, real-time, longitudinal field study of decision making in an orchestra, involving the qualitative analysis of a range of data. Their work considers the roles of individuals and groups and how they affect the ability of the organisation to determine direction and pursue it. Although the language used is that of the

management discipline, the principles can be readily translated to the concept of HRPs and their stakeholders.

By analysing “the micro-level processes and practices involved as organisational members work to construct and enact organisational strategies, through both formal and informal means” (Maitlis, Lawrence 2003, p111), they propose that episodes of strategising are likely to fail when:

- key actors do not interpret issue as relevant to their situation and as having the potential to further their own interests
- the issue is not interpreted and labelled in a way that is legitimate within the existing organisational discourse
- organisational politics preclude agreement on the definition of the concept, and there exists no actor powerful enough to impose a definition
- the pre-existing discursive resources of key actors are highly incompatible (i.e. they don't speak the same 'language')
- organisational politics do not allow for the assignment of responsibility and accountability in a way that benefits key actors
- the concept definition is highly complex and internally inconsistent
- key actors lack political skill or domain-specific expertise
- the strategic concepts are defined in terms of the organisation's weaknesses rather than its strengths (which parallels Senge's concerns regarding the effect of negative visions (Senge 1990)).

4.2.5.2 Leadership and Motivation

In his research on leadership, Adair noted that there were three interrelated but distinctive sets of needs which must be met: those of the task, the team

and the individual (Adair 1983). Looking beyond leadership itself, it is clear that all three aspects are relevant in any project and must be addressed in order for the project to succeed, and that an excessive focus on any one or two aspects will affect performance. Likewise, in establishing an HRP it is important that these are considered in a balanced way and provision made for all three sets of needs to be met. This must go beyond the 'project management' approach which typically focuses on the task, with the team and individuals treated largely as resources. Within the HRP, individual motivation is likely to be a significant factor and it is appropriate to reflect upon the implications for the diverse participant groups of motivation theories such as:

- Maslow's hierarchy of needs (Maslow 1943),
- Alderfer's hierarchy of needs (Alderfer 1969),
- Herzberg's satisfaction/dissatisfaction theory (Herzberg 1968)
- theories based on expectancy, instrumentality and valence (Vroom 1964),(Lawler, Porter 1968).

Job characteristics such as variety, autonomy, responsibility, challenge, interaction, task significance, goals and feedback all have motivational properties (Torrington, Hall 1991). Whilst the creation of an HRP may provide opportunities here, the potential for the absence of these characteristics to cause dissatisfaction (Herzberg 1968) when compared to existing norms in the partner organisations is also a significant risk.

4.2.5.3 Change Management

The creation of an HRP is, in itself, a change process. It requires that individuals do different work, or work with different people, or conduct that work in a different location or a different way in order to get the benefits associated with the partnership. As a result, change theory applies – in terms of the both perceptions of the impact on each participant as an

individual, and in terms of their perceptions of the effects of possible responses. In addition to the details of the change itself, personal, group and organisational factors will influence behaviour (Bowman, Asch 1987), and these will vary across the range of participants depending on their own experiences and the norms within the different partner organisations. Strategies of participation, education and communication, negotiation and power may be used to drive the implementation, and these will need to be tailored for the different groups.

4.2.5.4 Organisational design

In his work on organisation design, Child explores the challenge of defining 'good performance' and notes that issues include:

- how to weight different success criteria
- the quality of goal setting, both in terms of content and the target level of performance
- the organizational constituencies or stakeholder groups, including managers, employees and the community.
- the timespan over which performance is sought: balancing short- and long-term objectives (Child 1984).

Whilst these are issues in any organization, it is clear that within an HRP they are particularly important, since the challenge is likely to be exacerbated by the diversity of the partners. He further notes that managerial preference and market conditions will affect the organizational design (Child 1984). In the HRP context, managerial preference is likely to differ significantly between the partners and may be a source of tension and conflict; whilst the market conditions will depend upon the reputation of the partners and the resultant pressure upon the partnership for early successes to gain acceptance.

4.2.6 Knowledge Management

Since “research is about generating knowledge” (Lee, Lings 2008, p6), organisations and partnerships established to conduct research are, by definition, undertaking a form of knowledge management (KM). There are seven distinct KM processes (Brown, Ragsdell 2009):

1. Knowledge Identification: identifying both knowledge needs and sources;
2. Knowledge Generation: gathering together documents, people, resources and previous knowledge to generate required knowledge.
3. Knowledge Elaboration: ordering and refining new knowledge by testing, analysis and indexing to “assess knowledge relevance, value and accuracy” (Liebowitz 1999, p37).
4. Knowledge Preservation: storing explicit knowledge in both electronic and paper form; and preserving tacit knowledge through mentoring, apprenticeships and socialisation.
5. Knowledge Mobilization/Sharing: making knowledge available in various forms and across the organisation, including socialisation through communities of practice and professional training.
6. Knowledge Presentation: presenting the knowledge in a suitable form for it be understood and utilized, perhaps in training or to support.
7. Knowledge Evaluation: assessing the use, organizational value and personal value of the knowledge in order to inform Knowledge Identification (Brown, Ragsdell 2009).

In the context of an HRP, all seven processes are relevant although they may be undertaken by different parts of the partnership and in different parts of the research lifecycle as indicated in Table 4.1.

Table 4.1 Knowledge Management Processes

Planning processes	Research processes	Exploitation processes
Evaluation Identification	Generation Elaboration Preservation	Mobilisation / Sharing Presentation

Those involved in HRPs are responsible for the implementation and operation of a knowledge management system: a complex socio-technical construct which integrates elements of people, process, technology, information and infrastructure within the multi-organisational environment. This has implications for the technology needs of HRPs: “optimal communication and knowledge flow between intra and inter-organizational partners can be *supported* by information technologies, but it is not *assured* by them” (Balthazard, Cooke 2004, p.1, emphasis in original text). It is clear that whilst technology may have an enormous role to play in the movement of knowledge, the ease or difficulty with which this is achieved is largely a factor of social context (Brown, Duguid 1998). The performance of the HRP as a knowledge management system cannot be reduced to the ‘sum of individual component performances’, but is an emergent property of the HRP as a whole.

The issue of culture, and indeed different cultures, within the HRP is important to its effectiveness as a knowledge management system. “In many organizations, especially bureaucratic ones, employees and managers are discouraged from sharing knowledge and expertise” (Liebowitz 1999, p40). In such organisational cultures, knowledge is seen as power, and protectionist practices may be expected. Where there is a culture of competitiveness between employees, strict hierarchies and adherence to rules and formal procedures, knowledge sharing may be difficult to initiate and support. The ‘knowledge transfer distance’ (which may, for example, be

physical, temporal or intellectual) between individuals and groups within the HRP will further impact the ease of knowledge sharing (Brown, Ragsdell 2009). As Swan et al stress, “people-management issues do indeed pose critical constraints on knowledge-sharing” (Swan, Robertson et al. 2002, p185). Such constraints may have a significant impact on overall HRP performance, unless structures and reward systems are carefully designed and take into account the different cultures of the partners.

According to Oliver and Kandadi, there are ten important factors in the creation of an effective ‘knowledge culture’ in organisations: leadership, organisational structure, evangelization, communities of practice, reward systems, time allocation, business processes, recruitment, infrastructure and physical attributes (Oliver, Kandadi 2006). These are a mixture of people and technology issues, but all have implications for the way in which HRPs are established and operated. Dixon et al note that different approaches to developing the enterprise impact the social and structural capital which is developed, in both the short and longer term (Dixon, Brown et al. 2007). By responding to the social as well as individual context, and using technology to support informal interaction, facilitate global reach and reciprocity, it is possible to enhance organisational performance and engender interactivity, participation and learning. However, approaches to access and reciprocity remain complex socio-technical issues (Brown, Duguid 1998).

4.3 Research Methodology

If systems engineering aspires to the status of a serious scholarly discipline “it will have to show that within the subject there is a cycle of interaction between the formulation of theory relevant to serious problems or concerns, and the testing of that theory by the application of methodology appropriate to the subject matter...[I]t will lead to ideas from which we can formulate two kinds of theory, substantive theories about the subject matter ... and methodological theories concerning how to go about investigating the subject matter.” (Checkland 1981, p7).

Choice of methodology affects not only the way in which the research is conducted, but also:

- the way in which the data are analysed
- the way in which validity is demonstrated
- the type of knowledge contribution that can legitimately be claimed
- the applicability of that knowledge to other contexts

4.3.1 Principles

No attempt is made here to conduct a comprehensive review of literature pertaining to research philosophy and methodology: such a study is well beyond the scope of this research. Nevertheless, it is appropriate to establish a basic framework of principles underpinning the selection of research methodology in order to identify relevant literature and thence choose, with the necessary justification, an appropriate methodology for the main study. This section draws primarily from Lee and Lings to identify the main concepts and issues to be considered (Lee, Lings 2008).

4.3.1.1 Scientific Theory and Methodology

Most engineers and scientists are raised on the principles of scientific theory: theories which are based on natural laws and empirically testable, but which remain tentative: for however much supporting evidence is collected, a single piece of contrary evidence disproves the theory. Although this is often loosely referred to as positivism, realism is a more accurate descriptor in most cases since it extends beyond strict positivist beliefs to accept things which are not directly measurable: something which is necessary even for theories of particle physics (Lee, Lings 2008).

Realist research will typically follow the Hypothetico-deductive method illustrated in Figure 4.1.

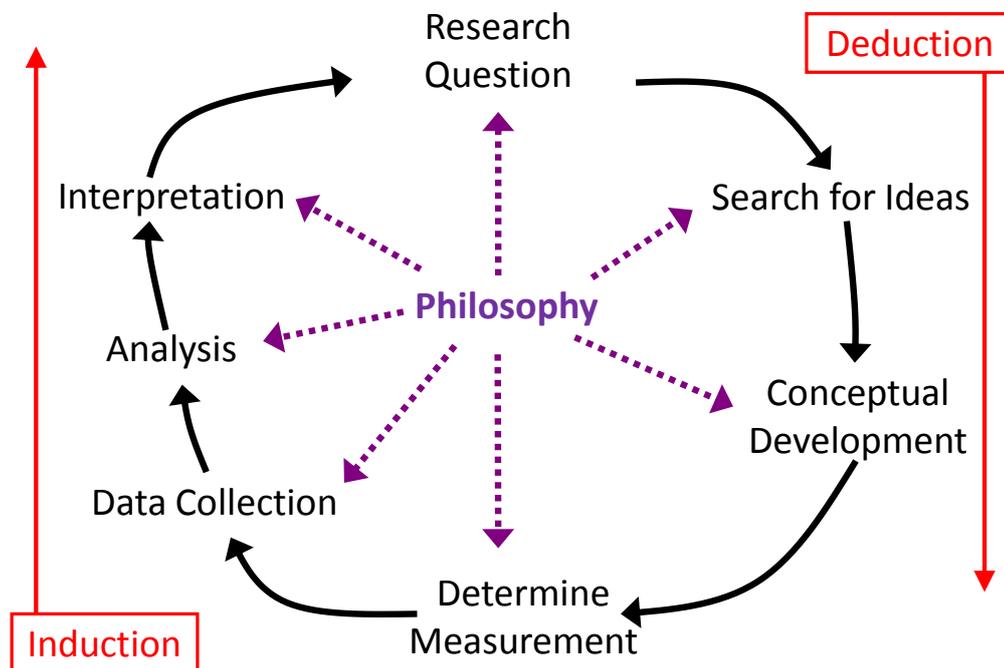


Figure 4.1 Hypothetico-deductive Method

The research hypothesis is founded on theory, and data is sought to support or disprove it. In effect, it is a search for ‘the truth’, based on the assumption that the truth is ‘out there’ simply waiting to be discovered. The hypothesis is either true, or it is not. The supporting scientific methodology focuses on the repeatable: the same chemicals, under the same conditions, will react the same way, no matter where or when the experiment is conducted. Any differences are explained by errors: unplanned changes to the input parameters, or inaccuracies introduced by the researcher or the equipment.

A potential concern, identified in a paper on Work and Organizational Psychology, but equally applicable to systems engineering, is that researchers with a scientific or engineering background do not make a conscious choice to adopt realism as the basis of their research, but that it is simply the default option: the approach is seen to be simply ‘research’ rather than one of many possible approaches to research, and accordingly researchers do not feel the need to spell out their assumptions because it is accepted practice (Symon, Cassell 2006).

The issue is not simply procedural, since “to work within the positivist systems paradigm is not simply to hold a belief in objectivity, a correspondence theory of truth and an ontology of precise facts; it is also a disposition to seek quantifiable variables in a practical situation, to reach for modelling tools, to seek work where such traits find a congenial home, and to communicate with others who do the same”(Spaul 1997, p327). It is, for many, an unconsciously adopted way of life rather than a deliberate choice in research design.

4.3.1.2 Interpretivism

In dealing with social sciences, including the science of socio-technical systems in which humans play an equal or greater role than engineered artefacts, the assumptions underpinning realist research may be challenged. Although the early work on socio-technical systems still took a realist approach, pioneered by the Tavistock Institute in the 1950s, this appears to reflect the heritage of work design (Eason 2006) and a domain of relatively simple, stable organisational systems. As systems become more complex and interconnected, ‘right’ and ‘wrong’ solutions can no longer be defined in terms of natural laws. Different people will make different interpretations and take different decisions at different times: they are not repeatable like a chemistry experiment. Making sense of these systems requires a different approach.

Interpretivism is taken to denote an alternative to positivism or realism which is predicated on the view that the subjective meaning of social interactions is an important differentiator between studying people and the objects which are studied in the natural sciences. Interpretivist research is essentially an inductive process in which theory is generated from data. It seeks not to explain, but merely to understand. Furthermore, understanding itself is transitory and linked to context: knowledge is primarily descriptive and immersion in the context itself is necessary to understanding. (Lee, Lings 2008).

4.3.2 Implications of Philosophy on Methodology Selection

It is common to relate realist and interpretivist research to quantitative and qualitative methods respectively. Whilst this may be broadly correct, it is by no means true in all cases. In general, interpretive approaches avoid quantitative techniques for a number of philosophically-driven reasons:

- When quantifying data, it is mapped to the researcher's perspective rather than preserving the perspective of the individual participants.
- Quantification loses the nuances of language and meaning which are present in interviews and observation
- In order to do quantitative research, the theory must precede the data such that key aspects can be quantified (Lee, Lings 2008).

In contrast, the main preoccupations of qualitative research are:

- Seeing through the eyes of the people being studied, and attributing meaning to events
- Description, and the emphasis on contextual meaning
- Emphasis on process
- Flexibility and limited structure
- Concepts and theory grounded in data

However, interpretive research is not synonymous with qualitative data collection. Statistical data, for example, is often used; and in interpreting the transcripts of interviews the frequency of occurrence may also be analysed. However, the main preoccupations of quantitative research – Measurement, Causality, Generalisation and Replication – remain fundamentally at odds with the interpretivist paradigm.

Equally, positivist or realist research is not completely dependent on quantitative data, and the researcher's natural bias and perspective may drive realist research where quantitative data is inappropriate or unobtainable. This approach, known as Imperialism, "represents a fundamental commitment to one epistemological position but a willingness to incorporate other strands of management science if they seem to be useful"(Jackson 1997, p351). In the area of organizational research, it is suggested that 'qualitative positivism' is more common than qualitative research informed by other epistemological perspectives (Prasad, Prasad 2002). The real challenge here is to avoid slipping into atheoretical pragmatism by combining opposing theories, although pragmatists would argue that any theoretical distinction is artificial (Jackson 1997).

4.3.3 Validity Principles

In research where the methodology is not explicit and 'what counts as knowledge' is not declared, it is difficult to either challenge or defend the validity of the approach other than through the 'reasonableness' of the results. However, validity is a major – but as yet largely unrecognised – issue for systems engineering research.

In quantitative research, key issues are:

- **Reliability:** the consistency of a measure of a concept, in terms of its variation over time (stability), relationship to other measures (internal reliability) and reliance on a particular observer (inter-observer consistency).
- **Measurement validity:** whether the measure of a concept really measures that concept, not only intuitively (face validity) but also based on known data (concurrent validity), future expectations (predictive validity), a theoretical relationship (construct validity) and comparison with other sources (convergent validity).

- Internal validity: the validity of the apparent causal relationship between dependent and independent variables, i.e. that the independent variable is at least in part responsible for the variation in the dependent variable.
- External validity: whether the results can be generalised beyond the specific research context
- Ecological validity: whether the findings obtained under study conditions have relevance in a natural setting (Bryman, Bell 2003).

In qualitative research, alternative measures are used to avoid the presupposition that a single absolute account of social reality is feasible. Lincoln and Guba propose two primary concepts:

- Trustworthiness, which is made up of four criteria which paralleling the equivalent criteria (in parentheses) in quantitative research:
 - Credibility (internal validity)
 - Transferability (external validity)
 - Dependability (reliability)
 - Confirmability (objectivity)
- Authenticity, which addresses the wider political impact through five criteria:
 - Fairness: whether the research represents different viewpoints
 - Ontological authenticity: whether the research helps members arrive at a better understanding of their situation
 - Educative authenticity: whether the research helps members arrive at a better appreciation of the perspectives of other members

- Catalytic authenticity: whether the research has acted as a catalyst for engagement in change
- Tactical authenticity: whether the research has empowered members to take action (Lincoln, Guba 2002, p588).

4.3.4 Systems Engineering Research Methodologies

Having highlighted the basic principles of research methodology to be considered, consideration now moves to extant approaches, starting with those in systems engineering itself. Although methodology should be a primary consideration in the early stages of any research program, evidence suggests that this is often not the case. For systems engineering research in particular, it is quite common for it to be treated as an afterthought or – worse – ignored completely. Expected publication venues for systems engineering research have been reviewed and found to be lacking in methodological rigour.

4.3.4.1 *Systems Engineering*, the Journal of the International Council on Systems Engineering

Papers published in *Systems Engineering* generally address the application of systems engineering and describe the processes or methods used in its application, rather than the overarching methodology which underpins the work. This appears to reflect the background and interests of the readership, leading to substantive advances in the discipline.

According to the Editor-in Chief (Sage 19 January 2010)

“Systems Engineering research is an extraordinarily broad subject, in that one can do research into any of the many systems engineering subject areas and professional practice areas. Certainly we are interested in systems engineering research and SSE research methodologies for the journal. As a society with a majority of members who are industrial or government practitioners and not academics, it is not unreasonable that the majority of

papers published in the journal of the society would not be research papers per se. But certainly we are interested in and do publish papers that make a valuable contribution to Systems Engineering Research.”

Nevertheless, this practical approach does not demand that those papers demonstrate methodological rigour.

4.3.4.2 Conference on Systems Engineering Research

The Conference on Systems Engineering Research (CSER) is an international annual conference organised and hosted by leading universities in the field of systems engineering research and attracting largely academic participation. A detailed review of the papers presented to CSER in 2008 and 2009 revealed that only a small percentage of papers explicitly addressed issues of research methodology, as follows:

- In their paper exploring systems thinking as an emergent property of teams, Lamb et al. follow the practices outlined by (Valerdi, Davidz 2007) for empirical research in systems engineering. In establishing an exploratory research framework based on grounded theory techniques they are guided by literature on team cognition, team-based design thinking, team theory, and organizational culture (Lamb, Nightingale et al. 2008).
- In developing a framework to boost the systems capability of small and medium-sized defence contractors in Australia, Tran and Huynh also selected a grounded theory approach to provide a methodology for generating theory directly from the analysis of their unstructured data sources, such as case study reports and interview transcripts (Tran, Huynh 2008).
- In contrast, Berglund and Malmgren’s retrospective analysis of the requirements management in the design of a medium sized tanker adopts a qualitative, “value-laden systems approach”, again drawing data from multiple information sources. However, they recognise that this approach causes difficulties in the generalisation of the findings and emphasise their intention to present experiences instead (Berglund, Malmgren 2008).

- Taking a different approach altogether, Ferris proposes that engineering design can be considered to be systems engineering research when it is performed in a situation of considerable complexity and lack of clarity of objectives (Ferris, Cook et al. 2008).
- Rowell et al use a case study approach, analysing historical data in order to look for trends in the nature of engineering change within a complex product development cycle (Rowell, Duffy et al. 2009). They explicitly adopt a positivist philosophical stance, analysing data without the knowledge of those creating it in order to remain “unbiased”.
- Soares and Vrancken adopt a methodology which is “inspired by Action Research”, working with practitioners “in order to apply the developed theories and test them in practice”, leading to successful pilot application and changes to working practices.(Soares, Vrancken 2009)
- Broniatowski et al draw strongly on theories and approaches from mathematics, psychology, medicine and behavioural science to derive their methodology to study decision making in committees of technical experts. They use a quantitative approach to analyse the strength of social networks through the analysis of meeting transcripts, with the intention of producing generalizable findings and developing theory.(Broniatowski, Magee et al. 2009)
- Gill’s analysis of “systems people” in a research organisation formally adopts an interpretative (ethnomethodological) approach based on Grounded Theory (Gill 2009).

Lack of discipline in terminology is a common problem, with many researchers failing to underpin their substantive content with methodological clarity, explicit description and rigour, and others using the terms ‘method’ and ‘methodology’ interchangeably to refer to the procedure followed (Brown 2009). This makes it difficult to (1) compare research results across studies, (2) communicate results to sponsors, and (3) share results with other disciplines. However, if advances are to be made in SE research methodology, it is necessary to clearly define the two and to respect those

definitions. Over the past 5 years a small minority of authors have started to recognise the importance of explicitly identifying methodological options for systems engineering research. In some cases this has resulted in an overview of research methods (Cropley, Harris 2007), or the classification of research approaches based on a formal taxonomy (Ferris 2009); a smaller subset has addressed the more challenging issue faced here: that of selecting and implementing a research strategy appropriate to the systems engineering research study being undertaken.

4.3.4.3 Contemporary Systems Engineering Research Approaches

It has been proposed that in systems engineering research, where the researcher is typically interested in contemporary events over which he has no control and where research questions might be of the form “How?” and “Why?”, then a case study approach is advised (Sage, Friedman 2004), (Martin, Davidz 2007). These papers give thorough consideration to issues of validity, drawing heavily from Yin in this area. Yin himself notes that case studies are preferred when examining contemporary events, when relevant behaviours cannot be manipulated. Case studies rely on primary documents, secondary documents, cultural and physical artefacts as well as direct observation of events and interviews of the persons involved (Yin 2003). Yin notes that case studies were traditionally viewed as a ‘less desirable’ strategy, often because of the lack of rigour by investigators. He stresses that every investigator should endeavour to report all evidence fairly and emphasises that “case studies, like experiments, are generalizable to theoretical propositions and not to populations or universes”. Thus a case study does not represent a sample: rather, the goal is to expand and generalize theories (analytic generalization) and not to enumerate frequencies (statistical generalization) (Yin 2003).

One problem that remains is that many systems engineering researchers do not have the necessary methodological knowledge to tackle social research and most systems engineering research programmes do not provide this

training (Valerdi, Davidz 2007; Valerdi, Davidz 2009; Brown 2009). As a consequence, those researchers who tackle the issue are often self-taught and this can lead to misinterpretations which may not be spotted by peer reviewers who themselves lack the same training. A common flaw is the confusion between the functionalist or positivist and interpretive paradigms, and the use of quantitative and qualitative methods, with a number of authors (for example (Valerdi, Davidz 2007; Copley, Harris 2007)), wrongly suggesting that non-positivist research is *synonymous* with qualitative research (Symon, Cassell 2006). Nevertheless, for the blind to lead the blind and open the debate on this issue is better than for the discipline to stand still (Brown 2009). In essence, the plea is for systems engineering researchers to take not only their systems engineering but also their research methodology seriously, to seek real data even when this is difficult to obtain, and to address issues of validity in their work (Valerdi, Davidz 2009).

4.3.4.4 Research Methodologies in the broader Systems discipline

The broader discipline of general systems research provides a much more extensive body of knowledge and notably extends into the same management domains now being explored from a systems engineering viewpoint. In stark contrast to systems engineering research, the philosophical and theoretical foundations of systems research are both clear and precise. Much of the groundwork was laid between the 1970s and early 1990s with seminal contributions from leading contributors (such as Ackoff, Beer, Checkland, Churchman, Flood, Habermas, Jackson, Keys, Mingers and Mitroff) extending across the spectrum from functionalist 'hard systems' thinking to emancipatory and postmodern approaches. An excellent overview of this is provided by Jackson which addresses not only the systems aspects but also the philosophical constructs upon which the methodologies are based (Jackson 2003). Later works have attempted to address questions of pluralism at various levels from methods to paradigms, in effect drawing together the philosophical and theoretical bases to challenge the need for the atheoretical pragmatic approach which

characterises the majority of systems engineering studies (see Jackson 2003; Mingers, Gill 1997; Flood, Jackson 1991). Multi-methodological approaches are supported by Jackson's concept of generic methodologies reflecting the four major ontological stances (functionalist, interpretive, emancipatory and postmodern) (Jackson 2003).

Thus the 'critical systems thinkers', rather than guiding the researcher towards a particular preferred research design, opens up a world of possibilities with remarkably little constraint as long as there is clarity in the ontological stance that is taken. Their emphasis is to "develop methodological pluralism in a theoretically informed manner" (Midgley 1997, p250), and as a result they are "in advance of organisation theory in working out the implications of pluralism for those who wish to actually intervene in problem situations"(Jackson 1997, p366). Furthermore, this approach offers the theoretical basis lacked by the applied disciplines such as information systems, operations research, evaluation research, management consultancy (Jackson 1997) and, it is suggested, systems engineering.

4.3.4.5 From method to methodology

"The distinction between methodology and methods is crucial here. Methodology is a higher order term that refers to the logical principles that must govern the use of methods in order that the philosophy/theory embraced by the approach is properly respected and appropriately put into practice. Methodology is not detachable from the philosophy/theory of the particular systems approach, or, therefore, from the approach itself. Methods, however, concerned as they are with achieving more specific procedural outcomes, are detachable and can be used in the service of other systems approaches with varying degrees of success and failure"(Jackson 2003, p43).

For example, methodology can be the holistic systems thinking approach that many systems engineering researchers employ. On the other hand, method refers to the specific approach taken by the researcher such as the

measurement instruments, the (statistical) analysis techniques or the modelling techniques that the researcher may choose to apply. Both methodology and method are important but it is often the case that method is the primary consideration in systems engineering researcher. This may derive from an early age, when as students of science they learned to describe the method used when undertaking an experiment in the laboratory. As they progressed, they would refer to the physical law or chemical process under observation as the 'theory', applying different 'laws' or equations to different parts of the experiment. Although too seldom discussed in its own right, the overarching scientific methodology guides the collection of empirical data under appropriately controlled conditions and the use of those observations to reinforce or falsify the theory. For many scientists, and those who subsequently become engineers, the assumptions of the scientific methodology are so embedded in practice that they have become virtually invisible.

This distinction is considered critical within the systems science community. From Flood's perspective, method and methodology are separable, but the *principles* of the methodology remain key. As long as the researcher complies with those principles then any method or combination of methods may be used (Flood 1995). As a result, it is argued that the link between methodology and the methods, tools and techniques normally associated with it can be relaxed, but clarity regarding the paradigm which is being served must be retained (Jackson 1997). Ultimately, "what is done will be both user-dependent and situation-dependent but should embody the principles of the methodology"(Checkland 2008). For systems problems, quantitative modelling methods may provide useful answers "when there is genuine agreement on the nature of the problem"(Midgley 1997, p253). In contrast, debating methods can be useful for qualitative research, supporting the development of mutual understanding and enabling decision making in situations where there is open disagreement, but that does not imply that they are universally applicable. In coercive contexts, where an uneven

balance of power exists, they are likely to be ineffective as disagreements are difficult to bring out into the open (Midgley 1997).

4.3.4.6 From methodology to multimethodology

“Systems practitioners must be allowed the greatest freedom possible, within pluralism, to tailor their use of methods, tools and techniques (just as with methodologies) to the complexities of the problem situation they are seeking to intervene in and the exigencies of that situation as it changes during the intervention”(Jackson 1997, p369).

However, properly-founded multi-methodological approaches are likely to be particularly demanding for those involved. As a result of their organization-based Action Research, Carrizosa and Ortegón noted that the use of methodologies rooted in different paradigms in the same intervention relied upon the methodological competence of those involved, and that in order to manage the incompatibility between paradigms, they needed many forms of representation including symbols, analogies, images, ‘espoused’ and ‘in use’ theories, models and metaphors (Carrizosa, Ortegón 2007). This is a significant potential constraint on the research methodology and is consistent with the experience of the pilot study, where unfamiliar methods were branded ‘too complex’ by stakeholders, and limited their willingness to actively participate in the action research approach.

Mingers suggests that since all problem situations are complex and multi-dimensional, analysing a problem situation from a single perspective or paradigm will always ignore important aspects from other paradigms, and so a range of methodologies should always be used. However, for researchers, the cultural and cognitive feasibility of working with several paradigms and switching between them must be considered. This applies both at an individual level, and in the context of organisational culture and norms (Mingers 1997). For the researcher to be able to tolerate different methods and appreciate the resulting divergent conclusions requires the adaptability of

a methodological chameleon, with a daunting array of skills and attitudes (Jackson 1997).

4.3.4.7 Multimethodology vs Atheoretical Pragmatism

Systems engineering research lacks both fundamental systems engineering theories and an overarching methodology for the discipline. As a result, much existing systems engineering research has followed an approach best described as 'atheoretical pragmatism', combining techniques from different strands of management science and systems practice to build up a tool kit through a process of trial and error, but drawing superficially (if at all) from any recognisable theoretical position (Midgley 1997). The methods used for data collection and analysis, whilst potentially valid in their own right, lack any formal connection to the knowledge which the researcher believes may be derived from the work, but are justified purely on the basis of results achieved (Midgley 1997).

Although methodological pluralism and atheoretical pragmatism are superficially similar in that both aim to develop a "flexible and responsive practice of intervention"(p251), critical systems thinkers criticise this approach on a number of grounds:

- This 'trial and error' approach requires costly and extensive social experimentation: without theory there is no mechanism to understand why methods sometimes work, and sometimes do not.
- Pragmatists lack a "common theoretical language" through which to communicate and share learning (Midgley 1997, p251). The lack of an explicit theoretical underpinning to pluralistic practice results in strong experiences but weak publications, and provides no basis upon which consultants, academics and students can learn (Jackson 1997).
- Solutions which appear to be effective in the short term may in fact have negative longer term consequences, but there is no common way to express 'success'.

- Methods often work because they reinforce the position of those in power and are therefore supported, which may lead the researcher to become an unwitting accomplice to maintaining the status quo. (Midgley 1997)

4.3.4.8 Incommensurability

All systems methodologies – and all research methodologies - make different philosophical and theoretical assumptions. In order to mix them or combine them in a framework, this has to be justified at a philosophical level. Some authors claim that this cannot be done (Lee, Lings 2008): that the paradigms themselves are “irrevocably incommensurable”(Midgley 1997, p256). Others suggest that the paradigm gap can be bridged by rational analysis, or at least that communication between paradigms is possible even if unification is infeasible and undesirable.

However, any attempt to connect methodologies across paradigms inevitably requires that assumptions are made which other methodologists may disagree with. There is no position which is outside of the paradigm debate from which to argue this point (Midgley 1997), and it is somewhat contradictory to suggest a high level position with no ontological or epistemological claims of its own, which can somehow tolerate competing assumptions in lower-level paradigms (Mingers 1997).

4.4 Summary

The literature review has identified a paucity of published research literature specifically on heterogeneous research partnerships, none which seeks to identify and understand the way in which systems engineering has been used in their creation and operation. Concepts from systems engineering and related fields which may be relevant to HRPs have been identified for use in the case study design.

Similarly, the body of systems engineering research literature from which methodological guidance can be obtained is equally limited. A significant factor is the widespread lack of attention to methodology within the discipline as a whole. It is necessary to draw upon the related body of methodological work from systems science to provide the philosophical framework for this research.

5 CASE STUDY DESIGN

5.1 Introduction

Over the past four chapters, relevant literature has been identified and reviewed and a pilot study has been conducted to explore issues further. Chapter Five now draws from this in order to establish a philosophical framework, identify concepts and models to support further research, and to develop the research design for that work.

5.2 Philosophical Framework

Based on the foregoing literature review and analysis, the following philosophically-consistent research framework has been established:

5.2.1 Ontology

Within this research, reality is considered to be subjective, and is collaboratively constructed between the participants in HRPs as they interact with each other. Individual experiences cannot be separated from the holistic socio-historical context.

5.2.2 Epistemology

It is not possible to discover the “rules” of applying systems engineering to HRPs which explain behaviour in all instances, or to provide statistical generalisations and thus predict performance. Rather, the research seeks to enable understanding of how systems engineering is, or may be, used to good effect.

5.2.3 Axiology

The aims of the research are:

- To understand the nature of HRPs, including their context and the issues they face
- To understand how systems engineering is used by those establishing and operating HRPs
- To understand how systems engineering, taken in a broader sense and unconstrained by the traditional 'hard systems' process-centric approach, might be applicable to this class of problem.

5.2.4 Methodology

The research methodology is based on Jackson's Generic Interpretive Systems Methodology developed as part of his Critical Systems Practice (CSP) methodology (Jackson 2003). Whilst different philosophical positions can be adopted within CSP, all apply a structured way of thinking focused on improving real-world problem situations by using systems ideas and appropriate methods, models, tools and techniques, which should be consciously adapted to the particular circumstances.

Claiming to use the interpretive systems methodology must be justified according to the following guidelines (Jackson 2003, p309):

- a. there is no assumption that the real world is systemic;
- b. analysis of the problem situation is designed to be creative and may not be conducted in systems terms;
- c. models are constructed that represent possible 'ideal-type' human activity systems;
- d. models are used to structure debate about changes that are feasible and desirable;
- e. quantitative analysis is unlikely to be useful except in a subordinate role;

- f. the process of intervention is systemic and aimed at exploring purposes, alleviating unease and generating learning;
- g. the intervention is best conducted on the basis of stakeholder participation;
- h. changes are evaluated primarily in terms of their effectiveness and elegance.

Furthermore, use of the methodology should yield research findings relating to one or more of:

- the theoretical rationale underlying the methodology;
- the methodology itself and how to use it;
- the methods, models, tools and techniques employed;
- the real-world problem situation investigated.

Experience from the pilot study indicates that items d. and g. above (debating change and stakeholder participation) are likely to be highly problematic, and that the stakeholders involved in the operating, managing or working within HRPs are unlikely to be willing or able to engage in open debate with other participants. There appears to be a fundamental conflict between the need for an interpretive approach in order to uncover the richness and complexity of HRPs, and the discomfort of participants with adopting such an open approach which may be interpreted as critical of their customers and peers, or which may interfere with established contractual positions.

In order to address this issue, respecting what Checkland calls the 'cultural feasibility' of interventions (Checkland 1981), two key steps are to be taken:

1. Intervention in the problem situation is addressed at the 'HRP community' level, rather than for specific case studies. Thus the intent is not to directly influence the way in which any individual HRP

operates, but rather to intervene at a more generic level where principles can be debated and potentially adopted without the awkwardness and potential contractual conflict associated with a particular HRP.

2. The intervention itself, rather than attempting to induce change in existing HRPs (which would cause stress and would be expected to be resisted), will be through the development of guidelines for those involved in planning and operating future HRPs. This will enable change to be implemented within the HRP community at times when it is desirable and appropriate to do so. This means, however, that introducing change and reviewing the impact of that change is outside the scope of this thesis.

These two points imply that the research outcomes will need to have some degree of theoretical generalisability: that is, that the guidelines will be constructed in such a way as to be broadly applicable to other HRPs without attempting to achieve the statistical generalisability of a realist methodology.

5.2.5 Methods

The research will draw upon field data from a number of case studies, focussing predominantly on interviews but also including primary documents and meeting observations. The models, concepts and principles developed from the pilot case study and literature review will be used to frame the interview questions and inform subsequent data analysis.

5.3 HRP Concepts

5.3.1 Concepts and principles

The following concepts and principles form the basis of this research:

- **Complexity:** HRPs are complex entities which cannot be reduced to simple representations and cannot readily be fully understood
- **Lifecycle:** HRPs may have a lifecycle, either natural or imposed or a combination of both, which may be helpful in understanding how to create and manage the partnership
- **Systems Engineering:** Systems engineering is a means to understand and engineer complex systems, but different systems approaches will be applicable in different situations.
- **Heterogeneity:** Participants in HRPs have different drivers by virtue of their different backgrounds and personal or professional circumstances. HRPs will be judged as successful by those involved if they meet their own individual or organisational objectives. This may include hard measures such as financial outcomes, and softer measures such as prestige and reputation.

5.3.2 HRP Models

As a result of the literature review and pilot study, a number of models were developed or identified in order to establish a shareable frame of reference between case studies. Each model was established independently in its own right and provided a different perspective which might help in the elicitation and analysis of data from the case studies. Some models were taken directly from the reference literature and applied to HRPs, whilst others were developed from scratch to suit the HRP context.

5.3.2.1 HRP Lifecycle Model

The HRP Lifecycle Model was developed based on the pilot study. Figure 5.1 illustrates a generic HRP lifecycle with five phases: Creation, Implementation, Sustainment, Transition, and Termination.

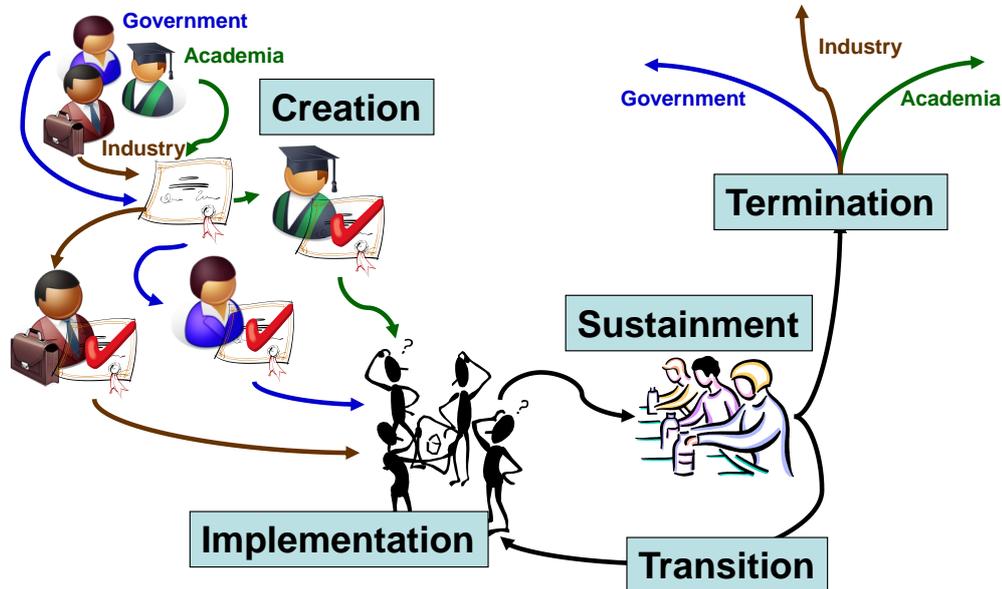


Figure 5.1 HRP Lifecycle

Creation is a politically-driven process, in which the idealism of key influencers is turned into agreement, and the necessary support is obtained. It involves the initial inspiration, detailed planning, negotiated agreement between the partners and independent approval by each partner.

Implementation is the establishment of the HRP which uses people, money and other resources to create desired research outputs which meet the requirements and satisfy senior stakeholders. It is the process by which the initial inspiration becomes reality.

Sustainment is the operation and maintenance of the HRP: maintaining access to required resources, delivering desired outcomes and ensuring ongoing support through stakeholder review.

Transition is the conversion of the HRP to operate under new rules and/or with new resources; including establishing mechanisms to satisfy new requirements and new stakeholders.

Termination is the final phase in which the partnership is dismantled and independence reasserted.

5.3.2.2 Generic Conceptual Model

The Generic Conceptual Model illustrated in Figure 5.2 draws from the conceptual model used within the pilot study, but also considers the relevance of the different levels in the hierarchy to different stakeholder groups.

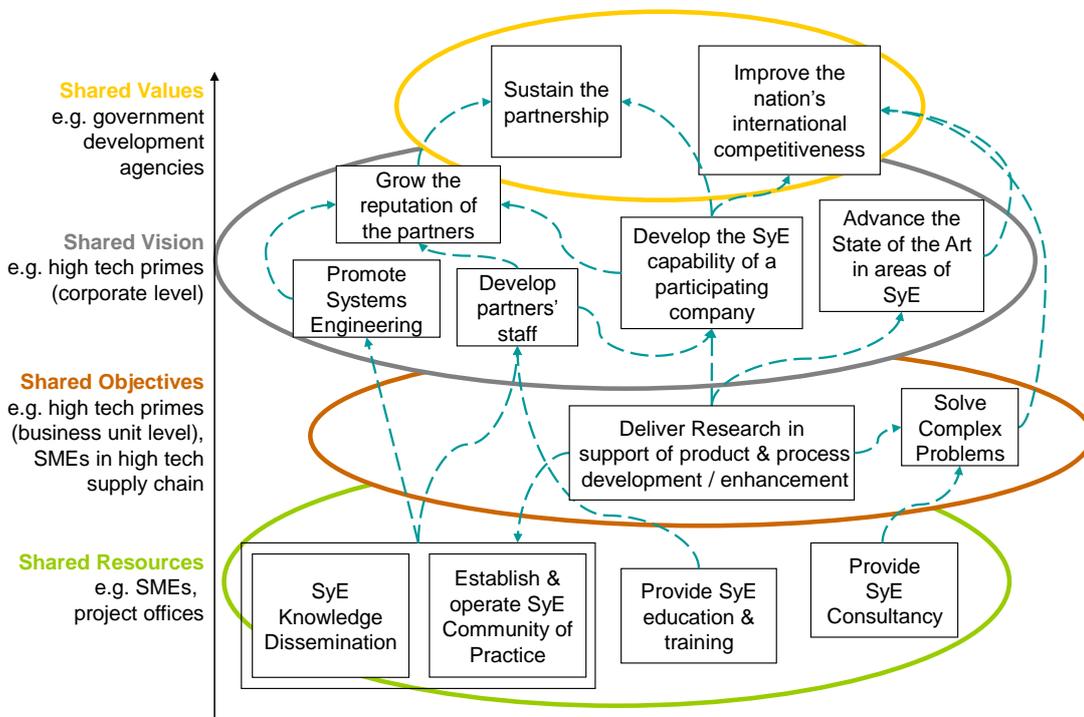


Figure 5.2 Generic Conceptual Model

The model reflects the fact that whilst national priorities will influence the involvement of government agencies in HRP, industry relies on more tangible results and this emphasis becomes more marked for smaller organisations.

5.3.2.3 Academic Motivation Model

Figure 5.3 draws on the concepts of motivation theory and recognises that within the academic environment there are cycles which may be thought of as ‘survival’ and ‘reward’ which are impacted by industrial collaboration.

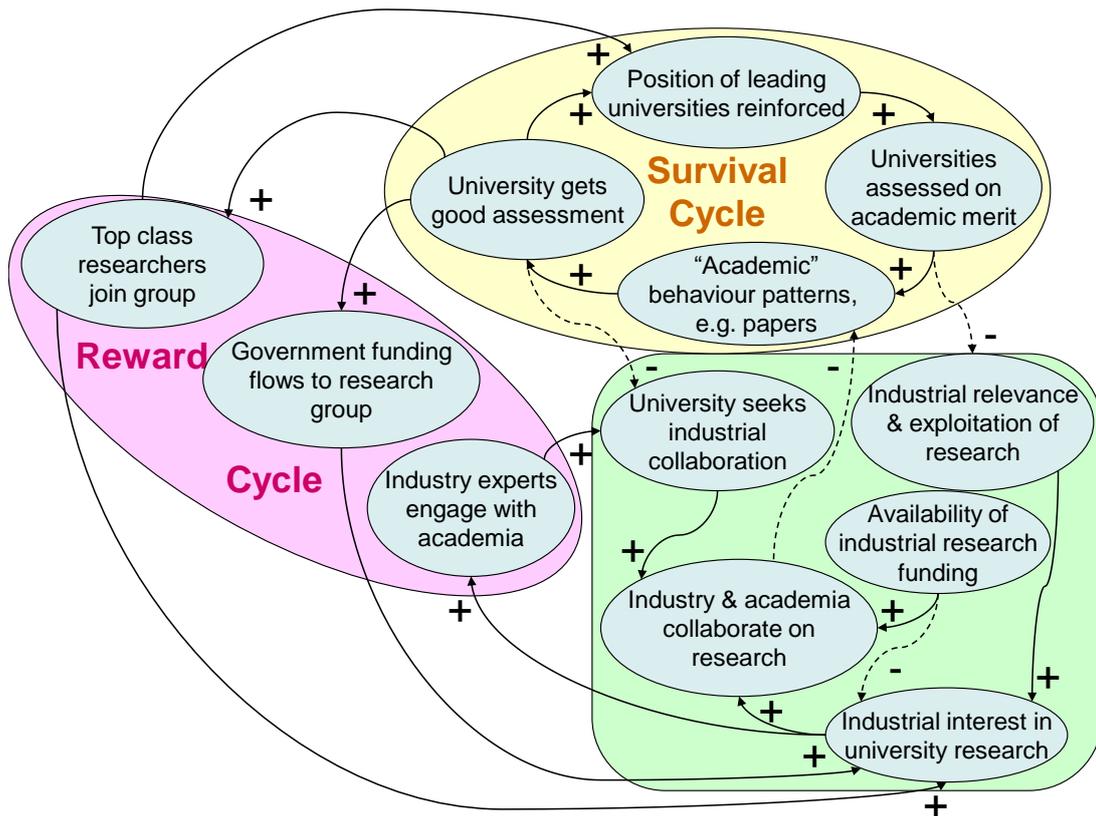


Figure 5.3 Academic Motivation Model

Whilst the dynamic links between the survival and reward cycles, and those between the reward cycle and industrial collaboration are positive, those between the survival cycle and industrial collaboration are only negative. This suggests that industrial collaboration will only be successful if the survival needs are satisfied first, and not threatened. Furthermore, it suggests that the collaboration requires the engagement of industry subject matter experts, not just project managers, in order to be rewarding.

5.3.2.4 Systems engineering approaches in defence

Figure 5.4 illustrates the role of different types of systems engineering in a defence context. It suggests that softer systems techniques may be more applicable than traditional systems engineering for HRP (Valerdi, Brown et al. 2010).

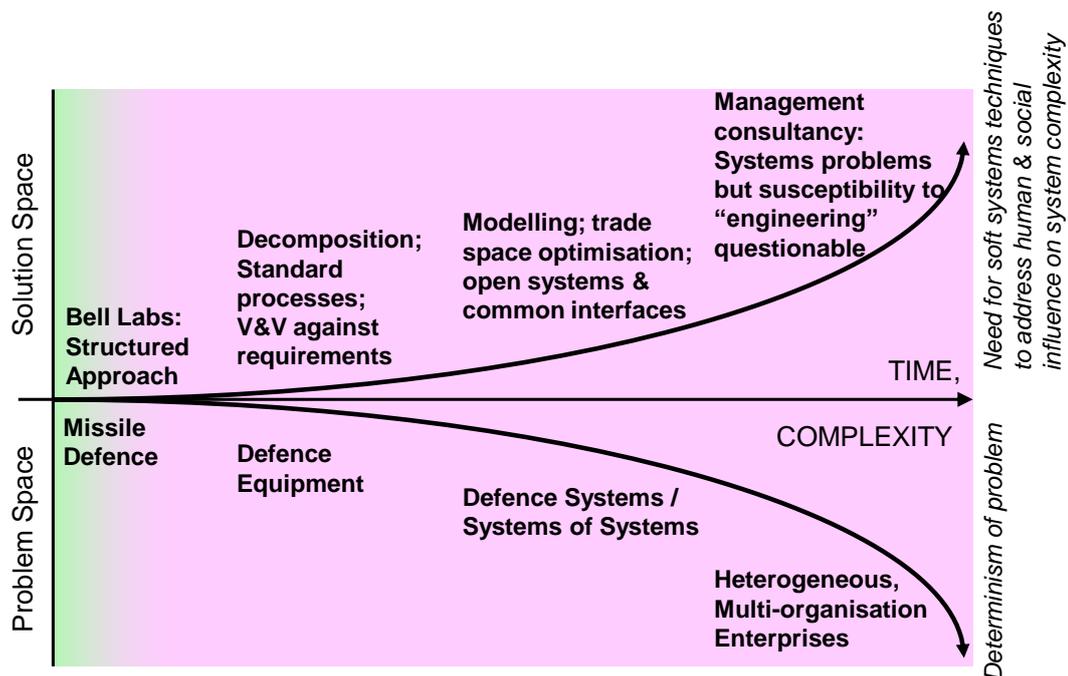


Figure 5.4 Systems Engineering Approaches in Defence

5.3.2.5 System of Systems Methodologies (SOSM)

The SOSM (Jackson 2003) shown in Figure 5.5 provides a framework to consider how systems approaches are used in HRP.

		PARTICIPANTS		
		UNITARY	PLURALIST	COERCIVE
SYSTEMS	SIMPLE	Simple – Unitary (Hard Systems Thinking)	Simple – Pluralist (Soft Systems Approaches)	Simple – Coercive (Emancipatory Systems Thinking)
	COMPLEX	Complex – Unitary (System Dynamics, Organizational Cybernetics, Complexity Theory)	Complex – Pluralist (Soft Systems Approaches)	Complex – Coercive (Postmodern Systems Thinking)

Figure 5.5 System of Systems Methodologies

The model suggests that the role of hard systems thinking (including traditional systems engineering) is limited to the *simple-unitary* context where participants have similar values, beliefs and interests, and share common purposes and agreed objectives in relation to simple systems. Other approaches such as system dynamics are considered better suited to the *complex-unitary* context where systems are more complex and outcomes less determinate. In *pluralist* contexts, where although the basic interests of participants are compatible their values and beliefs differ, approaches such as SSM are considered more appropriate. Although part of Jackson's model, *coercive* contexts are not considered relevant to HRPs.

5.3.2.6 Conceptagon

The Conceptagon in Figure 5.6 represents a canon of twenty one systems concepts intended to support the achievement of both completeness and balance in systems thinking (Boardman 2010).

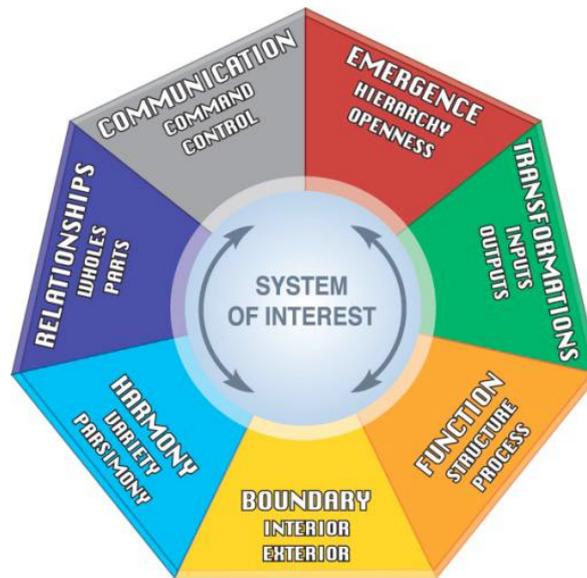


Figure 5.6 Conceptagon

Each of the seven 'triples' encourages consideration of balance around a particular fulcrum such as 'Boundary', with the balance between (in this case) 'Interior' and 'Exterior' considerations maintained in dynamic equilibrium.

5.3.2.7 Action Centred Leadership

The Action Centred Leadership model in Figure 5.7 is taken from the work of John Adair. Adair expresses the team development process as a coherent whole encompassing task, team and each individual (Adair 1983).

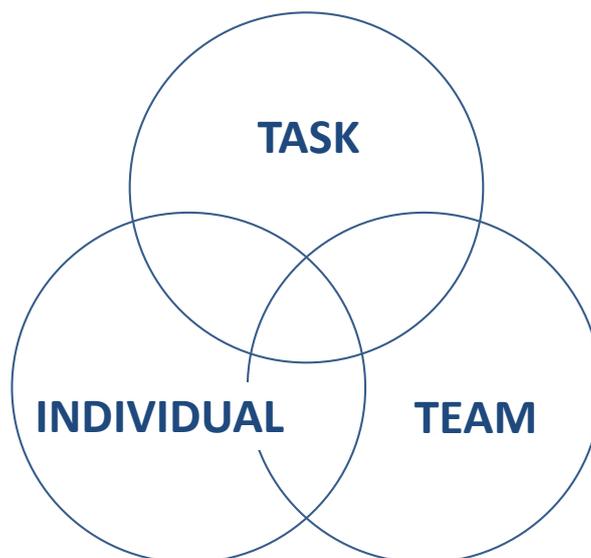


Figure 5.7 Action Centred Leadership

Task recognises that the group's function (in this case the HRP's function) is to accomplish defined results, making actions and interaction task-centred.

Team recognises the need for working relationships to be developed and maintained within the HRP in order to accomplish the task, and demands that interpersonal relations are, to some extent, people-centred.

Individual recognises that beyond satisfying basic survival needs, people within the HRP are motivated by needs for security, self-esteem, self-fulfilment and the respect of others.

5.4 Case Study Selection

5.4.1 Selection Criteria

All primary case studies were selected on the basis of the following criteria:

- They were 'Partnerships' which involved the sponsoring company and at least 1 other participant organisation, but did not involve the establishment of a separate legal entity.
- They were 'Heterogeneous' and involved at least two sectors (government / academia / industry).
- They were 'Research Partnerships', primarily focused on research and technology development in an aerospace & defence domain.

In addition, all primary case studies were either ongoing or had completed within the past 18 months in order to ensure that data was current and that the accuracy of recollections had not been eroded by time.

The requirement to involve the sponsoring company benefitted the research (by facilitating access to people and information) and ensured the applicability of the results to the company. This requirement was not applied

to the non-UK case study as no such case study could be identified. The case study selected met all the other criteria.

The timing criterion was not applied for secondary case studies. Since secondary case studies were introduced by interviewees in the form of a contrast or comparison to a primary case study, this would have been unnecessarily restrictive.

5.4.2 Validity of selection

Snowball sampling (where the initial group of contacts are used to establish contacts with others) (Bryman, Bell 2003) was used, both for the case studies and interviewees. This makes no attempt to be representative of the 'population' of possible case studies and interviewees: in fact, in the very concept of a 'population' of HRPs is problematic, given that new research partnerships are being established all the time, and those involved in them are changing regularly.

As a result, the sample of case studies is biased but selected to provide learning from HRPs in which the sponsoring company is involved and from which they can derive valuable lessons. Personal judgement, based on involvement in different HRPs over a period of more than ten years, drove the criteria for inclusion.

Within both industry and academia, it was common for the same people to be involved in multiple HRPs at the same time, and many of the potential respondents had had varied careers with experience across all three sectors. A number of interviewees provided data for more than one case study and drew from broader experience than could be reported through this research approach. Primary case studies had multiple interviewees and therefore much richer data was available. Secondary cases had, in most cases, data from only one interviewee but were used by the interviewee as a comparator, typically highlighting particular strengths or weaknesses compared to the primary case studies.

5.4.3 Constraints

Although the area of study involves HRP's in the defence domain, other than conforming to this generic type of complex defence-related research, the research programme content itself is unimportant for the purpose of this study. Thus types or levels of definition of information which are commercially or nationally sensitive are not necessary for the purpose of the study and would only serve to restrict accessibility to the data unnecessarily. This type of data was not collected.

In order to maximise access to information on a range of HRP's, including those which were felt to be less successful and from which valuable lessons might potentially be learned, the decision was made for case studies to be reported anonymously. This anonymity was applied both to the HRP and to the individuals who agreed to be interviewed.

5.4.4 Primary Case Studies

5.4.4.1 Case Study A

Case Study A was established in 2003 as a £60M, 10 year initial partnership between a Company, a University and local government, with plans to embrace other industry sectors & academia. The collaboration established a physical centre for systems engineering research and training where academic staff and industrial employees are co-located, overseen by a joint management structure, in order to help companies focus on the challenges inherent in the design and development of complex systems. There were six interviewees for Case Study A.

5.4.4.2 Case Study B

Case Study B was a £32 million aerospace programme addressing key issues relating to unmanned autonomous aircraft. It involved a consortium of major aerospace companies, working with a number of small companies and

academic staff. Case Study B was supported by national and regional Government investment to ensure that the aerospace industry maintained its global strength and developed world class technologies in line with the National Aerospace Technology Strategy. There were four interviewees for Case Study B.

5.4.4.3 Case Study C

Case Study C was set up in 2007 between a Company and a government customer to develop a shared understanding of capability drivers, alternative solutions and potential exploitation routes for technology, and to reconcile these with available research budgets, resources and timescales in order to remove duplication and to understand the impact of decisions on programme risk and on the sustainment of relevant industrial capability. There were three interviewees for Case Study C.

5.4.4.4 Case Study D

Case study D was an £8.4M research programme established in 2006, jointly sponsored by a government funding agency and a Company, and delivered by a consortium of ten UK universities. The programme aimed to define, develop and demonstrate approaches to system of systems engineering needed to support network enabled capability. There were nine interviewees for Case Study D.

5.4.4.5 Case Study E

Case Study E was set up in 2005. It was a 'virtual centre of excellence', managed by an industrial consortium and funded jointly by government and industry participants, providing an overall budget of £60M. Its core goals were to research innovative technologies relevant to autonomous systems and, through the adoption of systems engineering approaches, to facilitate pull-through of the technology into military capabilities. There were five interviewees for Case Study E.

5.4.4.6 Case Study F

Case Study F was a government-funded strategic initiative established in 2008 to enhance the management of software intensive defence systems, and thus to reduce risks, delays and cost overruns. Case Study F was an open consortium of industrial and academic organisations, intended to support the UK software systems engineering community. It comprised core members who managed the programme, and associates who participated in delivering the broader objectives. There were five interviewees for Case Study F.

5.4.5 Secondary Case Studies

Secondary case studies were highlighted by interviewees and presented as a comparison to the primary case studies. Although, where possible, some background research has been done on the secondary case studies, largely from internet sources, the information relies largely on the commentary of a single interviewee and as such is likely to be both limited in scope and biased in nature. The purpose of including the material is to add richness to the discussion of certain issues, rather than to imply generalisability.

5.4.5.1 Case Study G

Case Study G was a £6M five-year research programme established in 2005, jointly sponsored by a government funding agency and a Company and delivered by a consortium of four UK universities. It aimed to develop techniques, methods and architectures for modelling, designing and building decentralised systems that could bring together information from a variety of heterogeneous sources in order to take informed actions. Case Study G had only one interviewee.

5.4.5.2 Case Study H

Case Study H was a research programme funded by a European agency. Only a limited amount is known about this HRP. Case Study H had only one interviewee.

5.4.5.3 Case Study I

Case Study I was a five-year, £6.5M research programme undertaken at 10 UK Universities sponsored by a Company and government funding agency. It undertook research into novel technologies for the next generation of unmanned air platforms. By designing and building a representative air vehicle and conducting a real flight campaign demonstrating the new technology, it took the technology to a higher level of maturity than is usual in academia. There were two interviewees for Case Study I.

5.4.5.4 Case Study J

Case Study J was established in 1979 by UK aerospace companies to demonstrate the credibility of UK industry to deliver a future fast jet. The five member industrial consortium was self-funded and managed, and continued to work together on the development of technologies and strategies of mutual interest more than thirty years later. Case Study J had only one interviewee.

5.4.5.5 Case Study K

Case Study K was established in 2007 as a Centre of Excellence on a University site. Four industrial core partners each committed £1 million over five years to support research into a particular area of technology for high-tech, high-value vehicles such as aircraft, ships, high-speed trains and high-performance cars. There were two interviewees for Case Study K.

5.4.5.6 Case Study L

Case Study L is a government-funded programme at a university which builds on an existing partnership between the university and a Company.

Only a limited amount is known about this HRP. Case Study L had only one interviewee.

5.4.5.7 Case Study M

Case Study M was established in 2003 as a customer-industry partnership to analyse problems, examine options and de-risk requirements. The HRP was governed and funded by the customer and involved a broad community of partner and competitor companies. Case Study M had only one interviewee.

5.4.5.8 Case Study N

Case Study N was a 3 year £600k government-funded programme which ran between 2003 and 2006. This project aim was to extend CFD-based aeroelastic prediction tools to realistic aircraft geometries. Case Study N had only one interviewee.

5.4.5.9 Case Study O

Case Study O was a bilateral agreement between a company and a university. Only a limited amount is known about this HRP. Case Study O had only one interviewee.

5.4.6 Non-UK Case Study

The final case study is unique within this research as it is drawn from outside the UK, but is in many other ways similar to the UK case studies. It is included to enable consideration to be given to whether obvious national differences exist, and whether there are differences in practice which might make the formation and operation of HRPs more or less effective.

5.4.6.1 Case Study P

Case Study P is a five-year contract to establish a research centre focused on systems engineering research, supported by researchers from more than a dozen universities and research centres. It aims to enhance the definition,

synthesis, integration and test, deployment, and support of complex systems and enterprises. There were four interviewees for Case Study P.

5.5 Data Sources

For each Case Study, data was obtained from a number of sources.

5.5.1 Published sources

Basic data describing each case study was collected from published sources including conference and journal papers written around the case study, the case study's own website and other websites such as those of funding bodies. Other publications from the case study such as material advertising the launch and other events, annual reports etc were also accessed.

Published sources were used as the primary data source for such 'factual' information to enable contact time (in meetings and interviews) to be focused on perceptions and issues rather than the collection of basic data.

5.5.2 Meeting observations

Four of the case studies provided an opportunity for the author to attend management meetings as follows

Case Studies A and E: The author had been a participant at a managerial level in both these HRPs prior to the commencement of the research, and thus had access to participants, both on an individual basis and collectively in meetings.

Case Studies C and F: The author was invited to attend the management meetings of these two HRPs during the course of the research.

The decision was made not to directly record the meetings, for several reasons:

- The research content discussed in such meetings might occasionally be of a classified nature, potentially rendering the recording classified too.
- The location of most meetings was such that recording equipment was not normally allowed in the building.
- The meetings took place between individuals in relatively senior positions in their respective organisations. The information and opinions that were shared were not always the formal positions of their respective organisations and were often shared in confidence. Although it might have been possible to stop recording at certain times or to delete sections of the recording, there was a significant risk that recording such conversations might compromise the natural flow.

In all the meetings, the author was welcomed to the meeting as “one of us”. The fact that detailed meeting notes were being taken did not appear to disrupt the flow at all, and in fact on several occasions the author’s meeting notes were used to supplement the formal meeting minutes.

5.5.3 Interviews

5.5.3.1 Interviewee Selection

Interviewees were selected on the basis of

- Current or previous personal involvement in the Case Study, so that their perspective was that of a participant rather than an outside observer.
- Some involvement in or familiarity with systems engineering, which should enable them to recognise where systems engineering was used or could have been used.
- A leadership role which would give them visibility of, and potentially influence over, the way in which the HRP was run. This was to focus the

data collection on the management intent behind the case studies, rather than add the complexity of views from across the workforce.

Recognising that there may be a reluctance on the part of some individuals to share their views openly in front of other stakeholders (Midgley 1997), interviews were held on an individual basis. As with the meeting observations, the decision was made not to record the interviews. It was felt that the interviewees would be much less likely to share their views openly if they were being recorded.

All proposed interviewees agreed to be interviewed. In one case this was not possible due to travel plan conflicts. In two other cases, it appeared impossible to arrange availability in spite of numerous opportunities. It may be postulated that these individuals felt that they had peer pressure to agree to be interviewed, but in fact did not want to participate, or did not feel that the commitment of their time would be adequately compensated by the benefit likely to ensue.

All the primary cases had 3 or more interviews, up to a maximum of 9 for Case Study D. Typical interviewees gave their views on one or two HRPs, up to a maximum of five.

For Case Study E, the author had also conducted a small number of senior stakeholder interviews on behalf of the HRP in 2006, prior to the commencement of this research. Notes from those interviews form an additional data source.

5.5.4 Internal documents

In a number of cases the author was given access to or copies of documents internal to the case study such as letters, reports, contractual documentation etc. This applied in addition to those case studies where there was direct access to participants.

5.6 Interview Overview

5.6.1 Interview themes

After being given an overview of the research aims, each interviewee was asked:

- To focus on their opinions rather than facts about the HRP, which could be gathered elsewhere (in order to maximise the value of face-to-face time)

- To characterise the HRP based on the themes derived from the pilot
 - Complexity
 - Objectives
 - Lifecycle
 - SE techniques
 - Perceptions of Success

All interviewees contributed to at least one theme but not all themes were drawn from each interviewee or each case study.

5.6.2 Interview recording and analysis

During the interviews the notes were categorised according to the five themes drawn from the pilot study. Although sheets had been prepared to assist in note-taking during the interviews, it quickly became apparent that whilst this was an effective prompt to ensure the themes were discussed, the interviewees were all very willing to talk about the HRP and expressed their thoughts at length. In some cases, detailed background on the history or their role was given, resulting in notes which filled many additional pages. Apart from thematic prompts the interviews were largely unstructured, and interviewees typically moved between or returned to themes as the

conversation progressed, resulting in notes which did not neatly follow the pre-prepared sheets.

As data was collected and analysed it became clear that several other themes were emerging, including the nature of relationships within the HRP; the contracts, management controls and IPR agreements that were in force; cultural issues between participants and available resources, primarily in terms of people and money. This resulted in a final structure for the case studies based on ten commonly-referenced themes.

5.6.3 Interview order

The scheduling of interviews was determined primarily by convenience, according to the travel plans and availability of the interviewees or interviewer. No attempt was made to complete all interviews on one case study before embarking upon the next, and indeed a number of interviewees provided data on several case studies during the same interview. As a result, the exploration of themes developed iteratively as learning from different case studies matured over a period of approximately 9 months between first and last interviews.

5.7 Research Validity

5.7.1.1 Credibility

In order to avoid anecdotalism, the narrative was constructed from all the quotes captured in each case study, weaving together complementary and conflicting views within the pre-determined structure, rather than basing the analysis and conclusions on a small number of quotes or examples to epitomise key points.

Respondent validation was used to confirm the transcription of the interviews into the case studies. After each draft case study was prepared from the interview notes it was sent to the relevant interviewees for review. Each

interviewee was given the unique reference number for their own quotes and asked:

- To confirm that the text correctly captured their meaning.
- To identify any content which was too sensitive or in other ways inappropriate to be included in the final thesis.

The interviewees were asked to supply replacement text in either of these cases and this was incorporated into the case study.

The purpose of this was three-fold. Firstly, it enabled confirmation that the author had correctly heard and understood the interviewee's comments. Secondly, it enabled confirmation that when the comments were combined with others within the overall structure of the case study, that the meaning was not distorted. Interviewees were invited to correct any inaccuracies in their own comments at this stage but had no influence over the inclusion of conflicting comments from others. Finally, it enabled interviewees to rephrase their comments where they felt that their original words had been too colloquial or may be misinterpreted by others.

It is notable that no interviewee tried to influence the way in which the quotes of other interviewees were recorded, although several observed that the comments of others regarding the challenges faced left several of the case studies with an 'overly negative tone'.

Since the aim was to validate the interview data rather than find the 'truth' about each HRP, additional data from other sources was not included in the case studies until after respondent validation. However, once all the interview data had been included and checked, additional data from other sources including websites, meeting minutes, reports etc was incorporated into the case studies, providing either reinforcing, contradictory or simply additional perspectives integrated within the established framework.

Data from the author's participation in Case Studies A, C, E and F was not explicitly referenced except where documentary evidence existed. However, it influenced the construction of the case studies in two ways:

- By providing access to documentation which was not publicly available and which could be incorporated as evidence within the case study.
- By enabling a richer understanding of the context in which the interviewees operated, and thus supporting the interpretation of interviewee comments.

5.7.1.2 Transferability

Triangulation across a total of sixteen case studies was used to draw out similarities and differences. Although all case studies met the HRP criteria, they ranged from those in the early stages to some which were complete, and from those perceived as very successful to others which were less so. All had different leaders, used largely different approaches at the detailed level, and had different partners.

5.7.1.3 Dependability

5.7.1.3.1 Transcription of data

Interview notes were captured by hand. In order to create each case study, the text from each interview was transferred into a table with rows representing the section headings and columns for each interviewee. A sample row for the 'Role of Systems Engineering' from Case Study F is shown at Table 5.1.

Table 5.1 Sample Collated Interview Data

Interviewee	Fi	Fii	Fiii	Fiv	Fv
<u>Role of Systems Engineering:</u>	<ul style="list-style-type: none"> • Did architectural design of processes for resource management. • Not to my knowledge in any formal way • Company viewpoint – followed the usual process • Customer – no evidence of SE approach 	<ul style="list-style-type: none"> • Ignored overhead of doing internal review process. Intolerable even on £5M programme. Embarrassingly large: level of effort too great. 	<ul style="list-style-type: none"> • Traceability from vision to what we're doing 'ought to be agreed'. • The organisational outline was specified in the ITT and bid documents i.e. Joint Boards, Management Group: not a lot of room for manoeuvre. • We had no input to architecture: customer had decided what it was going to do, what the architecture was. Have subsequently done things like 'combining' (dropping) themes. • Customer now talking about rationalising meetings – tinkering around the edges. 	<ul style="list-style-type: none"> • 26 tasks, 22 active: building a coherent whole out of bits is tricky 	<ul style="list-style-type: none"> • Don't use formal technique: look for solution holistically. • Look for things that are important, not obvious. • Like a chef: some things in presentation, adds to taste, brings out flavours: ambience, music, crowd, noise. • Start with a bundle of constraints. What are all the bits? Prioritise. • Mistake to write them in a list

The case study was then written taking data from each row across all interviewees. Occasionally some data fell more naturally into a different section as the narrative evolved. All data was used by the time each case study had been completed.

5.7.1.3.2 Categorisation

Categorisation of the data was originally based on the interview data. Interviewees were asked questions based on the five themes which emerged from the pilot study and these were initially used to structure the case study narrative. As more data was collected, five more themes emerged as a result of repeated references by a number of different interviewees. It was felt that the ten themes provided adequate but not excessive definition for the data in developing the case study narratives.

5.7.1.4 Confirmability

In order to understand the way in which the author's biases might affect the research, it was first necessary to identify what those might be. The following quote is taken from the author's research report at the end of the first year of research, which described in some detail the author's background and experience:

"Taken together, these elements are the foundation upon which this research is built – an enthusiasm to challenge accepted practices and for holistic thinking, coupled with an acute awareness of environmental influences; a recognition of the diversity of stakeholder perspectives and a fundamental belief that openness, cooperation, shared understanding and trust are critical to the effective operation of any organisation in a dynamic and challenging environment; and a conviction that systems engineering, taken in the broadest sense, holds the key to unlock many of the world's big problems, and many more of the small ones." (Brown 2007b)

The data collection and analysis looked for evidence to support or refute the assumptions implicit in this 'foundation': whether or not the objectives of the HRPs were understood and shared and the nature of the relationships between participants; the environment of resources and control systems that operated, and whether indeed the HRPs were created in a way which enabled them to meet their objectives. Holistic themes considered the concept of a lifecycle and the complexity of the HRP. The use, or not, of systems engineering was explored; and finally perceptions of success were sought in order to understand the causality: had the mix of characteristics enabled the HRP to succeed, or not.

The motivation for the research was on the basis of personal experience and significant anecdotal evidence over a number of years that few, if any, HRPs would be universally described as 'outstandingly successful', and that there is, in most cases, scope for improvement.

6 CASE STUDY FINDINGS

6.1 Introduction

Within Chapter Six, data from different interviewees and other data sources has been integrated in order to construct sixteen separate case studies based on the framework of ten themes, as follows:

- Objectives
- Nature of Relationship
- Contracts, Controls and IPR
- Culture
- Resources: People
- Resources: Funding
- Lifecycle
- Complexity
- Role of Systems Engineering
- Perceptions of Success

In Chapter Seven these characteristics will be compared across the case studies in order to draw out common and contrasting messages.

6.1.1 Terminology and referencing

In order to preserve the anonymity of the case studies, generic terms have been used for the participants as follows:

- The “customer” is the primary source of the research requirement and/or funding
- The “company” is the principal or sole industrial partner
- The “partners” are other industrial participants
- “Academia” and “universities” are both used for academic participants.

Throughout the case studies, quotes from specific interviews are referenced in the form '(Xn)' where 'X' is the case study (letters A to P) and 'n' is a Roman numeral representing a particular interview within that case study.

Anonymity of documentary references within the case studies was preserved by using only the first two letters of the author's surname and creating a sanitised reference list at the end of this chapter to cover all documentary references from the case studies. Any mention of individual HRPs within document titles and website addresses, and any other data such as location which might directly identify the HRP have been removed from these references. Where appropriate, case study references have been used to replace the HRP name.

6.2 Case Study A

The HRP in Case Study A was established in 2003 as a £60M, 10 year initial partnership between the company, lead university and Government funding agency. The collaboration established a physical centre for systems engineering research and training where academic staff and industrial employees were co-located, overseen by a joint management structure, in order to help companies focus on the challenges inherent in the design and development of complex systems.

6.2.1 Objectives

The objectives of the HRP in Case Study A were to provide "cheaper, faster research"(Ai) for industry by enabling "industry and academia to work side by side"(Av) and to "collaborate on research and allow cross-fertilisation of industrial / academic approaches"(Av). The intent was for "multiple cross-sectoral stakeholders"(Aiv) to see it "as a key component for systems engineering competence"(Aiv) although there was "a question of how the objective of getting third parties on board was valued"(Ai), particularly during the first five years.

There was general consensus that the objectives were “very aspirational”(Aiii) and “idealistic”(Av). It was noted that it was “an experiment”(Aii), that the “feasibility of the requirements was untested”(Ai) and that there was no certainty “if it could be achieved”(Aiv). It was seen as necessary to “make a leap of faith to innovate”(Av) although this may have been unrealistic. “Naively so”(Aiii). For the academics, one of the problems was simply to understand the nature of systems engineering research and how it might apply to them (Br___ 2008).

Fundamentally, it was noted that the specific written objectives were different for the different parties involved (Do___ 2002a) and that these could be considered “adequately conflicting”(Ai) or “all different, but all capable of being satisfied at the same time”(Aii). In either case it was considered clear that the parties “did not have common objectives”(Avi). It was felt that the objective of “academic excellence was fairly orthogonal to the company’s value & relevance; and equally orthogonal to SME’s value & relevance”(Ai) but that in order for it to succeed “objectives couldn’t be mutually exclusive: even if not completely aligned there had to be a win-win”(Avi). It was felt that “what each enterprise wanted to get out of it”(Ai) was known: that the company understood the university’s “primary driver was papers”(Avi) and that the university understood that the company “needed tangible outputs”(Avi).

At a technical level, it was felt that the aim was to “find the novel systems practices to solve novel systems problems”(Ai). Although formal “requirements addressed research outputs, themes and topics”(Ai), there was “not a consolidated programme”(Avi) and work done within the HRP had to be on a “real needs basis”(Aiv).

6.2.2 The nature of the relationship

The HRP was based on a long-standing relationship between the university and the company (Do___ 2002a). However, although projected as “an

academic / industrial partnership to conduct research”(Av), “partnership was one thing it wasn’t. It never was. It was never set up as one”(Aii). Describing a partnership as “both trying to achieve something by working together that couldn’t be achieved or would take longer without”(Aii), the interviewee noted that it was hard to imagine that “anyone thought it was a partnership”(Aii). The challenge of establishing a true partnership rather than the usual customer/supplier relationship had been identified early on (Ja____, Si____ et al. 2003). In its current state, the HRP was described as “a research arm of the company”(Av), a view which excluded university staff. It was noted that there was “lots of collaboration at a strategic level and at a personal level, but not at an operational level across various people”(Av) and that the objective of having “co-located teams”(Aii) of “industry and academia sitting and working together hasn’t happened”(Av).

There was an expectation that the HRP would “grow through multi-partnering” to become a UK centre of excellence which would “become the first port of call for systems engineering capability brokerage” (Ph____ [undated]). This would “require different academic partners”(Ai) and for the HRP to expand to encompass these partnerships with the lead university acting as the hub (Ja____, Si____ et al. 2003). This expectation was, however, quickly reduced to a ‘network of universities’ (Do____ 2003) rather than a partnership, and there was no evidence of any more formal arrangements (such as subcontracting of work or secondment of researchers to other universities) being achieved.

Similar expectations existed regarding the inclusion of additional industrial partners (Do____ 2003), (Ph____ [undated]), (Ph____ 2005), but in spite of the general intent to evolve and add new partners to the HRP, it was unclear “what sort of agreement was desirable if a new partner arrived and wanted to join”(Aii). Different options for levels of partnership were considered in conceptual terms (*SEIC Partnership (framework)*. undated) but not defined in detail. There was a concern that “common ground shrinks as the number of partners increases”(Aii) and “the obvious way to get value was to abstract

away the detail and jointly fund ‘vanilla flavour’ work”(Aii), but that this would result in “taking our eye off the ball”(Aii) for existing research. In spite of the “enthusiasm for widening the partnership”, the development of good relationships and discussions with a number of companies, the target of achieving an additional full industrial partner remained over a number of years and this continued to be a barrier for organisations unwilling or unable to join the bilateral partnership (Br___ 2010a).

Complex influencing structures existed within the partner organisations (Do___ 2002a), and these remained dominant: controlling the flows of money and people as well as imposing organisational change on the HRP participants. Although there was a focus on the processes for jointly operating and managing the HRP, the emphasis on maintaining the underpinning relationship was missing from the planning (Ja___, Si___ et al. 2003) and only evident when things became difficult. A showcase event, with invitations to staff sent jointly by the most senior sponsors in the university and company (Pe___, Im___ 2007), and subsequent regular meetings at a number of senior levels including a bi-annual ‘stakeholder relationship meeting’ reflected the eventual recognition of the oversight.

Over time, the university increasingly reinforced the notion that it conducted research and teaching in this technical area *independent* of the HRP, as well as inside it, particularly in venues where it might hope to attract new partners or collaborators who may be put off by the close relationship with the company (Ka___ 2010), (Br___ 2010a), (Case Study A newsletter 2009).

6.2.3 Contracts, Controls and IPR

The three way HRP was based on a “ten year contract with public and private investment”(Ai). The contract “was complicated”(Av) but “a fixed document, enforceable, that doesn’t change”(Av). Whilst the academic partner “felt that the 86 page document was far too complicated, it was all necessary”(Aii). It was noted that each partner came from “a different space, a different

dimension and had different success factors”(Aii) and that it was possible to “take the individual vision statements independently”(Aii). The third, funding, partner was felt to be “completely ignored once we had the money”(Av).

“Considerable effort” went into the development of commercial and legal frameworks to enable “a range of different operating models to be used” (Ja___, Si___ et al. 2003) although it is unclear how extensively these were exercised. “Silly IPR requirements were imposed”(Ai) so that everything was owned by the company. Although they were “supposed to be balanced”(Ai), they were actually “designed in an unfair way”(Ai), which was “contradictory to the internal legal and constitutional agreement”(Ai) and became “a source of resentment and frustration”(Ai).

Although “not commercially driven”(Ai) and “not an enterprise that makes money”(Ai), the HRP was described as being “driven by the company”(Avi). There was a view that “it doesn’t matter”(Avi) to the university.

The HRP’s strategy was felt to be “set by metrics that we had to satisfy”(Aii) to the exclusion of anything else, as the Strategy Board “could never override metrics since it had no teeth by comparison”(Aii). Important but ‘hard to measure’ factors such as the underlying relationship between the parties were not reflected in the metrics, which focused on ‘easier to measure’ operational factors (Do___ 2002a) such as headcount, funding and publications (Case Study A 2005). Although using “familiar measures”(Av), they “didn’t work across the HRP”(Av) and there was a sense that the “system always had to prove itself”(Av). “Metrics to justify your existence diverted effort from what it was supposed to be”(Av) and “in the early years, the partnership drowned in metrics, which curtailed its ability to evolve and take risks”(Av). There was a view that “all the metrics were based on the company’s objectives” (Avi) and that the university would “do the minimum to demonstrate that it was a ‘good citizen’”(Avi). It was felt that to “mutually oblige each other to do something and spend a long time measuring it”(Aii) was harmful to the HRP, wasting time and effort as each side did “a merry

dance seeking to convince each other that we were meeting our obligations”(Aii). It was felt that to be effective “measures must address both sides”(Avi) but that “they should be side effects, not why you do it”(Aii).

6.2.4 Culture

One interviewee felt that the HRP was based on a “good cultural match”(Ai) with an “industry-friendly university”(Ai), where the “history of the relationship had aligned the cultures”(Ai), which were thought to be “very engineering-dominant on both sides”(Ai).

However, another suspected that since the organisations were “from different worlds”(Av) “there would have been a huge amount of misunderstanding, even over the meaning of words”(Av) and gave the example that ‘enhanced recognition’ “was a marketing thing to the company, but meant money to the university”(Av). It was felt that they “could say the words to each other and never think that they might mean something different”(Aii).

There was a recognition that the organisational structure should reflect the different roles and needs of the principle partners, and that operational processes should range from company-specific to university-specific, with two-thirds of the processes being joint in some way (Ja___, Si___ et al. 2003).

6.2.5 Resources: People

One interviewee noted that the issues in the HRP were “mostly about people and culture” (Aiii). People issues were highlighted in a number of different ways and it was suggested that partnership was “only between people, not institutions”(Aii), based on “establishing what you had in common”(Aii). Cooperation between research managers, technical specialists and academic staff was identified as necessary to achieve the desired leverage from academic research but it was recognised that a ‘not invented here’ attitude among industrial participants could jeopardise this (Do___ 2007).

A key element of the HRP strategy was to identify how the “requisite level of expertise” would be established and maintained (To___ 2008). “Ensuring the provision” of an appropriate resource base was always recognised as a challenge (Ph___ [undated]), but a number of recruitment and secondment strategies were identified at the outset and the risk that it may not be possible to transfer enough experienced staff was considered small (Do___ 2002a). However, this assessment proved to be misguided. Those involved from the university side were “overloaded with other projects in the same domain”(Ai) and that the early phases were “put together as your night job, in addition to the day job”(Av). “Not enough talent and staff”(Ai) were involved and there was a recognition of “relying on heroes”(Ai). The physical location of the HRP was “too far away from their home base for academics”(Ai) and “was never really sold as ‘the place to go’ to enhance your career, so it didn’t attract people willing to collaborate and talk”(Av). Recognising that it was not possible to “buy the right people as ‘off the shelf’ components”(Ai) attempts were made to “make some of our own”(Ai), realising that these would be “critical, long lead items”(Ai). It was noted that the “risks of relocation”(Ai) had not been managed and that the original idea of “cycling through secondees was practically impossible”(Aii).

It was felt that the HRP was “lacking some kind of continuity”(Aiii). Although the “knowledge and will were still alive in people’s heads”(Av), there had been several leadership changes and the original champion was considered to have been already past their peak “in terms of influence”(Av). Notably, of the early leadership on both sides of the HRP, four had since passed away and another five had retired during its early years. The handover to an Implementation Team meant that “those involved in the design didn’t carry it through to operation”(Aiii). Whilst the goal “was clear within the small group involved in creating the entity”(Av), there was doubt “whether it was clear to and bought in to”(Av) by the senior leaders in both organisations. Changes to personnel were felt to impact the complexity of the HRP. “A lot of what went on depended on people arriving and leaving. Attitudes and ways of working changed”(Av). The potential for the HRP to flourish in the future was

felt to depend “on who was in charge”(Av). Furthermore, the original structure of nine research themes was felt to spread resources too thinly, making it difficult to maintain resource levels and demonstrate leadership in every area (To___ 2006).

Personalities had also played a part in the way the HRP had developed. One interviewee believed “that the wrong person was in charge at formative times”(Av) as it “needed someone in charge who could work out of the box”(Av). “Lots of personalities clashed: in the university, the company and between them. Those clashes were a fundamental cause”(Av) of issues in the HRP. “Relationships were strained until the soft issues were sorted”(Ai). There were issues “around interrelationships, the set-up of the team, outward-facing roles and the relationship to the university”(Av).

6.2.6 Resources: Funding

“In the early days, money was easy”(Aii) and costs for users of the HRP were “offset by a subsidy from head office” (Ph___ 2005). As time had progressed, funders were “less prepared to give it blank cheques forever”(Aiv) and researchers “had to win contract funding from sundry business units and others”(Aii) based on a realistic charging rate (Ph___ 2005). This led to a “very tactical approach, living hand-to-mouth on yearly contracts”(Aii).

“The university was in the same position. They thought they had it tough, but we thought they had it easy”(Aii). It was felt that “good academics could get money: they worked the system and got the grants”(Aii) although it was noted that funding bodies had more high quality proposals than money such that “with grant applications, it was a lottery over what would get funded”(Aii).

There was felt to be a mismatch between the strategic intent of the HRP and sources of funding. “The thing that would determine strategy was money”(Aii). The expectation of alignment between company and university work “totally denied reality and how work came in. You couldn’t pick and

choose – it was all funding driven”(Aii). It was felt that the concept of a strategic research agenda “was only strategic if funding was forthcoming”, and whilst it “may not have had all the money, no money was not acceptable”(Aii). It was also felt that although there may have been a desire to “have work in strategic areas, you couldn’t do it unless someone would pay for it”(Aii). The HRP was “not resourced in a way to fulfil the vision”(Av) and was “constrained by money and no new equipment”(Av). This was reflected in the website which was not maintained and had not been updated for two years (Case Study A 2009).

One challenge was felt to be that “the scale of the HRP was so small compared to the scale of interest to a business unit financial director, so if you made your pitch at Board level it was down in the noise. £20 billion budget lines were important, not £1 million”(Aii). “Board level support was necessary but not sufficient”(Aii): you needed to “establish a clear link to where the £1million decisions were made”(Aii).

There was also a concern that “the business case was based on a flawed model which never held water”(Aii) so that “to make value, funding agencies would have had to spend money on company problems”(Aii). Leverage from “significant levels of external funding” was part of the business case (Ph___ [undated]). This required a high level of cooperation between the university and the company in order to benefit the university’s pursuit of research income (Do___ 2007), whilst ensuring that the metric did not result in the capture of “non-aligned funding” simply to achieve financial performance (Ph___ 2005).

6.2.7 Lifecycle

In creating the HRP, “the people who agreed were at such an elevated level they had no grounding in what would actually happen”(Aii) and there was a failure to “figure out operationally how it would work first, not after it was too late”. As a result “reality was different from what was thought should

happen”(Aii), and this had not been resolved. In comparing the HRP to that in Case Study F, one interviewee described it as “a sick old patient”(Ai). Some risks to the set-up of the HRP, such as attracting the right staff, remained unresolved and continued to have an impact, but without the early management focus on them (Ja____, Si____ et al. 2003).

The HRP was “in continuous transition”(Ai) and “would continue to evolve”(Ai). The research “needs would continue to evolve rapidly”(Ai) and the “academic subject will evolve for the foreseeable future”(Ai). However, there was a risk that this would simply “perpetuate ongoing messing”(Aii) in the way that the HRP functioned.

Within the lifecycle, different ‘time constants’ for the different parties meant that alignment, whilst not impossible, required agility. It was noted that the university’s time constant was “three years at best, whereas the company had volatility and changed every year”(Aii).

The operational agreement was based on an expected term of ten years, with four exit strategies covering a range of options from breach of contract to mutual consent. It was notable that no option for continuation beyond ten years was included (Do____ 2002a).

6.2.8 Complexity

Complexity within the HRP was observed in a number of different ways. Fundamentally, the topic area was considered “too esoteric”(Avi) and with “no product to relate to”(Avi) and “no visible way of exploitation”(Avi). The scope was described at “limitless”(Ai), leading to the expectation that “almost every problem would be different”(Ai).

Although the business processes of the two partners were individually considered straightforward, “integrated processes”(Ai) were considered highly complex. It was noted that there were “lots of incompatibilities between extant processes such as funding cycles, levels of oversight and

styles of management”(Ai). The aim was to “integrate two existing systems for added value”(Ai) and it was noted early on that “joint processes needed defining”(Aiii). However, several years into the HRP the “extent of joint-ness in areas of the current operation”(Aiii) was in doubt.

The complexity was felt to be exacerbated by the fact that “other related research partnerships were established concurrently”(Ai) and that “the boundaries of the system were not scoped”(Ai), leading to “too many stakeholders”(Ai) who were “overlapping and confused”(Ai). It was suggested that “at the time we felt we could manage five things at once”(Ai).

Overall the HRP was felt to be a “complex evolving system which essentially depends on two main elements: the contract with its stated constraints, limitations & goals and the resources in the system – essentially people and, to a lesser extent, technology”(Av).

6.2.9 The role of Systems Engineering

It was felt that the effective use of systems engineering varied through the lifecycle, to the extent that although “a systems approach was used”(Ai), one interviewee felt that “the systems engineering failed”(Aii) and another felt that the “hard systems engineering could have been better”(Ai). Overall it was felt that “there was inadequate definition of the problem domain”(Ai), and this “should have gone up two levels”(Ai). It was felt that “the key was to understand the problem”(Aii) but that the team “came up with a solution before understanding what we were trying to do”(Aii). Not doing “enough systems engineering” at the next level up was felt to be a “big failing”(Ai). “In the last year or two, we recognised that we never were doing systems engineering, we just thought we were”(Aii).

At the concept stage, it was felt that a systems approach had been adopted successfully and that “the techniques drove the vision”(Av). A worldwide analysis of stakeholders was done (Do___ 2002a). The team “did the requirements specification, functional & non-functional requirements, risk

analysis and prioritisation, viewpoint analysis, house of quality (QFD), etc”(Av). There was “a lot of consensus over the requirements”(Av) from the various parties involved and it was felt that the team “got the top end of the V right”(Ai) within the systems engineering process. Various tools and techniques were used at this stage, including a synthetic environment to create “virtual reality models”(Ai) of the building and “reviewing all the different aspects of the system, for example what would be in the laboratories etc”(Av). Requirements were captured, detailed, prioritised and traced back to strategy and objectives in a 51-page document (Do___ 2002b). Conflicting academic and industrial requirements were identified but these were to be addressed “through the organisation structure” which ensured “a balance of academic and industrial views” (Ja___, Si___ et al. 2003). However, the aspirations and expectations that were established had many dependencies identified which were reliant on understandings and agreements with groups and organisations outside the HRP, who were not directly party to the agreement. Ensuring that these commitments were honoured had led to “an unintended tactical, piecemeal approach” with numerous independent programmes from which it was difficult to derive leverage (Ph___ 2005).

However, there was a “discontinuity in systems engineering between concept and implementation”(Av) such that “in implementation and managing the place, systems engineering went out of the window and it became a business that had to fulfil metrics”(Av). The broad conceptual boundary for the HRP (Ja___, Si___ et al. 2003) was not operationalised, and in fact the implemented boundary was comparatively narrow. There was uncertainty whether “the performance metrics link directly to the requirements”(Ai) and it was noted that there were “no verification methods or plan for the requirements”(Ai). The requirements themselves were felt to be a “decent set”(Ai) although they “concentrated on output”(Ai) and addressed only WHAT in terms of “research outputs, themes and topics”(Ai) and not HOW these would be delivered. Overall it was felt that the requirements addressed “the products, but not the processes”(Ai).

“There was no architectural design in process terms”(Ai) which meant that no “research management architecture”(Ai) was created. It was “naively assumed that both organisations had processes. Integrated processes weren’t created”(Ai). The team “never looked at control structures and procedures from going live and then evolving”(Av) and didn’t “design the processes making sure they were the right ones for the capability in the HRP and the problems to be solved”(Ai). Following a review a few years ago it was felt necessary to “intervene to design the processes because it wasn’t working”(Ai), but although these “research project processes were a recent example of trying to improve alignment between objectives(Ai), this “first attempt still wasn’t working”(Ai).

6.2.10 Perceptions of Success

Overall it was felt that by “getting to know a small group better and sharing the same common interests and insights”(Aii) the HRP was “more value than a standard partnership”(Aii) and that “arguably nobody else was doing any better”(Ai). It had “not matched its business case”(Aiii) and had “fallen short of the highest aspirations, but was still there”(Aiii), suggesting that the “partners must have still seen value”(Aiii) even if they “couldn’t articulate the benefits”(Aiv). It was felt that it was “not a failed system, but one which had evolved outside the perspectives of those who worked on the early stages”(Av). Although “from different perspectives it had not fulfilled its potential”(Av) and had “never been able to hit the grand strategic issues”(Aiv), it was “always trusted and given the benefit of the doubt”(Aiv).

In considering the future, there was “an awful lot the team got right in the early stages of implementation”(Av) and it was felt to be “a great complement to its foundations that it could evolve”(Av). “Because it was a working system with lots of bits that were good, it was capable of evolving in many directions”(Av). Another interviewee was less optimistic and felt that it “could be made to work”(Aii) but would “take a lot of effort”(Aii), and that “it wouldn’t take much to make it go badly wrong”(Aii).

6.3 Case Study B

The HRP in Case Study B was a £32 million aerospace programme addressing key technological and regulatory issues relating to unmanned autonomous aircraft. It involved a consortium of major aerospace companies, working with a number of small companies and universities. The HRP was supported by Government investment at both central and regional levels to ensure that the aerospace industry maintains its global strength and develops world class technologies.

6.3.1 Objectives

The HRP in Case Study B had a “strong, clear”(Biv) “very simple goal”(Biv) and was “aimed at a single solution”(Bii) to “enable the market”(Bii). The “super-ordinate goal was to ‘do it first’ and provide national advantage by being the first market mover”(Bi) and “creating a standard”(Bi).

There were “three primary areas for research: technical, regulatory and demonstration (both to funding stakeholders and for public acceptance)”(Bi). “Government funding agencies all had different interests”(Bii) and partners all had competitive drivers. Although clear, the nature of the participants in the HRP meant that the “single objective”(Biv) was also “the only thing that could be agreed upon”(Bi). It was recognised that whilst the HRP “needed a shared reason and a common vision, the direct benefit didn’t have to be the same to all parties”(Bii).

The HRP aimed to deliver research at “low TRL, maybe 4-5 for the demonstration system. If the TRL was any higher, the group would struggle to collaborate”(Biv) due to competitive pressures.

There was a focus in the HRP on the longer term business opportunities. At the culmination of the programme there was an expectation:

- To understand and agree with the regulator the route to product certification
- To have encapsulated the lessons learnt into the UK regulations and to be leading the world regulatory development
- For the partners to be able (individually or collectively) to develop and sell products and services suitable for the new market
- To have conveyed to the wider community the benefits of the new market
- For spin-off opportunities to have been identified and for exploitation activities to be in place (*Case Study B End Goal 2011*)

6.3.2 The nature of the relationship

The HRP “brings together disparate competing bodies with a common goal”(Bi) and involves “all sorts of parties, including well over 80 companies, 10-15 universities and 7 government agencies”(Bii). Creating it meant “putting together diverse unknown stakeholders”(Biii): generally “people didn’t know each other, and were largely competitors”(Bii).

The “fragmented industrial membership quickly polarised into three groups”(Bii). Although there were “big problems to start with”(Biv) and the “first 6 months was very hard”(Bii), it was “OK when everyone understood the boundaries, including what they would share with everyone and what they would not give away”(Biv).

The HRP had “no official lead”(Biv) and since it involved “all competitors together”(Bii), “nobody allowed anyone to have the advantage”(Bi). Although it “had no leader, the three top jobs were filled by one company, voted in by the other players”(Bii). “Despite sensitivity of holding all three key posts, the company was good at putting strong people into these roles”(Bi), and

although “there were occasional leadership challenges, the vote always returned to the same leader”(Bii).

The programme of work comprised “16 separate projects, arranged so that there was at least one company per project”(Bii). “Not everyone was in every project: participation was based on mutual interest and capability”(Bii) whilst “ensuring that various people run projects”(Biv).

Remarkably, the participants were “not natural bedfellows and yet were able to work as one”(Bi). After three years it was “a very close-knit community: at a recent event you couldn’t tell where each speaker came from and they didn’t reveal their company as they spoke”(Bii).

6.3.3 Contracts, Controls and IPR

The HRP was contractually complex, with “63 signatures on the original paperwork”(Bii) and a total of “187 signatures required to launch the programme”(Bi). However, this did have the benefit that “once signed on the dotted line, it was difficult to walk away. If anyone had pulled out it would have collapsed”(Biv).

“Seven companies and eight universities were the basic partners”(Bii), and “each company had a representative on the board”(Biv). It was felt to be “very important that those who fund were directly involved”(Bi). All funding bodies had “equal status”(Bi) in governance, independent of the scale of their investment.

There was an “operating group below the steering board for tactical management. In many cases, the same people attended both meetings”(Bi).

Although “each project had separate intellectual property”(Bii), “the aim was not the development of IPR, but the opening of the environment”(Bi).

6.3.4 Culture

The culture of the HRP had evolved through the lifecycle from the “spectacular early meeting: venomous, ridiculously long”(Biv) with people “ganging up and switching allegiances”(Biv) through “forming, storming, norming”(Biv) to performing. It was necessary “to get through the early problems to make it a success”(Biv).

6.3.5 Resources: People

Within the HRP there was a “focus on people making things work”(Bii) at all stages of the lifecycle. After they had “struggled to find a programme director”(Bii), it was a “great credit to”(Bi) the individual who took that role that the programme developed effectively. In addition, the chairman “had pulled everyone together and did such a good job”(Bii), “using facilitation skills”(Bi) rather than being “directive”(Bi). These key roles were held on the basis of “merit-based selection”(Bi) and although “not without challenge”(Bi) the “incumbents were voted back”(Bi).

It was noted that these partnerships “needed very competent people to run them. Those who were very good at it all tended to have a systems engineering background and were able to look at the bigger picture”(Bii). “It needed someone who understood what we were trying to do”(Bii).

6.3.6 Resources: Funding

“Funding came from seven industry members and six government bodies”(Bi) It was a “mixed investment, large and small, all 50:50 funded”(Bi) There was a “big enough pot of money”(Biv) to attract traditional competitors and provide “good leverage”(Bi) on the funding.

The “funding hiatus in the middle was an issue”(Bi). The company which filled the leadership positions “took a patriarchal role, continued its funding and held the HRP together”(Bi). With only one exception, “all industrial

partners committed some level of funding during this period to help keep the teams in place”(Biv). This was “a pragmatic solution: wasted gearing but not wasted effort”(Biv).

The government funding and multiple partners provided “good leverage”(Bi) on the investment but added complexity. The funding bodies were “not used to working together: each had to approve the programme individually and align as far as possible”(Bi).

6.3.7 Lifecycle

It was noted that in the creation of the HRP, “one of few ways to make it work was to know the people and the organisations”(Biii). Nevertheless, the nature of the partners meant that “the first year was very tense”(Biv).

The HRP was a “six year programme in two phases of three years each. “The first 18 months was about understanding the problem”(Bii). During the first phase the HRP:

- Engaged with the regulators to understand the issues
- Developed appropriate technology to TRL 3+
- Culminated in an integrated SE demonstration of the art of the possible
- Created an internationally recognised position for the UK (*Case Study B The Programme 2011*).

When Phase 1 ended in 2008, “there was a funding gap for over a year”(Bi).

Phase 2 was scheduled to last until 2013 and involved:

- Agreeing a process with the regulator to establish suitability of various engineering solutions from the safety perspective

- Creating a process to identify and engage with potential UAS end users to establish more detailed and specific user requirements
- Starting work to increase the TRL of particular technologies to TRL 6
- Progressing solutions through live flight trials (*Case Study B The Programme 2011*)

“Phase Two had proved difficult for funding”(Biv) from one stakeholder. “Most stakeholders were relatively supportive but wanted Phase One to be evaluated first, leading to a year’s gap”(Biv). The “interim evaluation and quarterly reviews were good”(Biv) but since “nobody’s going to sign up to”(Biv) the full funding on the basis of “a woolly statement”(Biv) it was unclear “how the HRP could have got around them wanting to assess the impact before entering the second phase”(Biv). One interviewee noted that “we were wearing rose tinted glasses at the start and assumed that it would come in with a couple of months delay”(Biv). In contrast, it had “taken a very long time to get the proposal through”(Biv). “Realism might have helped, but interim funding would have dried up if we had been too realistic”(Biv).

6.3.8 Complexity

The HRP was “commercially complex with 13 separate funding stakeholders”(Bi), one of whom “flowed money through the company into two broad programmes, with multiple parts below that level”(Bi). This approach to “funding was the issue: the structural complexity made it a real challenge lining up lots of stakeholders and their internal funding processes”(Bii). In addition, “programme division was necessary to avoid transgressing European state-aid rules”(Bi). Any chance of a simple programme structure “was compromised from the start”(Bi).

Overall, the HRP was felt to exhibit both “industrial complexity and stakeholder complexity”(Bii).

6.3.9 The role of Systems Engineering

In terms of its research focus, the HRP was a “good example of looking at the total system”(Bii). It was noted that they “were the only people in the world tackling this problem from a systems approach: technology, regulations, integration”(Bii). It incorporated “sixteen separate programmes with an integration layer that happened around it and brought all the elements together”(Bii).

The HRP took a “Whole system approach” which considered the system and its context in parallel:

- Regulatory requirements
- System of systems integration
- Engagement of the regulatory authorities
- Visualisation and experimentation in synthetic environments with validation of certain key technologies in flight tests
- Collaboration with other international bodies (*Case Study B The Approach 2011*)

In structuring the HRP the team “used classical systems engineering structure”(Bi). This included “developing the operational concept to understand ‘how does it work?’”(Biii). “A lot of it was about capturing requirements”(Bii) and there was a recognition within the HRP that users views, public perception and ethical issues were all “major issues”(Bii) which were to be addressed further in the next phase. Both projects within Phase 2 include elements of demonstration and interaction with the regulator (*Case Study B Current Projects 2011*).

Integration was felt to be “pretty good”(Biv) with “everybody involved in an integrated demonstration”(Biv) which involved “defining interfaces and exchanging software”(Biv). “The companies leading the demonstration had

done it before. The necessary focus was achieved by ensuring that there was “one project looking after the demonstration”(Biv). The guys knew what they were doing, and understood the timescales and what would be feasible. It looked pretty”(Biv).

6.3.10 Perceptions of Success

“Phase One was pretty successful, with government stakeholders relatively happy that we did what we said we’d do”(Biv). There were “at least 100 suppliers and good interactions”(Biv) with the stakeholders.

“By the end of Phase One, the team of people worked really well together and wrote a really good completion report”(Biv). An “independent review described the HRP as ‘best in class’ for collaboration and working together”(Biv) and reported that it had “delivered more benefit than promised in all the different forms required”(Bii), in spite of the fact that it had been “difficult”(Bi) to “show economic advantage”(Bi) for some stakeholders. This success “was the result of the planned delivery of those requirements”(Bii).

The success of the HRP “both in terms of collaboration and technological output is unquestioned”(Case Study B Project 2011). “You could see the success”(Biv). The “focused goal was the main success criterion: everybody wanted to get there”(Biv).

6.4 Case Study C

The HRP in Case Study C was set up in 2007 between the company and the customer to develop a shared understanding of capability drivers, alternative solutions and potential exploitation routes for technology, and to reconcile these with available research budgets, resources and timescales. The aim was to remove duplication and to understand the impact of decisions on programme risk and on the sustainment of relevant industrial capability in the military air sector.

6.4.1 Objectives

The HRP was established as an advisory body under the joint chairmanship of the customer and the company, providing advice to all its member organisations. It had no direct authority over any research programme, but was established to advise on “the likely consequences for industrial and research capabilities of any planned course of action” and identify opportunities to meet emerging requirements. There was an intention that agreements reached within the group would be “enacted in the partner organisations through its members” (*Technology Acquisition Plan, Appendix 2: Joint Technology Acquisition Process 2007*). Significant effort was expended in the early stages on agreeing the terms of reference.

Within Case Study C there was a view that “the bigger picture win had become the main objective” (Ciii) of the HRP but there was still difficulty articulating “exactly what we wanted to do”(Ciii) and a feeling that there was a need to “reconfirm objectives”(Ciii). Whilst it was felt that “both parties wanted to understand the technology and sustainment issues”(Ciii) and to be “as efficient as possible with the research budget”(Cii) ensuring “that the spend on technology was to maximum benefit”(Ciii), there was a concern that although there “may appear to be common objectives, these may not necessarily align and may be in conflict”(Ci). It was felt that “at a senior level, only the overall intent was agreed”(Ci) but at a working level there was “a recognition of pressures on all of us that helps us all to work on win-wins”(Ci). It was felt that the HRP could “support tactical activities”(Ciii) and effort was being made to address capability sustainment by “finding out the best way of escalating potential issues fast so that something could be done”(Cii), recognising that the “danger was the difficulty in restarting independent capability”(Ci) once it was lost. A fundamental difference which “couldn’t be solved at this level”(Ciii) was that industry “wanted a longer term assurance that they could maintain capability”(Ciii) and government “wanted it to be there when they wanted it”(Ciii).

Significant time was spent in meetings jointly planning interactions with senior decision makers within the customer organisation, with the aim not only of getting support for specific recommendations, but also for getting recognition and support for the processes being adopted. It was felt that “it would be brilliant to see research getting done in the right areas”(Cii) such that it resulted in exploitation onto products, but it was “difficult to understand the tangible outputs”(Ciii) of the HRP itself and there was concern that “vague and flexible terms of reference made sustaining the momentum hard”(Cii).

6.4.2 The nature of the relationship

Within the HRP there was an emphasis on the protection of information that was shared from both sides, with a significant proportion of reports, presentations, meeting minutes etc being protectively marked and such markings being respected. Nevertheless there was “generally caution in relations, not sharing differences but exchanging information ‘without prejudice or commitment’ to avoid unbalancing the field”(Ci). Financial information was typically not shared unless formally requested.

There was some difference of opinion as to whether the HRP was “unique”(Cii) or “similar relationships”(Ci) existed.

Although “it took a while to build it up, both through exchanging views and doing things together”(Ci) there was felt to be “an element of trust”(Ci). This was felt to be in contrast to more difficult situations with “more than one industrial partner”(Ci) where participants were competitive and “wouldn’t open up or say anything in public”(Ci). “Often badged as ‘talking shops’”(Ci), such groups were felt to “work well when people were open and contributed, but not so well when people were defensive”(Ci).

The HRP was characterised by “lots of ex-committee work, just coming together to make decisions”(Cii). Meetings also comprised presentations on work that had been done within the company, presentations on initiatives

from the customer, and information sharing on personnel and organisational changes, meetings attended etc by both sides. Discussions on 'the environment' within which the HRP operated tended to dominate meeting time.

6.4.3 Contracts, Controls and IPR

Having been established under another joint organisation that had since "gone away"(Ci), the HRP "doesn't report to anyone"(Ci). This was a concern, since although it "could stand alone without a commercial agreement"(Cii), it "needed exposure to get buy-in"(Ci).

Opportunities for the HRP to fast-track solutions were limited as "procurement policy made 'single source' difficult"(Ciii), with a "pretty constant pressure to compete where possible"(Ci).

It was felt that the HRP "may have reached the stage where there could be key performance indicators"(Cii).

6.4.4 Culture

Culturally, it was felt that "although there were a range of people around the table, most were technical or engineers and spoke the same language"(Cii) so that they "understood each other at the technical level"(Ci). However, one interviewee reflected on the "organisational stovepipes"(Ci) *within* one partner and noted that he "realised that I didn't understand they had a different perspective of the world"(Ci). Regular reorganisation was felt to introduce a "new culture every time"(Ci) and it was observed that there was "almost an airgap" between the research and acquisition communities (Br____ 2010a).

Within the HRP, in place of the "usual adversarial relationship between customer and supplier"(Ciii), "both parties were willing to change, out of necessity"(Ciii).

6.4.5 Resources: People

Although “very busy with other work”(Cii) one interviewee noted that he enjoyed participating and the feeling that “we’re making a difference”(Cii). Among the “like-minded individuals”(Cii), some were described as “excellent, positive and enthusiastic”(Cii); others identified as “key member” and “couldn’t do without”(Cii).

Although the HRP comprised “all volunteers with no authority”(Cii) there was a feeling that participants “maybe also needed the authority to make decisions”(Cii) and that “alternates who ‘had to ask the boss’ could be a problem”(Cii).

It was felt that the “set-up may be unique: having access to the right people who have access to the right people ... and if all those knowledgeable people agreed on something, it must be right”(Cii). Working through individuals and through multiple contact points was seen to be important.

6.4.6 Resources: Funding

The HRP itself received no direct funding with travel costs borne by the parent organisations and meeting costs borne on a rotational basis by the meeting hosts (*Technology Acquisition Plan, Appendix 2: Joint Technology Acquisition Process 2007*).

Its effectiveness was, however, impacted by the funding situation within the partner organisations. The chronic funding situation had created “a nightmare putting together the research programme”(Cii) with people “spending most of their time costing options”(Cii) and “nobody willing to make decisions”(Cii) about options which were “politically sensitive”(Cii). The “unaffordable”(Cii) programme which was “increasingly overheated and eventually in chaos”(Ci) meant that “a difficult decision had to be made”(Cii). It was hoped that a major review would “bring clarity and stability”(Civ).

Although it was recognised that “funding would be the key issue”(Cii), with “acquisition driven by value for money decisions, reversed for political reasons”(Ci) “the company never came begging”(Cii) and had worked to secure alternative funding sources. Restructuring within the customer organisation may help with “more control given to those better placed to decide how the money was spent”(Cii).

6.4.7 Lifecycle

The HRP was felt to be in a “continuous”(Ci), “never ending cycle”(Cii). Although there was “always research to do”(Cii) within the portfolio of programmes, “lifecycles were continually churning, and there were peaks and troughs that needed managing”(Ci).

At the start, as the HRP “moved from political to real”(Ciii), “relationships weren’t fully definable”(Ciii). In implementation they were “still thrashing around trying to understand what information we wanted on the table”(Ciii). There was “no steady state organisation”(Ciii) and “people changed all the time”(Ciii). This was felt to be “setting up the process”(Cii) and “once the hard slog was done it would just be a question of maintaining it”(Cii), although there was a concern whether there would be “enough to keep it going”(Cii).

There “was a while when it wasn’t happening”(Cii) and “we lost our way and could have pulled the plug”(Cii). Participants “wondered if we were getting to the point when we ‘knock it on the head’ under the ‘too difficult’ category”(Cii). However, a way was found to “take it further forward again”(Cii). Nonetheless, it was felt that another “‘so what’ point”(Cii) would soon follow.

6.4.8 Complexity

“The inherent complexity due to the scope was fairly high”(Ciii). This was felt both in terms of “many stakeholders”(Ci) in both organisations and those stakeholders being “quite stovepiped”(Ci)

Although terms of reference had been agreed, one interviewee noted that without “firm Terms of Reference or a set of objectives”(Cii) there were “different perceptions of scope”. They felt that one individual was using this “privileged position”(Cii) and “persistently attempting to broaden the scope”(Cii) beyond what was originally agreed. This was consistent with the different domain responsibilities, within their parent organisation, of the participants.

6.4.9 The role of Systems Engineering

Although not explicitly part the HRP’s approach, one interviewee felt that whilst “most people badge systems engineering as process, at a reasonably senior level, scientists and engineers just think that way”(Ci). In contrast, it was noted that within the customer organisation “there was a requirement for through-life plans, but what was lacking were the tools and ability to use them in a joined up way”(Ci).

Both more broadly and specifically as a means “for expressing requirements”(Ci), “roadmapping had been invaluable. We couldn’t have done what we’ve done without it”(Cii). “The whole point was that it was fairly universal”(Cii) and although people “may use different tools”(Cii) the output was “still recognisable”(Cii) even if “colours and symbols were different”(Cii). Based on this, “gap analysis produced a tangible output that could make a difference”(Cii).

6.4.10 Perceptions of Success

A self-review conducted 18 months after the HRP was established noted that:

- there had been good technical interchanges on a number of topics
- there were better links between subject matter experts in the different organisations
- all the right people were around the table
- there were improved behaviours and a recognition of the different cultures
- transparency between the organisations had been achieved
- differences between the planning processes in the different organisations had been identified.

The challenge was to achieve “more tangible results”: specifically, an end-to-end implementation and other case studies to demonstrate the efficacy of the approach, and an agreed process by which to share, understand and influence future plans. Barriers to this included an ever-evolving process and schedule with complex and changing stakeholder set, resource constraints and financial pressures, together with ongoing sensitivities with respect to competition (Ba____, Ho____ 2009).

Overall, the HRP was felt to have had “a mixed level of success”(Ciii), “slowly making progress”(Ci) and having “delivered some benefits, but not all”(Ciii). The “size of the network and contacts was massive, enabling influence and money to be found”(Cii). It was “seen as valuable in itself” (Cii) and “even if it did nothing else, it would still have been worth it for access”(Ciii) to the right people in the other organisation. Nevertheless, the fact that there were lots of areas “where R&D needed doing and nothing was being done”(Cii) risked “being terminal”(Cii) for the HRP and there remained a concern that anyone should “think we’re just wasting time”(Cii).

6.5 Case Study D

The HRP in Case Study D was a multi-disciplinary £8.4M research programme established in 2006, jointly sponsored by a Government funding body and the company and delivered by a consortium of ten UK universities and company researchers (Ne____, Mc____ et al. 2009). The programme aimed to define, develop and demonstrate approaches to system of systems engineering needed to support network enabled capability, but was terminated at its mid-term review after three years.

6.5.1 Objectives

Fundamentally, the research motivation behind the HRP in Case Study D “clearly had good intent”(Dii) and “was a really good question to ask”(Diii). There was a “very strong feeling”(Dvi) that there was “a strategic imperative”(Dvi) and it was felt that it “was right to fund a major programme”(Diii) in this “important”(Dii) area. The parties involved “all wanted the programme to happen”(Di). One interviewee felt that the “overall objective was to create a partnership”(Di) in this area: in other words that the partnership itself was more important than the research.

However, “taking the macro view, it was dealing with a very indeterminate thing, built around a buzzword. The lack of clarity wasn’t tackled”(Diii). Many interviewees echoed this concern about the “nice big woolly statement”(Dv) which provided a “big open space and no focus”(Dvi), written around a fashionable topic area where “nobody knew what it was”(Diii) and where “nobody could specify the problem well enough to agree”(Dvi). It was “very complex and encompassed everything”(Dv) and sufficiently “unfocussed”(Dvi) as to leave participants “not knowing what *the* issue was”(Diii). Without a “common understanding”(Dix) and with participants having “nothing in common”(Dvi), the HRP lacked “a shared objective”(Diii). There was “a risk of people working to a local agenda”(Diii).

With “no clarity of scope and objective, there was nothing to act as criteria by which you evaluate and align research”(Diii) and it was impossible to “build a clear, coherent research agenda”(Diii). There were “many stakeholders and many objectives”(Di): it was “obvious that company people didn’t know what they wanted”(Div) and “major stakeholders didn’t know either”(Diii). “Right from the start there was a failure to communicate and develop purpose”(Div). Noting that “clarity of objectives was critical”(Dv) and it would have been “much better to concentrate on a few small areas”(Dv).

“Nobody said what the advantage would be to the company”(Dv): they “didn’t know what the end product would be”(Div) and “couldn’t articulate the key benefits”(Dii). It was felt that “no business needed it”(Dix) and that the work was “academic and ethereal”(Dii). It was a “big mistake”(Dv) to select work “at low technology readiness levels where it was hard to see progress”(Dv). Most of the company representatives “didn’t understand how it could be exploited”(Di). Expectations of key stakeholders were not fully understood (Case Study D *Independent Steering Group Meeting 4*. 2009).

6.5.2 The nature of the relationship

The university participants for the HRP were selected “at the proposal stage”(Diii). “A number of universities”(Diii) were “down-selected and grouped into teams”(Diii). Academic theme leaders were then “told ‘this is your team’”(Diii). There was “no underlying coherence in the selection of universities”(Diii) and the “agreement was seen to be a compromise”(Dviii). As a result the HRP was “not a partnership but a set of warring tribes”(Dviii). It was, however, “much more transparent and understandable”(Div) than the HRP in Case Study E and “didn’t suffer from the same problems”(Div).

Although the review panel believed the HRP was a “cohesive partnership” in which university relationships and adoption of the HRP branding were both particularly and unusually strong (Ne____, Mc____ et al. 2009), this view was not reflected by many of the participants. The “composite of company and

researchers”(Div) was “not a good research team”(Div), and there was conflict between “doing good research and doing the research the client wants”(Div). However, there was “no friction between academics, except for two universities where the wider area of work overlapped”(Di). The “ultimate mechanism would have been to be able to change the academic partners”(Diii) but this was not done. There was also a “bad interface between corporate research and company stakeholders who had no clue why it was being done”(Div).

One interviewee felt that the termination “meant that you could never gauge long term commitment”(Div) and was “put off going into a partnership where they weren’t under control”(Div).

6.5.3 Contracts, Controls and IPR

The HRP was felt to be “contract-led”(Dvi), but was based on an “arcane, muddled, Byzantine contract”(Dvi). The three-way financial and contractual structures, covered only by “an eight page proposal”(Dv), “standard grant terms and conditions”(Dvii) and “two page memorandum of understanding”(Dvii) meant that the company was “trying to run the programme with no control over the finance”(Dv). A fourth part of the intended agreement “was never agreed”(Dvii) and “never properly signed up”(Dvii). This was “hard to manage”(Dv) since it was “hard to say you have got control when you haven’t”(Dv), consistent with the view of another interviewee who suggested that “it never works if run by a third party”(Dix). It was suggested that “the company won’t do it again” in that way, but in future would “pay for separate parts of the programme on a monthly or quarterly basis”(Dv) in order to retain control.

The customer was “a banker, who needed to show that it had spent its money in a way that furthered science”(Dv), but was “not terribly interested in outcomes”(Dv). Its “success criteria were ‘completion’ and ‘money spent’”(Dv), requiring the work to be “groundbreaking new stuff”(Dv) and only

recently asking for “an impact statement to identify the benefits to UK industry”(Dv). The experience “made the customer realise they weren’t managing the company relationship”(Di) and it was hoped that this would “get them to manage better”(Dii).

It was suggested that “if you want to lead in systems engineering you have to give stuff away”(Di) and “influence tools and processes”(Di) in order to “reduce cost and increase collaborative opportunities”(Di). This implied that the “business winning strategy should be to make everyone use your system”(Di), but it was felt that a key company stakeholder “didn’t understand”. In contrast, there was a concern that the company were “over-generous with their corporate investment”(Dii) and should not be funding such a significant proportion of the money “if it was going into the public domain”(Dv), given that “the rest of industry could come along to the industry day and get the same benefits without paying”(Dii). The termination of the HRP “allowed the company to re-engage at a more sensible level”(Dii). Ideally, the company would “rather have had twenty partners, especially on something like this”(Dii).

There was a view that the customer and company were “too geared around big programmes agreed on ‘day one’”(Diii) for funding to be “flexible enough”(Diii) and that “milestones needed to be sufficiently high level”(Diii) at the outset. It was felt that “statements of work and funding allocation shouldn’t be firmed up too soon”(Diii) to avoid having to “live with the commitment”(Dii). Although there was “nothing wrong with a lack of clarity as long as you had flexibility and could ‘roll up your sleeves’ for a year”(Diii) to define the problem, there was “not enough recognition of the need for flexibility”(Diii) and difficulties came with “trying to manage as a well-defined project when it wasn’t”(Div). There was “no mechanism to achieve flexibility”(Diii), rendering the “need to move emphasis from one university to another, cutting across contractual and financial inflexibility”(Diii) unachievable. There was a failure to recognise “the different nature of the early stages of the lifecycle, where research was a convergent process to

build up understanding”(Diii). “In the last year it was being treated as a project: task driven, with fixed milestones”(Diii).

The “lack of clarity was promulgated through the concept of a ‘more integrated world’ but thinking stopped there. Beyond that, everything was so unclear it was possible to create the illusion of progress”(Diii). Although “most academics would do whatever you ask them to do and rarely took money or support and then followed their own agenda”(Dv), “local agendas dominated and drove the programme”(Diii). With “nothing to act as criteria by which you evaluated and aligned research, everyone saw it as a means to do what they wanted to do anyway”(Diii). “As the HRP got further on, the incentive to ‘do their own thing’ got stronger”(Diii). So “when it came to assess it, the company didn’t know how to”(Div).

6.5.4 Culture

One interviewee felt that “the cultural mismatch was within the company, not asking the right questions low enough”(Dv). It was noted that “there were two camps”(Dv) in the company: “those asking the right questions but not involved, too busy and too remote”(Dv) and “those for whom it was a pet subject, who also researched and published”(Dv). There were “loads of people in the company who were happy to do research in their own area”(Dv) and “got on really well with academics”(Dv). These seemed to feel that there was “no need to show benefit”(Dv); however, “up a level in the company”(Dv) it was clear that the benefits mattered but unclear “where the benefit was”(Dv). There was a concern that “we played at these things”(Dix), allowing “too much distance between the project and the business”(Dix). It was felt that there was “a lack of coherence across the company”(Diii) and that, having “no overall company integrator”(Di), “the company was not well structured to exploit research programmes”(Di) of this nature. The review panel felt that the programme would not deliver its full potential unless both the researchers and the business sponsor “took *joint* responsibility for

exploitation” and made the necessary resources available (Ne____, Mc____ et al. 2009).

A similar mismatch was reflected in the views of another interviewee who observed the “change that happened in the company”(Diii) between the initial “technical/research perspective”(Diii) which initially drove the programme and the subsequent “change of responsibility”(Diii) towards “a much more short term ROI view of research”(Diii). It was felt that within the company “the techies didn’t have enough clout versus the businessmen who didn’t see the value”(Div). Given this mismatch, stakeholder engagement “was not good enough” (Case Study D *Independent Steering Group Meeting 4*. 2009)

Within the HRP, one respondent noted that the “research teams knew each other better”(Div) than, for example, the HRP in Case Study E. However, this may have had a negative impact on those without extant relationships, leading to a “lack of respect”(Di) from one university for “other non-defence participants”(Di). In addition, and perhaps consistent with the involvement of an existing community, there was a lack of adventurous and challenging research within the programme (Ne____, Mc____ et al. 2009).

It was felt that “the aim to publish together”(Dv) within the academic environment was poorly thought through since there would be difficulties agreeing “whose name came first”(Dv). It was “silly to try to get a whole set of universities to come together in that sort of fashion”(Dv).

6.5.5 Resources: People

Describing resource capability as the composite of “numbers, skills and knowledge”(Dviii), it was felt that “resource capability could meet the compromise requirement set, but not what the original intent was”(Dviii). One part of the company “worked better relationships and the quality of their engineers was good”(Di); another “had the wrong group working on it and should have used business process rather than technology people”(Di). Overall the resources were “inadequate”(Dviii) although the majority of

research groups involved were large enough to have reached a critical mass (Ne____, Mc____ et al. 2009).

There was felt to have been a “huge turnover of research assistants”(Dix). Inexperienced staff were an issue since “one who was inexperienced could be carried but, with this type of partnership, multiple inexperienced parties could be a struggle”(Div). There was a “low tolerance”(Div) to the learning that was required.

The issues were felt to “boil down to a lack of leadership on both sides”(Dvi), reinforced by the view that one leader had “no credibility”(Dix) although others “felt he did quite a good job of corralling academics”(Dv), “ensuring that researchers talked”(Div) and had “a lot of time for him”(Div). Within the company the HRP needed “ownership at a more senior level”(Di) from those with “influence in the business”(Div). The HRP suffered “when leadership changed and didn’t support it, causing implementers to flounder”(Dv): “lots of people tried not to get too involved”(Dv).

The HRP was thought by one interviewee to be “badly project managed”(Dix) although another noted that “project control hit with a vengeance”(Diii) in the later stages. It was felt that there was a need to “make people responsible”(Dix) for programme outcomes and to “invest in support”(Dix).

Within the HRP there “were people who had worked together before”(Div) although not in all themes. One interviewee thought that “generally academics didn’t like working together”(Dv), and that “the stuff working together was a bit fudged”(Dv). Another felt that “more frequent exchanges would have been better”(Div) and that individual theme leaders were “too narrow as a communications channel between theme participants and the project as a whole”(Div). Better use could have been made of “academic expertise below theme leader level”(Div).

Nevertheless, they “generally all worked well together”(Di), “had kept in touch”(Div) and “would work together again”(Div) having “got to know each

other and what contributions each could make”(Div). Termination of the HRP was not felt to “destroy trust between individuals”(Div).

6.5.6 Resources: Funding

The HRP was funded jointly by the customer and the company, with one-third coming from the customer and two-thirds from the company (Wo____, Os____ 2009). One interviewee noted that the ‘customer’ funding the research was “not very good at multidisciplinary problems”(Diii) and questioned whether they were “the right funding body for systems problems”(Diii), suggesting that alternatives might “deal with more indeterminate problems”(Diii) more often.

Recognising the need to get “sufficient scale of effort behind substantial business and research challenges”, there was an open invitation to potential collaborators from industry and academia to “explore mutually beneficial ways of working together” (He____, Gu____ et al. 2007).

When the company decided to withdraw at the review point, this created “an absurd situation, a ridiculous case where the customer had to pull funding because they didn’t have adequate backup funds to cover it. The company could have pulled the funding on a whim”(Dvi). It was felt that “in spite of the company pulling out on the business side, the customer should have given the project time and resourcing to continue based on the review feedback”(Div). “They could have found a replacement or do research that could be done with the available money”(Div) but this didn’t happen. Reflecting on this, the customer subsequently noted that a multi-partner approach to collaborative programmes with industry would be considered in future (Case Study D *Independent Steering Group Meeting 4*. 2009).

In addition to the business model which relied on “a bit of money from lots of different parts of the company”(Diii), “lots of universities invested and there were a lot of resources that weren’t paid for”(Di). Nevertheless, there was a significant underspend during the first phase of the programme (Ne____, Mc____ et al. 2009)

6.5.7 Lifecycle

The company and lead university “took the original proposal”(Dviii) to the customer, after which “lots of different partnerships and lots of different ideas got involved, which didn’t necessarily match the original. Outsiders from the original group brought in another set of requirements, money, stakeholders etc. Eventually there was a resolution but there was a lot of bad feeling, resource disposal and wastage, with good ideas and people being put aside”(Dviii). Another interviewee took the view that creating the partnership preceded “looking for a problem”(Di).

As a result, the HRP “had a long gestation period”(Di) which was, in part, seen as a good thing, since “by the time funding arrived the academics were used to working together”(Di). However, once “the money was there, the failure to create a suitable research programme in an acceptable timeframe was getting embarrassing”(Di) for the company. They “failed to fully exploit opportunities to shape research direction”(Div) and the project start was slow (Ne___, Mc___ et al. 2009).

The HRP was structured around “research and then an interim demonstration”(Diii), but “in the last year, effort was dominated by project reporting and demonstrations”(Diii). “Lots of effort was spent producing reports, milestone reports etc to serve project control”(Diii). Although the “universities were not integrators”(Dv) and were “not motivated”(Dv) by trying to “push from TRL 0-3 up to technology demonstrators”(Dv), “demonstrations became the programme for a good nine months”(Diii). “Hard expectations drove behaviours”(Diii) and “actual research dwindled”(Diii).

After 3 years, there was a review of the HRP. For some, there had been “a growing disquiet that it wasn’t what we wanted”(Dv) and “we felt that there was nothing that said we needed to continue”(Dii). “It was not felt to be a good programme”(Diii) and based on “the lack of obvious benefit, funding level and IPR arrangements it didn’t add up”(Dii). Although the customer

“rarely terminates programmes early, it can”(Di). It was thought to have been done “in a tactful way”(Dii).

Others disagreed. Since it was “always agreed that it would be an independent review”(Di) it was felt that the steering body and review panel “didn’t have enough autonomy”(Div). They “went into the review having already decided”(Div): it was “odd”(Div) that the company’s business decision was weighted “over evidence from the internal review”(Div). “The all or none nature of the review was strange”(Div). “The philosophy of the review was to redirect the work or terminate it only if “it was failing academically, for example it had no publications”(Di). They felt that “the review was positive and strong with only one area of concern, and that was short term exploitation - which seemed to become the reason for closure”(Div). “Never having known one to be stopped before”(Div), it came as “a shock”(Div) to some in both the company and universities: to others it was “disappointing”(Div). It was felt that “the customer failed the project”(Div) and that it was “silly to kill it after three years, when ‘where you were going and how you were going to get there’ was understood”(Div).

It was recognised that as a result of early programme termination “reputations can suffer as the result of an unexpected decision” and so a “planned and structured withdrawal process” was needed to allow researchers to transition to other work, for the reporting of work done to be completed and for outputs to be disseminated (Case Study D *Independent Steering Group Meeting 4*. 2009).

6.5.8 Complexity

Although the subject of the research was “not really that complicated”(Dii), the HRP was felt to be “inherently very complex with lots of technical and organisational complexity”(Diii). There was “more than one objective and no common language to express them”(Diii). “Given the lack of clarity, complexity flourished”(Diii) and “problems inherent organisationally were very

difficult to resolve”(Diii). “Every stakeholder had a different view, either slightly or radically”(Diii). With “100 people, there were 101 interpretations”(Dv). The “stakeholder complexity was very high”(Di). This “lack of a working definition” was ultimately cited as one of the problem areas for the HRP (Ne____, Mc____ et al. 2009).

The programme structure comprised of four Topic Groups, interlinked by four Cross-cutting Themes which were focussed activities of limited duration (He____, Gu____ et al. 2007). The relationship between the two was not obvious and gave the impression of unnecessary complexity and unresolved differences over the architecture of the programme.

6.5.9 The role of Systems Engineering

Whilst requirements were defined for the HRP, there were a number of issues. It was “not set up on coherent, agreed requirements”(Dviii); in fact one interviewee described the requirements as “tosh”(Dix). The requirements were “put in after the programme was established”(Di) and were “not clear or agreed”(Dviii) and “not understood”(Dix). Some company stakeholders had “hundreds of requirements”(Di) which were “useless except in a specific domain”(Di); others had “no requirements”(Di) or developed requirements “eventually”(Di); and another group “had no requirements but had nine research questions based on them”(Di). Other company stakeholders “couldn’t think of requirements but took a longer perspective and didn’t expect immediate use”(Di).

Recognising that “if you got into too detailed requirements for research you didn’t do research”(Di) because it over-constrained the solution, the “requirements were reformulated”(Di) and “high level business requirements were decomposed into research questions”(Di) “set at the right level”(Di). However, requirements verification and validation “to ensure the outputs would meet the requirements”(Dix) was not done. “Problems and solutions weren’t identified and didn’t intersect”(Dvi).

Although recognised as a “wide network of organisations, a system of systems in itself”(Diii) the HRP was “not scoped as a problem, identifying a boundary which defines research topics and organisation”(Dix) and deciding “what was in or out”(Diii).

Having “recognised the problem”(Div) there was a “weak attempt”(Diii) to clarify the objectives of the HRP, but with “no methodology”(Diii). A workshop with approximately 60 people “captured people’s knee-jerk reactions to some questions, but didn’t flesh out what was meant by the words”(Diii). Then “half a dozen groupings”(Diii) were created in an “equally superficial”(Diii) way, resulting in “half a dozen words representing the key attributes”(Diii). It was the “opposite to rigorous: wishy-washy! Horrendous, glib and very superficial. Completely inadequate given the complexity of the objective and scope”(Diii) and “didn’t succeed well for the project as a whole”(Div).

The demonstration “brought everyone together and helped researchers see how they fitted into the wider picture”(Di). It provided clear examples of multi-disciplinary work (Ne___, Mc___ et al. 2009) which were “beneficial for demonstration but also to integrate the programme”(Di). The “all-embracing scenario could be treated just like a story and used to generate ‘what-ifs’ and exemplars”(Div). Since there was “no interaction”(Dv) but it simply addressed “how they fitted into the story”(Dv), there was a question whether this truly represented integration. Nevertheless the scenarios enabled visibility of “how things cut across”(Div) the different areas of research and “what research themes were producing”(Div). Driven by the recognition that it was “important to demonstrate to stakeholders” (Diii) during the last year there “was a very strong emphasis on demonstration”(Diii) at a level that had not been previously anticipated. As a result, “most research stopped to service the demonstrator”(Diii).

For the HRP as a whole, systems engineering “was done a bit at the concept stage but not in later stages”(Dviii). By the end of the first phase, the overall

programme planning for phase two was impressive but this was not matched by technical planning of research and demonstration exemplars (Ne____, Mc____ et al. 2009). “Systems engineering was used”(Diii) at a theme or task level by some groups. However, “nobody wrote down the risks”(Dvi) and some “would argue that we didn’t manage the key stakeholders very well”(Di). There was an unmet need for members of the HRP management team to assume responsibility for risk management and exploitation management (Ne____, Mc____ et al. 2009). “The moment anything went wrong they had nowhere to go. No mitigation and no planning”(Dvi).

6.5.10 Perceptions of Success

Timing was critical. Although created when the research topic was “the big thing”(Di), it was “spread over a long period of time”(Dii). By the time of the review, “nobody was making those noises”(Diii) any more and the topic “went off the boil in the UK”(Dii). The lack of clarity had “made it difficult to build a shared objective”(Diii), and “into that situation all problems blossomed”(Diii).

Although an “independent review was positive and very impressed by some areas”(Di) and the “independent steering group was also very impressed”(Di), “right from the start the HRP had been ready for a fall unless clarity was created – and that wasn’t done”(Diii). “Good, high quality scientific research”(Dvi) had been undertaken and “individual stakeholders were working hard to deliver”(Dii) resulting in “some local good work”(Diii). The “most successful”(Di) areas of work were those who “set the question at the right level”(Di) and “best outputs”(Di) came from those who “brought different perspectives”(Di) to the problem space. The research community had established “significant momentum” and were “striving hard to deliver actionable new knowledge”, but at the time of the review there was a lack of both academic dissemination and practical exploitation of programme outputs (Ne____, Mc____ et al. 2009). Although one interviewee felt that “publications were on target”(Di), this was inconsistent with the findings of the review panel who noted that even the modest targets set were not being met (Ne____,

Mc___ et al. 2009). However, it was felt that working within the HRP enabled researchers to conduct better systems engineering than would otherwise have been the case, and to integrate their outputs into taught material within their university (Ne___, Mc___ et al. 2009).

Although “the quality of academic output” was not in question (Wo___, Os___ 2009), it was “recognised that it was not enough to show good research”(Diii) but they “actually needed to demonstrate it”(Diii). The effective utilisation of this type of research was identified as “a wide challenge beyond defence and beyond the UK” (Case Study D *Independent Steering Group Meeting 4*. 2009). Key stakeholders were “not convinced that it would materially change the direction of the company”(Dii) and “no immediate application”(Div) was identified. Without clear transition and exploitation routes, the company felt that further investment was not justified (Case Study D *Independent Steering Group Meeting 4*. 2009). Although the demonstration was perceived by some as “really successful”(Di) and it meant that “questions were now firmer”(Diii), the HRP “failed because the compromise was not what they wanted, the resources were not what they wanted, and for political and economic reasons”(Dviii).

“There were good bits and bad bits: it was clearly not all bad”(Div). Seen as “in some ways, very disappointing”(Div), it was “not a good experience”(Diii). “In hindsight, it was always going to be a sorry experience”(Diii).

6.6 Case Study E

The HRP in Case Study E was established in 2005 by the customer. It was a virtual centre of excellence, managed by an industrial consortium and funded jointly by the customer and industry participants, providing an overall budget of £60M. Its core goals were to research innovative technologies relevant to autonomous systems and, through the adoption of systems engineering approaches, to facilitate pull-through of the technology into military capabilities.

6.6.1 Objectives

The HRP in Case Study E was “clearly goal-oriented”(Eiii) and driven to “generate knowledge via research” (Case Study E Overview. 2005). Although there was “only one HRP objective, the partners had more than one”(Eii). These were described as “a spectrum: partners didn’t always declare their objectives – you had to speculate what they were”(Ei). These undeclared objectives were thought to vary between different organisations, with large, prime contractor companies wanting to demonstrate “working effectively”(Ei) with others and “supporting a systems approach”(Ei) whilst establishing the future possibility to “sell products and make a profit”(Eii); small companies experiencing “working with primes”(Ei) and universities and “enhancing their reputation”(Eii); and universities ranging from seeing it as “a source of money”(Ei) and “a productive area for academic research”(Eii) to being “motivated by systems ideas”(Ei). One university’s goal was to draw “from multiple funding sources”(Eiv) including the HRP to work in a particular research area. Within the HRP, “differing objectives were recognised, understood, managed and resolved, although there may be some who aren’t entirely satisfied with it”(Eii). This was done by “working out what the need implied for functionality; applying academic rigour but also focussing on outcomes”(Eii). It was understood that partners within the HRP “worked to totally different metrics. Academics wanted PhDs and refereed papers. They wanted to be the ‘world expert in X’ and were not interested in the rest of their theme, let alone other themes”(Ei). Recognising their need to be “on the cutting edge of hot activity areas”, the HRP needed to help them to spot challenges and undertake work of greater benefit” (Br___ 2006c).

The role of the customer was felt to be important, but he was “not sufficiently engaged to know what he wanted”(Eiii). “Setting boundaries for research objectives was tough. Good applied research needed customer feedback. It had been a bit vague”(Eiv). There was a “weak connection”(Eiv) to the customer’s technical advisers and their “engagement with the research was

minimal”(Eiv). Having provided the funding and participated to some extent in the review process, the customer was “not very involved”(Ev).

From the company’s perspective, the HRP was a way “to get work done and to see if this mechanism would work in getting people together, whilst providing an opportunity to direct and manage research”(Ei). It was felt that the aims of all the large partner companies were “to see a net return, to be seen to be partnering and to ensure nobody else was getting an advantage”(Eiii) as well as recognising that participation in several such partnerships was necessary before a company would be given the opportunity to lead one. It was felt that the company “didn’t see it as seeding or growing the research community”(Eiv) in this area.

Another interviewee felt that there was “some commonality of objectives at a level which was meaningless”(Ev), but “competition for prioritisation and allocation of funding “(Ev) at the next level, where “common objectives emerged for themes”(Ev). As a result of this flow-down, “research objectives on projects went through three or four translations and probably didn’t match the higher level”(Ev).

One interviewee suggested that the objectives were “not at the level of research challenges”(Eiv) but were rather “keeping the company and customer’s technical advisers happy”(Eiv). For other participants, competitive positioning and the reinforcement of their network was important (Br___ 2006a) and teaming itself was “hugely beneficial”, enabling them to learn from other partners, and to be drawn into and to influence their thinking (Br___ 2006d). Name recognition and the ability to demonstrate capability in managing and delivering research opened up the possibility of future opportunities. However, the actual value of the competitive advantage was dependent on the scale of the market and size of the advantage obtained (Br___ 2006a).

6.6.2 The nature of the relationship

The HRP was “a partnership in name only”(Eiii) but “run ‘in the spirit of partnership’ which meant that the prime contractor agreed it wouldn’t hold undue influence over the other players and was prepared to act for the greater good”(Eiii). Other interviewees described it as “a partnership between the customer and the company”(Ev), and “an effective partnership of big companies, SMEs, academia and the customer”(Ei) with relationships between them that “could be drawn as a messy picture of overlapping circles”(Eii). Several of the organisations were different business units of the same company, but “treated each other with the same distrust and disrespect as anyone else” (Br___ 2006c). Nevertheless, there was felt to be more cohesion in the strategy board for this HRP than for that in Case Study B, even though the interests of the participants were much less focused (Br___ 2006d). Additional work opportunities were offered where possible to those showing a “propensity for cooperation” with others (An___, Do___ 2008).

The company “regarded it as an experiment”(Ei) and “subsumed the role of a minor research agency with the aim of providing research for a third party (the customer) on a vague topic”(Eiv). The HRP was “part of a grand strategic approach”(Eiii) which “provides an acceptable face of business: behavioural, a goodwill relationship. It changes the attitude of relationships and allows trade on other things”(Eiii). It was “an enabler, not a delivery arm”(Eiii).

A “parallel, un-contracted path”(Eiii) provided data from the customer’s technical advisor but although structured to mirror the HRP structure, this was not always as effective as it could have been (An___, Do___ 2008). One interviewee felt that the company “acted as a buffer”(Eiv) and seemed to “prevent conversations”(Eiv) with the academic researchers who “gradually lost confidence in the company’s ability to judge requirements”(Eiv). There was a concern that “not enough time and thought was given”(Eiii) by the

customer. “We had to predict internally what they would want if they could express it. We got decisions on the wave of a hand”(Eiii).

In order for the HRP to be effective, participants needed to “subordinate outcomes to the HRP rather than their companies”(Eiii). It was obvious that “some were better at this than others in terms of both personal behaviours and influence”(Eiii), resulting in “conflict galore between participating businesses”(Ev) and “the worst example of partnership I’ve ever seen in my life”(Ev). There was “no doubt that partners came at it with a less magnanimous view, and that the prime had to moderate their view far more to make the overall partnership work”(Eiii). “In order to have that role, the ‘big player’ had to moderate to make it acceptable for the others, motivated by a belief that there was a bigger picture and that it was something that would serve the company well”(Eiii). For all the partners the “fear of not being involved”(Eiii) was a huge driver but it was nevertheless “very hard to describe the steering group as a partnership”(Ev). One company “tended to stand mostly on its own” and although “teamy” were not really “partners”. Nevertheless, they were considered a good part of the HRP and their research area “would be well run” (Br___ 2006b).

The relationship between the leadership and academic researchers was not entirely happy. One academic noted that they “always felt on trial, and that they needed to survive. The workshops felt judgemental rather than for constructive sharing”(Eiv). Another likened the HRP to a plantation, describing the customer as the “plantation owner”, the company as “plantation manager who writes the rules”, universities and research centres as “slaves”(Ev), and the theme leaders as “overseers”(Ev). Although “they chose to run the HRP through the overseers”(Ev) there was “no partnership between the overseers”(Ev) and in fact the “control system was in conflict with itself”(Ev). “Pre-existing relationships between the slaves and owner”(Ev) were not taken in account, and as a result the “slaves revolted”(Ev). In effect, “they couldn’t ‘buy-in’ research the way they thought they could”(Ev).

Throughout the HRP, considerable effort was put into communications, both internally and externally. This included the maintenance of a contacts list, used for invitations to conferences and showcase events and for the distribution of HRP newsletters, and internal mechanisms such as a shared data environment and wiki (An____, Do____ 2008).

6.6.3 Contracts, Controls and IPR

The HRP did not exist as a contracting entity in its own right (Br____ 2006a) but was structured around a prime contract with the lead company. It was “contractually fairly straightforward”(Ei) and “hinged on effective programme management”(Ei). The contract itself was “based on the contract from a predecessor programme, making negotiation very short and easy”(Eii). The HRP was “very stable in terms of operation”(Ei) and the “core reporting mechanisms of milestones and the quarterly technical digest operated throughout”(Eii), together with “basic stakeholder contact management”(Eii). Other things had “changed quite a bit as we went gone through”(Eii), but recognising that “tools and mechanisms could be used in other partnerships”(Eii) “some things that worked well were subsequently used elsewhere”(Eii) in the HRPs in Case Studies B and F. Overall operation was felt to be “complicated, not complex”(Ev).

Contractually it was “not that complex”(Eiv) but since it used “three-tier contracting”(Eiv) it was “not efficient, with lots of contracts”(Eiv). It was felt that “considerable commercial and management effort was dedicated over quite a long period” to establishing the HRP’s agreements and into “debating minute detail of wording of some clauses in them”, and that it seemed “disproportionate to the benefit obtained” (An____, Do____ 2008). Although “every provider had their own standard”(Eiv), there were “lots of instances rather than lots of types”(Eiv). Commercial relationships between the prime contractor and other partners were not always good, and certain contractual terms relating to IPR were “really disliked” (Brown 2006d). With “typically fifty to sixty research projects active at any one time, there were 300 live

contracts with associated invoicing etc”(Eii). The contractual cycle meant that these all had to be updated each year (Brown 2006b). At the start the HRP was felt to have been “naïve about the financial management”(Eii) and “some of the disciplines and process management should have been set up earlier”(Eii). A time-based financial model of the research programme was developed and this was very valuable to support the planning processes (An____, Do____ 2008).

The HRP’s “role was bounded by TRL 1-3”(Eiii). It was noted that a possible evolution of this HRP “aimed to go to higher TRL, but if you went much further it would risk conflict between consortium members”(Ei). Intellectual property was owned by the organisation generating it, but the customer and other HRP members had user rights (Case Study E *Overview*. 2005). All research suppliers had both “a business agreement”(Eii) and “an agreement with the customer to guarantee the customer’s rights”(Eii). The collaboration agreement addressed IPR and there were some “limited examples of merged IPR”(Eii) in some of the demonstrations. It was felt that the “current IPR agreements were largely OK for this as long as goodwill remained”(Eii), although “the jury was still out on this and issues were still expected”(Eii) to arise.

The HRP’s centralised, independent technical leadership was beneficial but also faced constraints. Research was organised around six themes, with three areas of cross-cutting systems engineering work (Case Study E *Overview*. 2005). Although theme leaders would progress potential research areas, contracts were “approved and issued centrally”(Ei). The process was “not totally democratic”(Ei), providing the ability to “steer things and have the final say”(Ei) whilst “understanding the aspirations of consortium members and the need to achieve balance between the themes”(Ei). There were “extra mechanisms to demonstrate fairness within a reasonable limit” and this applied both between themes, and between large and small companies and universities. The funding of small and medium-sized companies was typically “around thirteen percent, but self-limiting”(Ei), constrained by their

ability to do the work. During research task execution, this independent leadership could also deal with instances of consistently poor performance. It was noted that the customer “couldn’t do what we’ve done, and chuck out underperforming studies”(Ei), and that “it would be difficult for companies too”(Ei).

It was felt that the HRP would be “better if organisations were more open to sharing best practice”(Eii). The “closed nature of the conference”(Eiv), in terms of the sources of papers, was also felt to be a mistake: it “should have been an open conference for systems engineers”(Eiv) in order to draw in and leverage from other related work, and to “lead to a field of research inspired by”(Eiv) the HRP, “without which, the critical mass will be lost”(Eiv). It was noted that the HRP in Case Study D had “the same problem”(Eiv).

6.6.4 Culture

Within the HRP the “culture was quite complex, with customer, industry, research organisations and academia all different”(Eii) and a “need to translate customer culture and goals down to research”(Eii). Another interviewee felt that the representatives of larger companies “had a different attitude, not a different culture”(Eiii) and that “a chain of incidents put them in the job, so that as individuals they were very similar”(Eiii). Although there were “a significant number of overseas researchers”(Eii) involved in the HRP, there was not felt to be “much multi-national culture”(Eii). In fact, there was a view that organisational culture dominated national culture and that within the companies, “organisational character also worked internationally”(Eiii) .

One interviewee “never felt there was the development of a community of enquiry and interest”(Eiv) and that the “sharing of ideas never went on”(Eiv) in spite of the “huge trust component”(Eiii) which another interviewee felt characterised the HRP. Of the academics who were not interested in other themes, “some didn’t work and exited. Others changed”(Ei). There was concern that the HRP had too much of a contractual emphasis and that some

theme leaders were seen as project managers rather than part of the extended research team. Such “constructive relationships” were felt to be important for output, not only within a theme but also across themes (Br____ 2006c).

Within HRPs in general there was felt to be a “danger that you only collaborated with an element of an organisation which was allowed to ‘play’ and didn’t permeate the organisation itself”(Eiii), so that HRPs were “played by adjuncts to organisations, not the organisations themselves”(Eiii). Whilst the adjuncts were able to participate because they were “allowed to be different”(Eiii) they “couldn’t achieve success because they didn’t change the direction of the juggernaut”(Eiii) and therefore were not “dealing with the real problem and changing organisational behaviour”(Eiii).

6.6.5 Resources: People

There was significant difference of opinion regarding the effectiveness of the leadership team between industrial and academic interviewees. Whilst one felt that overall the “team was very good and mutually supporting except for one bad apple”(Ei) for which “a variety of means were used to mitigate the effect”(Ei), others felt that “research leadership was missing”(Eiv) and that it required “more than just good management of the project”(Eiv). One felt that “company people didn’t have enough freedom to allow greater variability in direction”(Eiv), but there was also a recognition that “individual theme leaders managed differently: some were better than others but since it was ‘Contribution in Kind, you couldn’t dictate’(Eii). Another interviewee suggested that the HRP was “made up of a series of subsystems, some of which were in complete conflict – effectively an interacting system with more conflict than collaboration”(Ev). These “subsystems had local partnerships and occasionally partnerships between them”(Ev).

There was a view that industry people who were “academically aware and had those behaviours and skills”(Eiii) were more effective in HRP roles and

that “certain roles required the ability to work with people across a range of areas as a ‘subtle bulldozer’”(Eii). This required “not just systems engineering skills but also interpersonal, communication and organisational skills too”(Eii) and was not helped by the fact that “systems engineers were trained to be conservative and risk-averse”(Ei). It was suggested that there “may be a need for a person description for these roles”(Eii) since the “wrong person could stymie progress”(Eii). Successful exploitation of low-TRL research was felt to benefit greatly from the involvement of individuals who were already engaged with related higher-TRL research in their companies (An____, Do____ 2008)

For those in leadership positions it was “a balance of interest between the greater good, public sector duty and longer term interests of the company”(Eiii). However, with experience in this type of role this was not seen as a problem. Without a “project hierarchy by right”(Ei) HRP leaders felt the need to “carry people with us by diligence and effectiveness”(Ei). Several leaders were specifically identified as “respected” (Br____ 2006d) and “important” to the programme (Br____ 2006b).

Although the “same people stayed with it all the way through”(Eiv) in some areas, in others there was “a high churn of people”(Eii) and this was a particular issue in the theme leader roles where “newer theme leaders were heavily disadvantaged without the programme history”(Ei). The effectiveness of the HRP was “partly down to individuals in roles”(Eii) and it “had worked best where there was consistency of direction”(Eii). In one case, however, there were “four people in that role who got pulled off to do other things, then the wrong person with no motivation”(Eii) was appointed, from which the HRP “lost some time”(Eii), possibly up to 12 months. For most theme leaders their involvement in the HRP was part time, and it was a challenge for their parent organisation to “try to make a full-time job” from this and similar or related roles (Br____ 2006c).

There was a view that the HRP “needed to approach the complex customer and material separately to the research community development, and explore jointly the domain and application”(Eiv), but that “lots of different participants”(Eii) meant that it was “hard to do that with something the size of the HRP”(Eiv). Effort was put into meetings where technical specialists could “come into contact and ‘rub-off’ on each other” (An____, Do____ 2008).

One interviewee noted that the “repetition of players was quite high”(Eiii) between HRPs and questioned whether it was “good to have the same players”(Eiii) in this type of partnership. Although this may enable the team to become effective more quickly, he felt that the “weight of evidence said ‘no’”(Eiii) and that “an element of old and new”(Eiii) was needed.

There was a concern about the “adequacy of the research base in academia” to support the programme (Br____ 2006b), and recognition of the importance of “attracting the interest of people with the right skills” and retaining that interest and involvement as the programme developed (An____, Do____ 2008). It was felt that the HRP should “have had much more commitment to education and training”(Ei) in order to grow the national capability in this area. The Engineering Doctorate programme was felt to be “a way of combining research and education to feed good people into companies”(Ei) but “hadn’t really worked for recruitment”(Ei) in this case. There was a feeling that the HRP was “still too dependent on overseas scientists”(Ei) who were “a good source of money for universities”(Ei) but “couldn’t be recruited”(Ei) by the industrial partners working in defence resulting in “no proper exploitation”(Ei) of the research. In part, the “rapid loss of expertise built up over several years”(Ei) was attributed to “waiting until the end of a contract to decide on continuation”(Ei), since “three to six months before the end, universities told their Research Associates to find another job”(Ei).

6.6.6 Resources: Funding

The HRP had a total of “six funding stakeholders”(Eiii), providing “customer direct funding, with Contribution in Kind from the partners to equivalent value”(Eii). For the partners, there was often a lot of “smorgasbord management”: trying to “operate as seamlessly as possible” between related programmes and get coordination between different funding sources (Br____ 2006c).

The HRP was “running a very lean management team. Artificially lean. The project manager was a charge on funding but put in many more hours than charged”(Ei) and the technical director only charged for certain things, and for example “not for time spent reading reports”(Ei). As a result it was an “effective consortium running on incredibly light overhead: averaging 5.4% over six years”(Ei) “with most of that funding the independent technical director”(Eiii).

The funding enabled research organisations to work in partnership with universities: something they were keen but generally unable to do as universities needed funding to support research staff and students (Br____ 2006a).

As the HRP approached the end of its six-year contract, there was recognition that the customer may not have had funding to continue, but that “our job was to try if asked to do it. We all understood the challenges”(Eiii).

6.6.7 Lifecycle

Although “different from the HRP in Case Study A, this HRP had a lifecycle in the same way”(Ev) although it was considered to be “artificial, and driven by the customer’s funding regime”(Ei).

Before bidding for the HRP, there was “a big argument about who the partners should be” and who should lead, based on both technical and

political factors (Br___ 2006b). The resultant team was considered to be “excellent technically, but a commercial ‘B’ team” which “signed up to the launch without commercial cover in place”(Br___ 2006d). The bid team drew experience from individuals who had recently bid for a similar HRP and lost, in part because they had made “too good a case for exploitation” such that the customer expected that the work would be done anyway with internal company funding (Br___ 2006c).

Having “identified thematic areas and asked academia for research proposals at the start”(Eiv) it had an accelerated creation phase and was “set up and running from nothing in the first year, at the same time as starting research”(Eii). This was a challenge because it “started at the wrong time of year for academic recruitment” (Br___ 2006b), and the “unknown” delay between bid submission and contract award led inevitably to the bid team “drifting apart and getting engaged in other work” (An___, Do___ 2008). The research focus of the HRP was “vague at the start”(Eiv) and ideally needed “a through-life connection to the customer”(Eiv). The need to establish a three-year programme at the start “seemed to surprise people”, resulting in a programme which “seemed to be thrown together in a panic” and which “differed in detail and in spirit from the original intent” (Br___ 2006b). The HRP “should have thought about the customer stakeholders earlier on”(Eii), as this would “probably have provided a better idea of areas for meaningful outcomes and focus”(Eii). Nevertheless, it was felt that “it was always going to take 1-2 years to get everyone on the same page” (Br___ 2006b).

Since the contract was for “three years with an option for a further three”(Eii), “after about 18 months or two years”(Eii) the focus moved to “persuading the customer to continue and explaining what would be done in the second phase”(Eii). At that point the success of the annual conference was considered to be key, not only in terms of the conference itself, but also the interactions around it at all management levels, managing expectations carefully to ensure a positive response from the decision makers (Br___ 2006c). The two-phase approach led to uncertainty in planning (An___,

Do___ 2008): the customer had been told by the HRP leadership that “two to three year contracts were inappropriate for university research, since this enabled PhD candidates to be appointed in only two years out of six”(Ei) and that “an evolving, rolling programme with something like a five year horizon”(Ei) was needed.

In the “fifth year of a six year contract”(Eii) the HRP was “moving from the basic research phase and trying to draw together outcomes”(Eii). The “plan for the last 18 months”(Eii) was to create “three systems exemplars”(Eii) to “pull together the strands of work”(Eii) and to “demonstrate and experiment with outcomes, as a springboard to exploitation”(Eii). At this stage “the theme basis was less important”(Eii). The research had produced “relatively mature building blocks”(Eii) making people “more comfortable to go broadly”(Eii) and work with the exemplars.

The last year was seen as the “termination or evolution phase”(Eiii). It was felt that generically this was a good thing, although the HRP did not want to terminate and “would have continued”(Eiii) or even “fought for continuation”(Eiii) if funding had been available.

The “HRP was always changing, with very little steady state”(Eii). Although “some things do just carry on, some change was needed to make things work better”(Eii).

6.6.8 Complexity

The HRP was “not complex in itself”(Ev) as an organisation, but “only complex because of the politics involved in it”(Ev).

The “structure and remit were complex, as were the relationships with research providers and how you made the stuff come together”(Eiv). Contractual relationships were “individually not complex”(Eii) but the “multiplicity of items was complex”(Eii). This “started to be obvious when you see multiple interaction relationships that exist”(Eiv). There was “complexity

in simply managing the totality of relationships, goals and reasons for involvement”(Eii) with “so many providers and research activities”(Eiv), but although “size was an issue”(Eiv) it was felt that it “was such that complexity was manageable”(Eiii).

The nature of the work was complex since for the research being undertaken, “nothing could be taken from the engineered world: there was no instance to draw upon”(Eiv) and “variables and relationships were not understood”(Eiv) making “climate research easy by comparison”(Eiv).

6.6.9 The role of Systems Engineering

In general, systems engineering was not “applied to set up and run”(Ev) the HRP: the “systems engineering was all in the work that was done”(Ev). However, there was some “thinking about the HRP as a system: how you sustain it, social aspects and design to minimise conflict between competitors”(Ei). Although the research area was “a vast field, with so many ways to cut the cake”(Eii), the research architecture was based on “major systems contributors”(Ei) as an “analogy to the body”(Ei) and it was felt that the “initial grouping was good”(Ei). “Project management”(Ev) was used, and there were “rows about configuration based on a systems engineering view”(Ev). A data model of the HRP was “created in UML, looking at the processes and data flow”(Eii). This “forced logical thinking” about the HRP as a system, and about where there might be process elements and interactions which needed development” (An____, Do____ 2008). It was noted that the “flaws organisationally sat on the periphery: they were all boundary issues”(Eiii). A ‘Stakeholder Maturity Model’ was also developed to analyse the effectiveness of the complex relationships within the various partner and customer organisations (Br____ 2006e) but no significant use was believed to have been made of this.

The HRP was “driven by needs, taking a light touch, not being prescriptive and recognising that in many cases nobody would consider requirements

until they could see a way to meet them”(Ei). However, there was “never a formal exercise to capture requirements”(Eii) and it was felt that there was not good understanding of the “diffuse”(Eiv) customer and user needs by the research community. Researchers who normally “contributed by understanding the domain well”(Eiv) “never got exposure to the problem domain: state of the art technology was secret and it was not a rich area of experience”(Eiv). “It was hard to have a view of what was needed”(Eiv) and “even an impoverished view would have been better than nothing”(Eiv). It was felt that “done again, people should be given more access”(Eiv).

The application of systems engineering in the research context of the HRP was “not easy” and not always as successful as was hoped (An____, Do____ 2008). Achieving integration of the research was a pervasive theme and considered “a measure of success of the systems engineering approach”(Eii) throughout the lifecycle of the HRP, although the mechanism for this evolved. The process was a mixture of top-down and bottom-up activities enabling needs to be expressed in terms of vignettes and capability challenges, and system concepts to be developed based on generic concept classes. Evaluation involved operational analysis, modelling and synthetic environments (Case Study E *Overview*. 2005), and was conducted at four different levels from the individual research package to the overall programme (An____, Do____ 2008). The focus on autonomous systems was “essential to provide a route for proper integration in a systematic and thought-out way” (Br____ 2006b). It was recognised that the “traditional approach was to disaggregate complexity to make it manageable”(Eiii) but that “the sum of the parts wouldn’t necessarily add up to the original goal. Command intent would be lost and strategic intent eroded”(Eiii). In order to “get it back, you needed threads to keep people aligned to the broader goal. This became a trade between vertical and horizontal: a force of will”(Eiii). It was recognised that, especially in the research environment, requirements should not be flowed down “beyond the point where the science runs out” (Br____ 2006b).

The first step was a mechanism to “provide guidelines”(Ei) which “captured requirements for products or outcomes”(Eii) and gave each project “a scenario to relate research to, to give a way of thinking about the problem”(Eiv). These “worked very well, with very little resistance from researchers, helping them and providing a focus to channel innovation”(Eii). However, some participants were more focused on “higher TRL but very low SRL concept work” (Br___ 2006a) and there were still presentations using TRLs when systems readiness was the real issue (Br___ 2006c).

Recognising that “academics didn’t always think about links”(Eii), the next step was to “force this thinking”(Eii) by “simply looking from another angle”(Eiii) in order to “associate research projects”(Ei). Working both “within themes and across themes, this approach had variable success depending on the individuals, with greater success in some themes than others”(Eii).

Demonstration was an ongoing theme, although one interviewee felt that the research challenge “to build a demonstrator”(Eiv) was “not a challenge at all, but just a methodological component”(Eiv). Integration “was led and carried out by the company”(Eiv) and “somehow the ownership of demonstrators by the researchers was never achieved: it wasn’t co-construction, and there was separation of what they were trying to demonstrate”(Eiv). This “integration through demonstrations seemed to be internal rather than shared by the community”(Eiv). It was recognised that there was a need to “think carefully about the goals of the demonstration”, and to address the specific concerns of contributors (for example academic rivalry, IPR, business objectives or funding). Agreement on responsibilities for the various elements, and where possible a view of ‘what next?’ if the demonstration was successful, were also seen as important. Technology roadmaps were generated to “visualise innovation efforts” across the HRP but there was also a need for a formal toolset to support planning of integration and demonstration across different research packages (An___, Do___ 2008).

In the end, this evolved to a new construct: “not just demonstrators, but a mechanism for integration, demonstration and evaluation”(Ei). This incorporated “integration by conceptual link or nitty-gritty interfaces to build sample systems”(Ei) which were “neither horizontal nor vertical, almost amorphous, scalable, based on what means we put into them”(Eiii). The approach avoids the problem of disaggregation and brings it back to something an external player would recognise”(Eiii). This had “some effect on people”(Ei) in both the customer and academic communities, helping them to “think of things as systems”(Ei). Although one industrial partner “enthused about”(Ei) this approach, there was a concern that this would “only work if it captures explicit research goals”(Eiv).

It would have been desirable to apply “more company effort to do trade-off studies in the early stages of research – either informally, or even better formally – and then review these with the results, combine them in different ways and assess the contribution of different research outcomes”(Ei) but the resource was not available to do this.

6.6.10 Perceptions of Success

In spite of “decent research outcomes and proof of concept demonstrations”(Eii) the “frustrating”(Eii) challenge remained “how do you take it forward to use”(Eii). “Exploitation was outside the remit”(Eiii) of the HRP but was “how success was measured” by both the customer and industry. There was a need to “see a path to market” (Brown 2006d) and to “understand what they would do with the research output”(Eiii) and it was felt that “the customer wasn’t internally joined-up enough to carry this through”(Eii). It was felt that “the environment it operated in made it fail”(Eiii) and that “in spite of good intent and goodwill, the wider environment was not shaped to make it succeed”(Eiii): in effect, that research “still faced the chasm of death, although we had moved it a bit”(Ei). The HRP was likened to a conveyor belt with “nothing at the end. Goods fell on the floor and

broke”(Eiii) because of the “complexity of the customer’s acquisition system”(Eiii).

Exploitation was important in different ways to different participants. It was “very important for survival” that what the HRP did had exploitation routes, perhaps through “niche marketing, licensing agreements, as systems integrators” or in other ways (Br___ 2006a). Academia viewed exploitation as both “academic publication to act as a basis for further research”(Eiv) and “exploitation elsewhere, making use of the research”(Eiv) but saw this as a broader responsibility and noted that “the company never took things forward itself: it was an intermediary, not an exploiter of the resources it put together”(Eiv). Noting that although “at first we just did what they said”(Eiv), over time there was effort to “do extra stuff if we could sell why it was relevant”(Eiv). This made it possible to “see routes to exploitation in other domains, extending the company’s business case”(Eiv). However, it was felt that “the desire to exploit and develop beyond the formal contractual boundary”(Eiv) was lacking and that a “separate funding stream”(Eiv) could have been pursued “right from the start”(Eiv) to provide a “push for exploitation”(Eiv).

Internally, it was felt that conflict within the HRP “impinged on the ability to get anything done”(Ev) but that “most big projects are like this”(Ev) and it was “not uniquely bad”(Ev), “reflecting other similar systems in applied research”(Ev). There was a concern that in spite of the emphasis on integration, “individual projects had no vision or picture of the whole. Even the demonstrations weren’t tied together, and how the projects fed in was unclear”(Eiv).

The HRP was assessed annually against the customer’s assessment framework. In addition, a complementary set of metrics was introduced during the third year (An___, Do___ 2008).

There was a view that HRPs could “make a difference”(Eiii) although it was “never as great as the original aim”(Eiii), raising the question “what is

success?”(Eiii). The HRP was felt to have had value in “understanding the skills and relationships that existed”(Eii), but ultimately “everyone measured it by what it did”(Eiii).

6.7 Case Study F

The HRP in Case Study F was a customer-funded strategic initiative established in 2007 to enhance through life capability management for software intensive defence systems, and thus to reduce risks, delays and cost overruns. Case Study F was an open consortium of industrial and academic organisations, which comprised core members who managed the programme, and associates who participated in delivering the broader HRP objectives.

6.7.1 Objectives

Although the “vision was couched in very simple terms”(Fiii), the objectives for the HRP in Case Study F were felt to be “confused”(Fiv), with the original “vision and objectives bearing no clear traceability to what we were doing”(Fiii). The original concept, “proposed in pubs and bars and on the fringes of other meetings”(Fii) was for “a national, all-inclusive enterprise”(Fii). “The original vision had ‘big ideas’ with lots of parallel approaches”(Fiii) and was “a lot broader, including working with the customer to come up with a set of implementation strategies”(Fiii). One interviewee felt that the HRP had “one dominant objective and lesser conflicting ones”(Fii).

Although the “traceability from the vision to what we were doing ought to have been agreed”(Fiii), it was felt that “the real goals didn’t align to the needs”(Fiv); that the vision of “helping on projects”(Fiii) was disconnected from the research projects that were actually funded, and that “many problems arose from not contracting for what they wanted and needed”(Fiv). The constraints of implementation were “preventing the vision from being delivered”(Fiii) and whilst the original aim was to “bridge the valley of

death”(Fiii), the “selection of low TRL research tasks which couldn’t be deployed on projects”(Fiii) meant that the HRP was “set up to fail”(Fiii).

As a result, there was a concern that “nobody knew what it was supposed to be doing”(Fiii) and “many within the HRP did not understand how what they were doing fitted”(Fiv). It was felt that “everyone had different objectives but they were not discussed or resolved”(Fiv). Going further, “with one exception, the customer guys didn’t seem to have had an objective except ‘career damage limitation’”(Fiv). It was felt that the customer “should have had the courage to say ‘this is what we need, go and create it’”(Fiv) but instead “they created a monster which didn’t fit with what they wanted and we hadn’t done much to fix it”(Fiii).

The “four aims from a technical perspective were applied research, pull-through of other research, mentoring and project-support interventions”(Fiv). However, following the selection of “a set of tasks far too close to basic research”(Fiv), it was felt that the HRP was “being inappropriately constrained to doing a small set of research problems and not a lot else”(Fiii). It “should have had people tackling organisational culture, but they wouldn’t have ‘bought’ it. Instead we needed to do technical stuff and build the socio-technical stuff on top of it”(Fiv). It was felt that some of the customer’s problems “would be solved by good practice which could be solved by mentoring”(Fiv). Process research was aimed at TRL6-8 but there were “a surprising amount of gaps in knowledge at TRL 1-3 that needed filling”(Fiv).

There was a “joint intention and a degree of contractual commitment to transfer to being self-sustaining by the growth in additional services such as consultancy, solution recommendation and review”(Fi). This was the “intention, but was dependent on the customer demanding such services”(Fi). The aim was “to move towards a body of knowledge”(Fiv) and to “train the trainer”(Fiv). There was also an intent to develop best practice guides, but the issue of how these would be validated was only “starting to be thought about”(Fi).

The aims of one partner were unclear, but it was felt that “even if the end goal or ambitions were different, the architecture could still work if the route was common”(Fii).

6.7.2 The nature of the relationship

The HRP was a “customer-funded research programme”(Fi) within which the relationship was one of “prime and subcontractors, not a partnership of equals”(Fi). Although the customer “forced a partnership, it hadn’t worked”(Fi). One partner “appeared to still be sulking”(Fii) and “had chosen to be unequal”(Fii). The main partners provide theme leadership as ‘Contribution in Kind’ (CiK) and the “company’s main role was project management”(Fi). Overall, with “lots of organisations involved”(Fiv) there were “some reasonably good relationships in parts, but not all”(Fiv). “By and large the organisations with theme leads did a good job”(Fiv) and “quite a number of partners delivered their side of the bargain”(Fiv). “Others just didn’t do things and didn’t reply to email”(Fiv). One partner was felt to be “in self-protection mode”(Fiv), but in spite of difficulties it “hadn’t walked away as it wouldn’t have been good for their reputation”(Fiv).

The company recognised that “sometimes it had to represent UK industry, not just the company. It was not just self-centred”(Fii). Another interviewee noted that the company “believed in pre- / non-competitive work”(Fiv) and that “raising the community competence was in their self-interest”(Fiv). It was, however, “partly altruism”(Fiv). The company “took the role of leading this seriously, and was not hiding behind the contract”(Fii), recognising “how far away from the ‘need’ the contract was”(Fiv). It sought to “deliver the right thing, without breach of contract”(Fii). The customer had “been quite impressed with this attitude”(Fii).

Although the customer was a “full partner”(Fii) it was felt that they “were not behaving in the way that was intended: weren’t receptive, and couldn’t use the information in the right way”(Fiii) leaving the HRP “unsupported”(Fiii).

Parallel reviews of research proposals conducted by the customer, and the HRP leadership (including the customer) underlined this issue: the heterogeneous nature of the customer resulted in some strong differences of opinion between the two reviews (Br___ 2009a). The relationship had been “very friendly although not entirely effective, with little pockets of success but a lot of problems being hidden”(Fiii). Changes to personnel brought “a lot less ownership”(Fiii) and “more formal, traditional ways of working”(Fiii). Further reorganisation meant “no formal contact”(Fiii) with this customer group in the future. There was a “productive tension between the customer’s technical authority and the industry and academic views which worked very well, prompted debate and enabled issues to be resolved”(Fi). Nevertheless, it was “hard getting it to stick”(Fiv) in the customer community and it was felt that they “didn’t understand the big picture and so managed the detail”(Fiv).

The “weak and fuzzy boundaries”(Fiv) within the HRP made it difficult to “present a coherent message”(Fiv). The “loose consortium”(Fiv) and “changes in personnel”(Fiv) didn’t support that.

6.7.3 Contracts, Controls and IPR

The HRP was “nominally fully funded”(Fii), leaving the customer feeling “more able to direct”(Fii) than with other comparable HRPs such as that in Case Study E. There was “contractual complexity”(Fiv) but it was felt that this may be attributable to “incompetence”(Fiv).” The inability to “solve simple problems made the whole more complex”(Fiv). Although the “contractual position was pretty simple”(Fii), the “governance structure was very complex”(Fiii), “unwieldy at best, and untested”(Fiii). “Trying to operate as ‘a family’ rather than in parent/child mode made it complex”(Fii). It was “operationally difficult to “balance this with ‘cracking the whip’”(Fii).

This complexity started early on with “enormous tender documents”(Fiv) and a “massive compliance matrix”(Fv) resulting in a very expensive bidding

process in which “most of the detail was irrelevant”(Fiv). It was felt to be “how not to do a research contract”(Fiv).

The HRP was “not a legal entity”(Fiii), so as “lead partner”(Fiii) the company “took the contract and subcontracted out”(Fiii). Although this was a “simple contract”(Fii), the fact that it had “more subcontractors than most R&D programmes”(Fii) meant it was “commercially hideous”(Fiii) and the “amount of nightmare it created far exceeded expectation”(Fiii). Although it was “contractually required”(Fiv) to be able to put tasks on contract within days, there were examples of tasks which took six to ten months. It could take “four to six months to change a paragraph”(Fiv) in the contract and changes to the consortium paperwork had to be flowed to over 25 companies. Overall the HRP was felt to be “commercially a complete nightmare: and hard to say whether the customer or company was worse”(Fiv). The need “to get much more agile”(Fiv) was recognised.

“Relationships were strained between everybody in commercial”(Fiii) with some commercial people adopting the “attitude that ‘you were stupid and didn’t understand’”(Fiii). It was felt that “everyone did this badly”(Fiii) and “there was a need to be much smarter”(Fiii) about commercial issues. Highlighting the problem, the original ‘agreed’ copyright statement was “inadequate and incorrect”(Fiii), resulting in “the re-issue of fifty documents”(Fiii).

“Astonishingly”(Fiv) all research task deliverables were “written into the contract”(Fiv) and in the early stages of the HRP, action was taken in response to any “deviations”(Fiii). As a result, people tended to focus on cost and schedule rather than the real engineering progress being made (Br____ 2009b). Subsequent changes in the customer organisation meant that although the “contract had not been amended”(Fiii), “implementation became based on quality, not timeliness”(Fiii). For the next phase the delivery schedule was covered by “research management plans”(Fiii) and the judgement of the management team regarding “satisfactory progress”(Fiii)

was accepted by the customer. This approach was “common sense and more hands off, but with less customer engagement”(Fiii). As a result, however, it was “harder to get hold of commercial people”(Fiii).

There was also tension in the HRP regarding the release of material. The “original vision relied on the vast majority of output going into the public domain”(Fiii), with “two document types”(Fiii) being created to facilitate appropriate distribution. However, “at least half of the research tasks were done in industry, with no vested interest to put the outputs into the public domain”(Fiii). The “focus going forward was for the customer to retain access but allow external publication and distribution of work”(Fiii). However, only one formal publication and “around twenty HRP-related papers”(Fiv) had been released.

Customer commercial practice meant that “the bidding process for research work was a nightmare”(Fiii) with everything subject to “open calls”(Fiii) which made “evaluation a nightmare”(Fiii). With “some of those bidding also on the evaluation team”(Fiii) there was a clear conflict of interest. Every requirement for “additional services was also to go to competitive tender”(Fiii). Out of “fifty or so members and associates”(Fiv), “most may want to bid for the work”(Fiii), making the whole process unmanageable.

Although “‘theme lead review’ works as the governance structure for research document outputs”(Fiii), it was unclear “how this would work for additional services”(Fiii) to enable the delivery of consistent quality advice and guidance. The “plan was that one individual was technically responsible for the quality of all outputs”(Fiii) and to ensure “consistent advice from consultants”(Fiii), but the feasibility of this was constrained by resource availability.

6.7.4 Culture

The HRP was “a cultural disaster”(Fii) with some academics who “didn’t understand a contract”(Fii) and “had no idea on delivery to

time/cost/quality”(Fii). One university was “by far the worst”(Fii), and highlighted as delivering “nearly always late, and not what was contracted”(Fii). Others were “OK”(Fii) or “excellent, and did what they said”(Fii).

On the supply side, there was quite a lot of common ground and a shared view of “what was wrong with the customer”(Fiv), but there was “currently no way of having an informed discussion” without “connecting technical problems to schedule and cost”(Fiv). There was a view that “ultimately to succeed, it needed cultural change”(Fiv) within the customer. Although “close contacts”(Fiv) were “OK”(Fiv) there was seen to be “quite a big gulf between us and the customer” which made the original vision for the HRP unrealistic. A “characteristic problem”(Fiv) was the “need to write a six to eight page executive summary for long reports”(Fiv).

The change in “lots of personnel”(Fiii) within the participant organisations caused a “huge cultural shift”(Fiii) in the HRP.

6.7.5 Resources: People

The management team appeared to have had clarity of roles with individuals describing themselves and others as “chair”(Fi), “senior sponsor”(Fi), “having technical focus”(Fiv), “having programme focus”(Fiv), “technical adviser”(Fiii) and “customer”(Fii); although the structure did require someone to “wear two hats as a member of the team and the customer, creating ‘interesting tension’”(Fii). Within the management team one “triumvirate worked pretty well”(Fiv) with “great engagement”(Fiii) before being impacted by the departure of a key individual. In another case the “relationship was generally good but with occasional misinterpretations”(Fiv). There was a feeling that the team were “getting to be experts at managing contracts under extreme uncertainty”(Fiii). However there were several negative references to different individuals “talking like he ran it”(Fiii), “doing what he thought was right for him”(Fii), “always active but in the wrong direction”(Fiii), “having his

own agenda”(Fiii) and “not having that sense of ownership”(Fiii) and well as those who simply “didn’t understand”(Fiv).

There was a general sense that the loss of two key people had been detrimental. In the first case, someone with the “intellectual capability to help define how to tackle things”(Fiii) “got pulled out in the later bid stages”(Fiii) and was “replaced at a critical time”(Fiii). More recently, a “good guy”(Fiv) who was “very helpful”(Fiv) and “had a feel for it”(Fiv), and had been able to “make up for the problems with broader engagement”(Fiii) was replaced by someone “less competent” who “couldn’t understand” and “didn’t seem to have the same ownership”(Fiii). Although these two individuals had “different views of implementation”(Fiii), they had a “shared objective”(Fiii). The HRP was “seeing change in personnel at all levels”(Fiv) and change within the customer organisation meant that many felt “they were about to be ‘sacked’ and didn’t seem very interested”(Fiii). “Strategically, the cycle of two-year postings was a big problem, made harder by the very technical nature of the research”(Fiv). In general, “customer project team staffing was a problem: they expressed user needs but couldn’t deal with the technical stuff. Even money wouldn’t help”(Fiv).

Within the ‘supply’ side of the HRP there were “two extremes of behaviour”(Fiii): those who “behaved very independently, were proactive but with little accountability or visibility to the management team”(Fiii) and “everybody else who exhibited almost total apathy, not doing anything unless specifically requested”(Fiii): who were clearly “competent but not motivated”(Fiii). The management team “spent quite a lot of time digging others out of holes”(Fiv). There was a sense that the degree of management control may initially have been inadequate in respect of actions which “made the management team very uneasy”(Fiii) and “proved to have a very negative impact”(Fiii), and that “in hindsight should have pulled the reins earlier”(Fiii). It appeared that this was changing and it was noted that a key individual “had recently grown a backbone”(Fii).

The “team didn’t get enough time to talk to each other”(Fiii) and “opportunities were minimal”(Fiii) for the team to gel. As a result, the HRP was “not a cohesive whole, but couldn’t retrench as it needed to be inclusive”(Fiv). Although it “took a while to build links”(Fiv) it was felt that “implementation was constrained because of the people”(Fiii) and there was a “lack of project engagement”(Fiv). Overload was a common theme, with various people described as being “very busy”(Fiii), “too busy to do their roles”(Fiii), being “short on time for research”(Fiii), having “not enough hours in the day”(Fiii) and having “more to do than the resources available”(Fiii). Even though one partner “had the money, they still couldn’t find the people”(Fiv). One commercial manager was “minimising their input” as they had “fifty-three contracts to manage, making this a ‘spare time’ job, not a priority”(Fiii).

At the proposal stage, it was noted that “engineers understood the technical bits and worried about the other stuff, where they expected the same clarity” but were unable to get it (Fv).

6.7.6 Resources: Funding

Since the customer “didn’t want to contract with a legal body (i.e. pay for bricks and mortar)”(Fiv), the HRP relied heavily on the level of management support provided by the company. However, “the longer it went on, the harder it would be to go to a legal entity”(Fiv). The “initial aspiration of becoming self-sustaining”(Fiv) had already been discounted as “no longer feasible or appropriate”(Fiv).

Funding for the HRP came from the customer’s research budget, with the associated constraint that it had to be spent on research. This was in conflict with the HRP’s broader vision and objectives (Br___ 2009b).

The HRP’s effectiveness in respect of its broader ambitions was limited by the scale of the investment. If it was “bigger and had more money”(Fiii) it would have been feasible to “name five people and train the trainer”(Fiii) in

order to promulgate a consistent message on the major issues - but “not at this scale where we’re spending £3M/year if we’re lucky”(Fiii).

In order to alleviate the difficulties of dealing with very technical reports, it was suggested that a technical author could be employed, but a question arose over “who would pay?”(Fiii) There was an unwillingness to “ask the customer to pay again for research output”(Fiv). It was also suggested that two tasks “should have been”(Fiv) funded from another source better suited to low TRL research.

6.7.7 Lifecycle

The original concept for the HRP was for a “national all-inclusive enterprise”(Fii) which was then modified by “the need to compete”(Fii). In “re-writing the question to frame it as a competition, they took a good idea and ruined it”(Fii). The attitude seemed to be “never mind the outcome, let’s have a competition”(Fii). “Those who would have been involved”(Fii) in the original concept “tried to form into one team but it fell apart”(Fii). Unable to “talk to the customer”(Fiv) “until they got through the compliance process”(Fv), the teams “had to guess what the problems were”(Fiv). In order to create “unique selling points, both teams diverged from the central position, resulting in completely incompatible solutions”(Fii). In reviewing the bids the customer “almost decided not to do any of them”(Fiv) but instead opted for “cherry picking”(Fiv) elements of the different bids and “merging”(Fii) them. As a result of this “forced marriage”(Fii) which “took as much effort as the original bid”(Fv), the HRP went through a difficult creation phase with a lot of change. Participants wondered “how on earth did we get here having started there?”(Fii) The original vision of the customer sponsor was not widely supported (Br___ 2010b).

The HRP was based on a “five year contract with a breakpoint after three years”(Fiii). After two years, the contract was extended to cover the full five year period. There was a desire to “create a rolling contract with no end

date, just adding to the duration two or three years ahead”(Fiii) but with changes in the customer organisation it was unclear whether this would happen. The HRP was “in the sustainment phase with new tasks starting”(Fiii) at the time of the interviews.

There was an initial desire to create an “initial operating capability”(Fiv) and then “full operating capability”(Fiv) but this was “a model which the ‘lords and masters’ didn’t buy into”(Fiv). This model “would probably have had a better chance of working”(Fiv) but it would have been “harder to bring in other companies”(Fiv). It was felt that the “management structure should be designed to evolve”(Fv) and that “improving capability over time may be possible, but we needed to show benefit first”(Fiv).

Although the HRP was seen as “a growing little baby, still on life support”(Fi) which “would die if you stopped funding”(Fi), there was originally a “degree of contractual commitment to transfer it to be self-sustaining”(Fi). However, it was “hard to see how this would evolve to a sustainable entity”(Fiv). There was a “danger that the future business model was not really transpiring”(Fi) that the HRP may “go into traditional research management, losing the novelty and technology transfer intention”(Fi). Despite the original objective to “become self-funding”(Fiv), there was “no demand”(Fi) from the customer for the additional services required to do this. It was felt that “an explicit step-change was needed”(Fiv) and that there would be a “need to change the model, re-write the contract and re-implement”(Fiv). As a result “it had been agreed to give up on the self-funding idea”(Fiii).

However, there was a concern that the HRP had produced insufficient outputs for the customer rather than industry and had the potential to be sidetracked by “individual agendas”. It was “at risk of dying from lack of relevance” (Br___ 2010b).

6.7.8 Complexity

The HRP approach was “not novel, just business as usual”(Fi). It was a “little enterprise that wasn’t novel or complex”(Fi), following a “well-trodden path”(Fi). There was “nothing novel about processes or stakeholders, all extant processes were reused”(Fi) and it “shouldn’t have been difficult to manage”(Fii). However, “organisationally, it was very much more complex than the HRP in Case Study E”(Fii) although the reason for this was unclear.

The “technology transfer process was more complex: trying to make the organisation behave in a way that products were used and valued”(Fi). It was felt that the “exploitation process was the complex bit”(Fi).

The research itself was “technically complex”(Fii) with “some problems that were genuinely hard”(Fiv) and “some individual research tasks that represented novel and complex thinking, although some were simpler”(Fiii). “If we really understood what we were trying to do it would be very complex. There were multiple causes we needed to address and any solution was necessarily complex”(Fiii), but the “complexity should have been in how these delivered the vision and what else was needed. We obviously had a gap”(Fiii).

6.7.9 The role of Systems Engineering

Systems engineering was not used “in any formal way”(Fi) in establishing the HRP.

From the company perspective, the “usual process”(Fi) was followed, raising a concern that the associated “‘embarrassingly large’ level of effort and intolerable overhead cost was ignored”(Fii). At the bid stage, no “formal technique”(Fv) was used. However, the solution was sought “holistically”(Fv), “starting with a bundle of constraints, identifying ‘what were all the bits’ and prioritising”(Fv). This involved “looking for things that were important but not obvious”(Fv). It was likened to the work of a chef: “some

things in presentation added to the taste and brought out flavours: ambience, crowd, music, noise etc”(Fv).

Although by “specifying the organisational outline in the Invitation to Tender”(Fiii) the customer “had decided what the HRP was going to do and what the architecture was”(Fiii) there was “no evidence of a systems engineering approach”(Fi) in this. This did not leave “a lot of room for manoeuvre”(Fiii) and although they had “subsequently done things like ‘combining’ (dropping) themes”(Fiii) and discussed “rationalising meetings”(Fiii) this was felt to be “just tinkering around the edges”(Fiii). The company “had no input to the architecture”(Fiii).

The HRP was “thought through ‘to a level’ by both customer and contractor”(Fi). It was “conceptualised and contracted for, but there were dependencies. The concept was not validated, not proven, and was not working”(Fi). It was felt to be “all about modelling: context, environment and interventions necessary”(Fi) and it had been necessary to decide whether to “just throw it in, or model it so that you knew”(Fi). Noting that “the latter may not have been do-able”(Fi), the HRP could “arguably have been designed up front more rigorously “(Fi). Nevertheless, the “architectural design of processes for resource management”(Fi) was done.

The integration of the programme was not planned, and with 26 individual research tasks “building a coherent whole out of the bits was tricky”(Fiv). Whilst the three themes were useful from a technical management perspective, they were less effective in engaging with the customer and on projects. A second framework of ‘Hard Problems’ was introduced to assist, but there was felt to be a danger that a number of discrete ‘pet topics’ were being pursued and that the structure was merely superficial (Br___ 2010c).

The vision for the HRP implied a culture change in the customer community, but no modelling was done to identify the stakeholders, to understand the role of the HRP in this change or to identify what else would be needed for the vision to be achieved. It was far from obvious that the majority of

participants recognised the socio-technical problem that was being faced, or that the expenditure of effort and funding in this area would have been supported (Br___ 2010c).

6.7.10 Perceptions of Success

Although “not set up to have the greatest chance of success”(Fiv) the HRP was “trying to do something worthwhile”(Fiv) and “may succeed in small areas and see benefit”(Fiv). “Most researchers were delivering useful output”(Fiii); however in some cases, though “intellectually sound”(Fiv), the content was inaccessible to non-experts and the “customer couldn’t understand them”(Fiv).

Indicators of effectiveness were not directly linked to the objectives but addressed:

- National recognition of the HRP
- Improvement to government acquisitions
- Commercial exploitation of the HRP’s capabilities
- On-time reporting
- Internal and External Communications
- Application to real systems

The associated measures were set against numerical standards, but where these changed over time it was unclear how this related to increasing confidence in each indicator or indeed to expected behaviours. In some cases, for example the generation of additional income streams, the standards were highly unrealistic given the lack of architecture or planning to deliver the change in business model over a relatively short period of time reflected by the figures (Case Study F [undated]). Furthermore, there was no

connection between the indicators of effectiveness and the HRP's contract: to deliver research tasks (Br___ 2009b).

The fact that the "real goals didn't align to the needs"(Fiv) meant the HRP was "not entirely without events and incidents"(Fiv). There was a difficulty "getting the customer to engage: they were 'down in the weeds', not managing what we should have been doing next"(Fiii). Nevertheless "we tried very hard to make it work"(Fii).

There was a concern that it "would end up with internal clashes"(Fiv). One interviewee was "dubious of the ability to meet the overall aim"(Fiv).

6.8 Secondary Case Studies

Secondary case studies arose as a consequence of primary case study interviews, where the interviewee compared a primary case study with another HRP from their experience. In most cases they were based on the input of a single interviewee, and information was provided in an unstructured way. The information for these case studies was generally more limited than in the primary cases and typically highlighted only a small number of characteristics of the HRP. Sections within these case studies where only the title is listed indicate that there was nothing in the respondent's comments, or in the published material that was accessed, relating to that characteristic.

6.8.1 Case Study G

The HRP in Case Study G was a £6M 5-year research programme established in 2005, jointly sponsored by a Government funding body and the company (both at a corporate level and through its business units and joint venture companies). Delivered by a consortium of four UK universities, it was focused on novel distributed information systems. There were four research themes within the overall programme.

6.8.1.1 Objectives

Within the HRP, it was felt that the “research goal had to be exploitation”(Gi) and that there was “pretty much a shared view”(Gi) that “maximum exploitation”(Gi) was “a good thing, not a distraction”(Gi). However, “exploitation didn’t happen by accident”(Gi).

Although “publish or perish”(Gi) drives academics, in this area it was possible to “write a paper about demonstrations and get a good paper”(Gi). It was felt that this “might be a characteristic of this field”(Gi) which helped to align industrial and academic objectives.

What was “in and out of scope”(Gi) was clearly defined, unlike the HRP in Case Study D where “nothing seemed out of scope”(Gi). There was a recognised “need to focus on key points, not 1000 different things”(Gi).

6.8.1.2 The nature of the relationship

The nature of the relationship was clearly shaped by the collaboration of competent individuals with an understanding of their partners’ needs. Within the company, the key architect knew the technical area and could “judge people who were good and those that weren’t, and down-select on merit rather than the ‘good mates’ principle”(Gi). In a complementary role, the lead academic “was a good supporter”(Gi) and “got universities to do a statement of work”(Gi). “Everyone had deliverables and they got chased if they were late”(Gi). The academic partners had “complementary capabilities”(Gi) in different areas which provided a nucleus and a way for other partners to get involved”(Gi)

6.8.1.3 Contracts, Controls and IPR

The HRP was “contracted directly”(Gi) to the lead university. Its governance architecture comprised “a strategic steering board which included the principal investigator”(Gi) and “looked beyond the immediate programme to further and future work”(Gi) and an extant company research committee. All

the funding partners were members of the committee in which they “reviewed the statement of work, etc”(Gi). HRP results were “presented to the group twice a year”(Gi) and included academic measures such as “publication statistics”(Gi). The partners “were involved and could be challenged on exploitation”(Gi). In contrast, one of the non-industrial funding customers “was much less interested in the outputs”(Gi). They “got the programme running but didn’t have anyone involved in monitoring”(Gi)

The programme was reviewed under the normal company processes. This was felt to support the programme, and “kept you on your toes”(Gi). Reviewers were “generally helpful”(Gi). “Design reviews were very hard”(Gi) however, and as a result of “the breadth of programme and seniority of reviewers”(Gi) “tended to focus on exploitation”(Gi).

There were “two big meetings per year, plus an internal workshop”(Gi). Invitees to the symposium included the participants, the company’s other business units and government bodies, but excluded organisations that were “too much of a competitor”(Gi).

6.8.1.4 Culture

Although there was a need to “translate between academics and the business need”(Gi), this burden appeared to be shared by both sides. It was noted that “an artefact of industrial research is the need to change. Part of it was changing the people you work with, and we have already done that”(Gi).

6.8.1.5 Resources: People

The HRP was “very much about people”(Gi). The “academic lead was very good, with standing in the academic community”(Gi) and was “very keen to work with us”(Gi) whilst others were identified as a “key person”(Gi), “very well respected”(Gi) “key in creation and technically knows the area”(Gi) and “worked together well”(Gi). There were “people with sufficient standing on both sides of the equation”(Gi), i.e. in both industry and academia.

In contrast, one “difficult individual”(Gi) was singled out as “much more of a problem”(Gi). He “didn’t listen and didn’t collaborate”(Gi) such that his contribution “could have had much greater value”(Gi) and was “not as powerful as it could have been”(Gi). His objectives were unclear and he was “tolerated”(Gi). It was suggested that as a “grand standing”(Gi) type of academic, it “could have been that he couldn’t find a niche for himself”(Gi) but nevertheless “more than one ‘problem child’ would be intolerable: it affected the feel of the project”(Gi).

The programme was based on the known skills of the key participants and designed to “play to the strengths of the team”(Gi) rather than “tell them too much how to do it”(Gi). It was felt that “strong characters who didn’t like direction could lead to a lower calibre team”(Gi).

6.8.1.6 Resources: Funding

Funding was split between the customer and the company. Within the company the “bulk of the money”(Gi) came from the central research budget with the remainder from four business units. Other related projects within the company made it possible to “connect internally”(Gi). Although recognising that this was “not something you could do in all situations”(Gi) this provided visibility of “windows of opportunity”(Gi) to the HRP.

6.8.1.7 Lifecycle

Within the HRP some of the “relationships were pre-existing”(Gi), enabling decisions to work with people on the basis that “he knew his stuff”(Gi). Since “you couldn’t know how you were going to work with someone unless you had” (Gi), carrying out a “smaller project beforehand and then building on success”(Gi) was felt to be a good approach.

Having the programme structured as “three plus two years was a good thing. Three years was enough to assess if it was working”(Gi). The “three year review criteria were ‘were we working with the right people’ and ‘could we work with them?’”(Gi). Although an issue for other HRPs, “taking on new

PhDs in the third year was not considered a problem, as it was assumed the programme would continue”(Gi).

As the programme was in its final year at the time of the interviews, the leadership were “looking for a way to follow-on”(Gi) with the intention that company funding would address “contribution in kind and exploitation”(Gi) in any future derivative programme.

Programmes funded from the central research budget “had a very hard annual cycle”(Gi). Although “small, niche problems could be tackled, you couldn’t do fundamental, ground-breaking research on an annual basis”(Gi). There was a “need to back universities over the longer term and avoid setting a programme of work over a one year period”(Gi).

6.8.1.8 Complexity

6.8.1.9 The role of Systems Engineering

Although the HRP was not ‘systems engineered’, “a set of requirements was developed before the project started, against which the programme was judged”(Gi). The importance of the ‘right requirements’ was recognised: “if you were too requirements-led it wouldn’t work in the university environment – but with no requirements nothing would get done”(Gi). It was possible to have “great departments and great people doing great stuff, but with no alignment to the business, the understanding could still be poor”(Gi).

Demonstration was felt to be “a really good tool: more exploitable and providing a focus for academics”(Gi). They could “define the problem space”(Gi) and show “how did each bit fit”(Gi). “Noddy demonstrations”(Gi) were felt to be particularly useful in these technical areas “to avoid getting lost in the mathematics”(Gi). Although the company was available “to assist with the demonstrations”(Gi) these were done by the lead university. It was felt that “if academics resisted”(Gi) involvement in demonstrations then “problems with integration in general”(Gi) should be expected, but it was recognised that “lots of variables needed to come together”(Gi) to create the

demonstration and “it was OK if some weren’t perfect”(Gi). The “demonstration domain was disaster relief, enabling academics to be involved without a problem but easily transitioned”(Gi) to a parallel domain of direct interest to the customer.

6.8.1.10 Perceptions of Success

In spite of the “risk that these big, quite complex programmes could go wrong”(Gi), the HRP was felt to be successful, attributed to a combination of “a very good academic lead and exploitation on the business side”(Gi). Over its 5 year lifespan the HRP produced more than 150 publications, won several awards and “generated a number of patents and technologies that have been exploited by the associated industrial partners”. A follow-on grant has been awarded to continue the work in this area (Case Study G, The Project *undated*).

6.8.2 Case Study H

This case study was based on the perspective of a UK partner in the HRP. The HRP conducted research for a European governmental customer in a consortium led by a multinational company based in Europe.

6.8.2.1 Objectives

The HRP in Case Study H was a multinational research programme focused on enabling technologies in a specific, security-sensitive area. There were “national differences in requirements”(Hi).

6.8.2.2 The nature of the relationship

The HRP was a European programme with four different countries involved.

To prevent a “stove-piped solution”(Hi) there was a “management committee with representatives from the different organisations who agreed the

deliverables”(Hi). Partners “often didn’t know anyone in the other organisations”(Hi) and “had to work through the company”(Hi).

The subcontract relationships included “academia, some of whom had never done this sort of thing before”(Hi).

6.8.2.3 Contracts, Controls and IPR

The contracting arrangement for the HRP was complex. Although the customer was in Europe, there was a UK body acting as “national bill-paying authority”(Hi) for “funding UK work”(Hi). They “had no contract” but “had a technical arrangement with the company”(Hi) in Europe. Deliverables from the programme “were sent to the company, then to the customer”(Hi) and “IP was freely available to all parties”(Hi)

A UK partner felt that they were “perceived as being obstructive wanting to cross ‘T’s and dot ‘I’s”(Hi) while the company “just wanted to move forward”(Hi). In hindsight, this may have been attributable to the partners “playing a waiting game”(Hi) until contractual cover was in place at the higher level.

Even between organisations who were familiar with working together, there were issues due to different operational and contractual requirements for this HRP. An existing partnership agreement between one partner and a university was “not seen as ‘enabling’ but ‘disabling’”(Hi) in this context and the intent was “to agree a different arrangement to facilitate progress”(Hi).

Since the research could touch upon “issues of national security”(Hi), “certain tangible and intangible assets couldn’t be discussed”(Hi). However, since academic participants “may have needed to talk to partners in other countries”(Hi), they would “either need an export licence”(Hi) or would need to “communicate through the partner”(Hi) who does have an export licence. A working assumption was that “everybody should have an export licence”(Hi) to avoid handicapping the programme with unnecessary communications constraints”(Hi).

There was a concern that “there were insufficient project reviews”(Hi) to ensure that “things that needed to be in place before starting, such as IP agreements, export licenses and payment arrangements”(Hi) were ready.

6.8.2.4 Culture

The HRP faced “different ways of working”(Hi) in different companies and countries, for example in commercial areas.

There was insufficient “customer relationship management activity”(Hi) – certainly at the UK partner level – to allow them to “build up a customer database”(Hi) and facilitate the establishment of “a collaborative group to support the customer”(Hi). Without the database, the UK partner didn’t “know who to go to”(Hi) to proactively set up such a collaboration.

6.8.2.5 Resources: People

The primary contact within the company “wore many hats: technical, commercial, contracts, project management etc”(Hi) and appeared to have “no targeted expertise acting in support”(Hi) for example on topics such as export licences. Similarly, there had been “only one person dealing with it”(Hi) in the UK partner and as a result, other individuals “hadn’t built relationships”(Hi). “Personalities and relationships”(Hi) were seen to be critical issues but “people didn’t understand the relationships”(Hi) and “organisations were structured differently”(Hi).

6.8.2.6 Resources: Funding

The complex commercial and contractual arrangement for the HRP meant that “funding routes were diverse”(Hi) and this had caused “issues with cashflow”(Hi).

6.8.2.7 Lifecycle

The HRP was “due to start delivery of research”(Hi) after about two years, having spent “one year in preparation”(Hi) when the UK body’s delay in

signing the enabling technical arrangement brought subsequent delays in the UK partner's involvement. This indicated that the HRP was already "operational whilst still in the implementation phase"(Hi).

6.8.2.8 Complexity

6.8.2.9 The role of Systems Engineering

6.8.2.10 Perceptions of Success

6.8.3 Case Study I

The HRP in Case Study I was a 5 year, £6.5M research programme being undertaken at ten UK Universities sponsored by the company and a Government funding body. Launched in 2004, it was undertaking research into novel technologies for the next generation of unmanned air vehicles. By designing and building a representative unmanned air vehicle and conducting a real flight campaign demonstrating the new technology, it took the technology to a higher Technology Readiness Level that was usual in academia.

6.8.3.1 Objectives

The HRP aimed to stimulate academic research which was better suited to the needs of industry, with an emphasis on achieving a specific integrated outcome "of practical relevance for industrial exploitation" (Jo___ 2010).

The HRP had "two 'Grand Challenges' set by industry: to research and demonstrate new technologies for achieving a maintenance-free Uninhabited Air Vehicle (UAV), and to achieve enhanced research impact through effective academic/ industry management and the exploitation of large-scale, integrated academic research"(li). Compared to the HRP in Case Study D, it had a "much clearer problem"(li) to solve, a "clearer scope"(li) and a "clearer objective"(li).

Although often not done explicitly, industry efforts to “explicitly link the research outcomes to their business needs and opportunities”, for example through roadmapping, was essential to enable exploitation (Jo___ 2010).

6.8.3.2 The nature of the relationship

The HRP involved an innovative approach to industrial/academic collaboration which involved fourteen research groups across ten universities (Jo___ 2010).

The HRP was “led by one university on the basis of an extant strategic relationship with the company”(li). “Relationships between academics were generally good, with a cooperative approach taken by all”(li). In one specific technical area, two of the universities were “in competition”(li) and this caused “tensions between academics”(li) within the HRP. In addition, there were “ongoing niggles”(li) in a technical area, attributed to “inadequate communications”(li) between three universities.

6.8.3.3 Contracts, Controls and IPR

It was recognised that the academics involved in the HRP needed to be able to publish in respected journals. A review process was established whereby all universities signed non-disclosure agreements and papers were reviewed by the company prior to submission to remove any commercially sensitive content. The company “did not impose unnecessary or unreasonable restrictions” enabling a balance to be struck between publication and company exploitation (Jo___ 2010).

The company was the major stakeholder in terms of both funding and control. As the programme progressed “the company’s emphasis and expectations increased regarding exploitation of research outcomes and on short-term delivery of specific cost-benefits”(li). Discussions on future funding possibilities emphasised “academics finding other sources of funding for research that the company could benefit from”(li).

However, it was noted that “for such leverage, the research needed to appeal to other applications and hence be a more general programme”(li) and that “to get someone else to fund, you had to release control to broaden the appeal”(li).

6.8.3.4 Culture

The HRP succeeded in “building an integrated team approach” around the development, integration and testing of a demonstrator. Without such a stimulus it was “very unlikely” that the HRP objectives would have been achieved (Jo___ 2010).

Within the company, there was a “transition of ‘owner’”(li) responsible for the research funding during the programme and this led to a focus on “much more short term, tangible outputs”(li). As a result, the “big picture of establishing a sustainable academic capability suffered”(li). Although the “overall collaboration across the programme and the outcome focus exhibited by academics were good”(li), “on occasions this change in focus caused problems for some of the academics”(li).

Although the “academics were used to operating in stovepipes, and didn’t usually get exposed to such a high degree of collaboration”(li), within this HRP the clarity of focus and objectives established by the Grand Challenges gave “an overall unity of purpose”(li) which meant that the “dispersive influences were easier to align”(li). However, special efforts were required to overcome the barriers, for example, conventional academic measures such as publications. Flexibility and cooperation were essential from all parties (Jo___ 2010).

6.8.3.5 Resources: People

One of the primary aims of the HRP was to develop “industrially relevant multidisciplinary skills” in academia. The focus on exploitation meant that the universities’ involvement went beyond technology research to systems integration. As a result, academics were able to develop these skills and

knowledge which would normally only be developed in industry. An important lesson, however, was that “the expertise and experience that is gained should be primarily vested in permanent academic staff” and not in doctoral students or postdoctoral staff who tend to be more mobile and therefore contribute in a less predictable way to the development of sustainable academic capability, although some may join industry as a direct result of their research (Jo___ 2010).

The tensions between short-term exploitation and long-term capability development were “felt by many people”(li) involved in the programme and “caused some strain on relationships”(li) and “ambiguity in some roles”(li). For example, “the lead person on the programme for the company effectively wore two hats: one as a research collaborator within the team and another as the main company representative engaging with the academics”(li). Whilst the former role “focused on making a valuable technical contribution to the research“(li), the latter was often associated with “financial and timescale pressure being put on academics”(li) and a “more adversarial”(li) relationship.

Within the overall research team an “open collaborative attitude was essential”(li) and some people “found this more difficult than others”(li). One academic “took the view that ‘if I approved something and it went wrong, I would get blamed”(li): “his whole attitude was to protect his own back”(li). This was “not helpful to the programme”(li) and frustrating for other researchers who “wanted to shout at him ‘start collaborating’”(li).

The involvement of “appropriate industrial people, with technical expertise, knowledge of industrial priorities, and the ability to influence internal industrial attitudes towards academic research” was felt to be crucial. The change in outcomes that was sought could not be achieved “by an administrative or financial relationship alone; close technical and programmatic engagement is essential” and this required a strong and ongoing commitment from industry. The assignment of “a highly experienced senior engineer” as Exploitation Manager was an example of this (Jo___ 2010).

6.8.3.6 Resources: Funding

When the programme started in 2004, the customer's funding model did not allow for the charging of academic staff time. This was a significant disadvantage for the programme which meant that the lead university in particular had to invest in the programme in order to support integration. The rules have since changed (Jo___ 2010).

Funding from the company was flowed through the customer and then provided as a "grant to universities"(li) in the same way as the HRP in Case Study D. It was noted that "when money gets tight, the long term, blue sky, speculative stuff goes"(li). As funding priorities changed, the HRP relied upon the "cooperation and understanding of academics" to maintain good relationships (Jo___ 2010).

6.8.3.7 Lifecycle

In the early stages of the programme, the "inevitable focus within each research group was on establishing the fundamental research progress in their area of expertise". As the programme progressed, the focus turned increasingly to integration. Around the mid-point in the programme, weekly coordination meetings were introduced. These were held face-to-face for about 12 months and subsequently using remote technologies over the Internet (Jo___ 2010). This clearly represented a significant financial investment simply in enabling the partners to meet.

Behaviours in the HRP were driven by the funding cycle. In the "run up to the three year review"(li), the company "declared that they wanted to see more rapid progress"(li). "There was a lot of effort and significant spending on an early demonstration system, in order to show progress at the mid-term review"(li). "After the review, that effort was largely nugatory"(li)

On the other hand, the "maturity of research at the review point helped focus the programme"(li). The "tangible-outcome question could be asked, to

enable changes to the programme”(li). As a result, at this stage some things “were discontinued as there was no obvious route to exploitation”(li).

6.8.3.8 Complexity

The “establishment of the Grand Challenges at the outset”(li) helped to “provide a shared purpose and a degree of clarity in the requirement”(li) and “reduced the complexity”(li) perceived within the HRP. Having a “clear, single ‘customer’”(li) on the company side meant that the programme “didn’t have to struggle with the problems associated with multiple stakeholders”(li).

6.8.3.9 The role of Systems Engineering

The solution to competition between the two competing academic partners was architectural: by “trying to partition into separate streams of work, both could do useful work and they didn’t have to collaborate so closely”(li). It was noted that “otherwise, they may have been at loggerheads”(li).

Two significant demonstrations were part of the programme, with the smaller system “providing a stepping stone for progressive risk reduction”(li).

6.8.3.10 Perceptions of Success

Although “it had been going the same way”(lii) until a new project manager was assigned, the HRP had “a lot less problems”(li) than the HRP in Case Study D. It would have been “better if the weather hadn’t affected planned demonstrations”(li), but was generally considered successful.

The publication review process was successful in enabling academic publication while protecting commercially-sensitive information (Jo___ 2010).

6.8.4 Case Study J

The HRP in Case Study J was established in 1979 by UK aerospace companies to demonstrate the credibility of UK industry to deliver a future fast jet. The five member industrial consortium was self-funded and

managed, and continued to work together through its working group and steering group on “the development of technologies and strategies of mutual interest” (Case Study J 2010). With only industry participants, it is not strictly an HRP on a continuous basis, but periodically works with the customer on specific contracts.

6.8.4.1 Objectives

The HRP’s “original clear objective”(Ji) was “to demonstrate the viability and credibility of UK industry”(Ji) in a particular technical area, “driven in response to the belief that the customer thought the UK no longer had a viable capability”(Ji). There was a “common threat that all competitors would go out of business”(Ji) if they did not work together.

A secondary objective was to then “prove that UK capability was dominant in Europe: to maximise UK benefit and jockey for position”(Ji), and to enable the customer to “fight for the UK position, confident that UK industry wouldn’t let them down”(Ji). The construct evolved to providing “leadership of thought”(Ji) in this area.

Over time, the objectives of the HRP had changed. Having succeeded in its original objective, the group evolved and “started doing R&D for the money, with less deep thought”(Ji). This persisted as the “motivation until two or three years ago”(Ji).

The HRP’s “purpose was reviewed repeatedly, for example as it bid for work, to ensure that the aspirations were sufficiently compatible with the aspirations and ethos of the group”(Ji)

6.8.4.2 The nature of the relationship

The HRP had “a family relationship. It had its ups and downs, it stuck together and aimed for survival”(Ji). As with any family there was “some conflict, but not a lot”(Ji). No company had ever left, and we had never

seriously debated ejecting anyone”(Ji). Leadership of funded work was “neither by turn nor seniority, but by appropriateness”(Ji).

“Originally, all the partners were under threat and petty differences were set aside”(Ji). The focus on survival led to what was “almost a joint activity with the customer, although the customer didn’t realise”(Ji).

Over time, businesses had “changed hands and changed names”(Ji), but despite “lots of change in the industry”(Ji), the HRP had been largely unaffected.

6.8.4.3 Contracts, Controls and IPR

This HRP is notable in that it existed with “no non-disclosure agreement, teaming agreement or partnering agreement. Just a handshake!”(Ji). Whilst the “leaders understood the commercial arrangements”(Ji), there were typically “new commercial people each time it bids for work, who didn’t understand”(Ji).

The HRP “in no legal sense exists, and therefore cannot accept contracts”(Ji). Although “contracts were awarded in its name, they actually went to one member in its name”(Ji). “Commercial people found it very difficult: for example terms and conditions, penalties etc were not flowed down to partners”(Ji). There were “no penalties”(Ji), simply an “agreement between honourable gentlemen who had never let each other down, and never would”(Ji). There was a commitment to “honour agreements”(Ji). When the HRP bid for work, this approach could cause difficulties internally for the lead company as “whoever led on a particular piece of work took all the liability”(Ji). There was “no markup on subcontracts”(Ji) and this “became a problem as we became more prescriptive about company processes”(Ji).

The HRP had “never accused anyone of failing to deliver. If there were problems, you’d roll up your sleeves and fix it. It was a family partnership.”(Ji) If something did go wrong then members “could retaliate,

but it would be MAD: mutually assured destruction, the nuclear option. Retaliation was never part of the HRP's culture"(Ji).

Although the viability and purpose of the HRP had been questioned over the years, members recognised the unique arrangement and had "never had the nerve to stop it"(Ji) recognising that they would "never manage to form it again"(Ji).

6.8.4.4 Culture

The HRP had a very strong sense of identity, founded on the stability of its membership. Most steering group members were originally working group members and had been involved for seven to ten years: for one member that figure was twenty-two years! "Corporate memory and passion"(Ji) were distinctive attributes and the most common "cause for departure"(Ji) was retirement. "Most members had 'gone native'"(Ji) and the relationship was more like a family than a collaboration of partners and competitors.

Its effectiveness was founded on "two relationships of trust: between the people in the working group and steering group, and between individuals and their employer"(Ji), where the emphasis was on "not doing anything to damage the HRP"(Ji).

6.8.4.5 Resources: People

Members of the HRP were "intelligent people with enthusiasm, capable of wide-ranging debate"(Ji). The style and focus of leadership of both working group and steering group was therefore important. For the working group, one former chairman "managed to draw them together to a conclusion"(Ji); another who was less effective but "absolutely delivery focused"(Ji) tried to "control the working group to deliver a 'thunk'"(Ji).

The former steering group chairman "only missed one steering group meeting in fifteen years"(Ji). Others who were "probably too busy"(Ji) and missed many meetings were seen as "an embarrassment"(Ji). After many

years of leadership from the company, an independent chairman with “a passion for the HRP”(Ji) was appointed.

6.8.4.6 Resources: Funding

“When it became clear that the HRP was successful, the second hurdle was finance. It wouldn’t have mattered without technical capability”(Ji)

Within the HRP, “no money changed hands except under specific contracts”(Ji). “Manpower costs etc, which amounted to a few days plus travel, ‘lay where they fell’”(Ji), and “there was internal funding of specialists as needed”(Ji).

6.8.4.7 Lifecycle

The HRP was quite a remarkable entity, having recently celebrated its 30th birthday.

After its initial success, it “went into ‘deep thought’ mode: it had got used to itself, and to working together”(Ji). From an engineering perspective, individuals “liked working together, being able to ‘do deep thoughts’ and think about future challenges”(Ji) to ensure that the UK retained its reputation for leadership “ready for the next round”(Ji); and it “became the market survey on private venture funding”(Ji).

“Then it changed again. Someone in commercial asked it to justify ‘just spending money’. The decision was made to go bidding for money in areas of its technical expertise”(Ji). Over time, it started to get funded work and this focus continued until a few years ago when the importance of re-establishing ‘thought-leadership’ was recognised. Members felt that it had become “moneygrabbing”(Ji) at the expense of its original purpose. The steering group chairman stood down, recognising that having led up to that point, it “would have been difficult to lead the change back again”(Ji), and a new independent chairman was appointed to lead this next phase.

The HRP appeared to be in a “repeating cycle of sustainment and transition, which may be overlapping”(Ji). Some thought had been given to termination, but “it was not so simple as just not having the next meeting.”(Ji) “There was a point where the culture became self-sustaining and now resists termination”(Ji). Reflecting the sense of family, there “would be a hell of a party/wake if it was decided to terminate”(Ji).

6.8.4.8 Complexity

6.8.4.9 The role of Systems Engineering

Since most members of the HRP were “systems engineers by background”(Ji) they had a “better understanding of impacts”(Ji) and tended to “behave in a systems engineering manner – but not always”(Ji). “Systems thinking rather than process”(Ji) was used.

Systems engineering “processes and techniques from the companies”(Ji) were used “in delivery of tasks”(Ji).

6.8.4.10 Perceptions of Success

“To a greater or lesser extent, the HRP had succeeded in its original objective”(Ji). Since then, it had become “the obvious and natural supplier of research work in the UK”(Ji) within its technical area and was “a team that was fielded in the international marketplace”(Ji). Companies that were not formerly members of the HRP competed for funding: they “lost, learned their lesson and asked to join”(Ji).

6.8.5 Case Study K

The HRP in Case Study K was launched in 2008 as a Centre of Excellence on a university site (Case Study K, About Us 2007). Initially four industrial core partners each committed £1 million over five years to support technology research relating to maintenance, repair and overhaul for high-

tech, high-value vehicles. Local government also invested £3 million (Case Study K Centre *undated*).

The HRP was used by interviewees to illustrate a different type of commercial model with multiple industrial partners.

6.8.5.1 Objectives

One interviewee described the HRP aim as the development of “technology as an enabler for Availability”(Kiii) of high value equipment. The emphasis was on “low to medium TRL enabling each partner to take it forward”(Kii) and exploit research outputs. The topic area was well defined and “people understood what it meant”(Kii).

The HRP Vision was to deliver sustainable integrated solutions “that industry cares about” in the chosen technology area. This implied providing “a steady flow of incremental improvements as well as game changing opportunities that result in added shareholder value and competitive advantage for our partners”. Its mission was to “become a globally recognised centre” developing innovative solutions through research, knowledge integration and coordination (Case Study K, About Us 2007). The focus was to “provide breakthrough performance and extreme affordability”(Case Study K Centre *undated*).

HRP operations were in three main areas: research, business development and knowledge base, which included teaching (Case Study K, Centre Operation 2007).

The strategic aims were:

- To Attract Investment – supplement launch funding by attracting additional investment from new core partners/members and research funding bodies
- Achieve World Recognition – working with industry and academic leaders

- Provide Technology Transfer – implementation of concepts and technologies within the industry and develop the associated skills base
- Become Self Sustaining – after 5 years
- Deliver Competitive Advantage – to the key stakeholders (Case Study K, About Us 2007).

6.8.5.2 The nature of the relationship

The HRP was managed by a “steering board”(Kii) which “decided the research agenda”(Ki). It was established by one industrial partner, and “although they no longer led it, their emblem was still on the paperwork”(Kii).

Nevertheless, the HRP was described as a “club” in which the funding partners were “members”.

6.8.5.3 Contracts, Controls and IPR

The organisation of the HRP was felt to “trade off leverage, control and exploitation”(Ki) in a positive way. As well as sharing the majority of the costs, Tier 1 partners jointly directed the programme. “It was a democracy”(Kii). “Common voting meant you couldn’t just spend your own money”(Kii), but that the centre pursued research into topics selected by the funding partners (Case Study K, Frequently Asked Questions 2007).

6.8.5.4 Culture

6.8.5.5 Resources: People

The centre’s core competencies were:

- Business Modelling & Simulation
- Business Transformation & Culture Change
- Demonstration & Fast Prototyping

- Analysis & Algorithm Development (inc. Data Exploitation)
- Systems Engineering /Architecture & Systems Integration
- Knowledge Integration (Case Study K, About Us 2007).

Among the key participants it was noted that the “technical director was a professor from industry”(Ki).

6.8.5.6 Resources: Funding

The HRP was based on “industrial collaborative funding”(Ki), supplemented by “consortium bids into a funding agency”(Kii) and some local government funds. The research programme was initially “completely funded by the partners”(Kii) with “Tier 1 partners each contributing £200k per year and Tier 2 partners paying £50k per year”(Kii).

By attracting multiple participants, partners and members benefitted from “highly leveraged R&D spend (from 1:10 to 1:20)” (Case Study K Centre *undated*).

6.8.5.7 Lifecycle

The company approached the UK government in 2006 with regard to setting up a research centre in the UK. An open competition was run and the university was successful in securing the Centre (Case Study K, Frequently Asked Questions 2007).

6.8.5.8 Complexity

6.8.5.9 The role of Systems Engineering

6.8.5.10 Perceptions of Success

The Centre was interested in high TRL (Technology Readiness Level) research and so the technology developed would be planned into the partners’ roadmaps and take the next step of going into service. This

commercialisation of the research was considered the ultimate measure of success (Case Study K, Frequently Asked Questions 2007).

Early progress in the HRP “seemed very positive”(Kii). After one year the feeling was “so far so good”(Ki) and that the HRP had the potential to be “huge”(Kiii).

6.8.6 Case Study L

The HRP in Case Study L was used by one interviewee from the Commercial function to illustrate some of the challenges faced.

6.8.6.1 Objectives

The HRP took recent research findings from engineering, technology, business and the social sciences and turned them into tools, techniques and processes suitable for widespread adoption by UK industry and the public sector. It aimed to enable organisations of all sizes and across sectors to realise value from complex, product related services (Pe____ [undated]).

6.8.6.2 The nature of the relationship

The government-funded programme built on the work conducted as part of a consortium led by the university and jointly funded by the government and one company (Pe____ [undated]).

6.8.6.3 Contracts, Controls and IPR

Within the partnership discussions, protection or release of intellectual property became a key trade-off and there was a “need to decide who made the decision, i.e. ‘who could say no to IP’”(Li) and allow it to be released. However, “typically nobody made that decision”(Li) and “there was no process to check what background intellectual property was being put in”(Li) to a partnership.

6.8.6.4 Culture

When the interviewee became involved in the HRP it had been “working for nine months without non-disclosure agreements (NDAs), contracts, etc. Absolutely nothing”(Li). “The Commercial function was not typically involved in partnership discussions. When there was a quote to do or bid/no bid decisions, you needed to have Commercial there – but with a partnership you could do all this talking as there was funding for these people’s time”(Li).

It was noted that “many commercial people wouldn’t be proactive at the beginning. It’s not a priority for them at that stage”(Li). However, “the person leading the development of the partnership might not know the right people to ask, for example to bring in the IP experts”(Li). “Admittedly commercial people were very busy and ignored emails if they didn’t understand the problem or what was needed”(Li).

Overall this was considered to be a significant issue but it was unclear “who should have been supporting this from a commercial viewpoint”(Li).

6.8.6.5 Resources: People

6.8.6.6 Resources: Funding

6.8.6.7 Lifecycle

The HRP was “derived from”(Li) an existing partnership. “At creation, the stakeholders were not the correct stakeholders: they were typically technical people, a champion etc. These were people at a suitable level with the authority to go and commit, but they were not in a proper structured area” to ensure that relevant checks and controls were in place. “All this had been going on, discussing with other partners, with technical and programme management people involved – they were all there at the creation stage but without anyone from Commercial”(Li). The first Commercial involvement was not until four months after funding had been received.

6.8.6.8 Complexity

6.8.6.9 The role of Systems Engineering

6.8.6.10 Perceptions of Success

6.8.7 Case Study M

The HRP in Case Study M was established in 2003 as a customer-industry partnership which was governed and funded by the customer. Working across the customer-industry space to analyse problems, examine options and de-risk requirements, it was created to help the customer to make better, faster and more informed, decisions (Case Study M 2011).

Its mission is “Serving defence as the definitive partnership providing decision support to enhance current and future military capability”(Jo___ 2008).

6.8.7.1 Objectives

This HRP was “a huge undertaking to provide decision support to the customer”(Mi) which “did anything the customer wanted from a three month experiment to a one day facilitated workshop”(Mi).

Following the three year review, it was asserted that the HRP “provides a vehicle for maximising alignment, securing stakeholder buy-in and mobilising resources” and that with these three components in place, the HRP could secure its desired position as a UK strategic asset (Jo___ 2008)

6.8.7.2 The nature of the relationship

The partnership comprises major UK defence providers and a diverse community of industry associates including small and medium enterprises, specialists, research establishments and major consulting companies (Case Study M, The Partnership 2011). However, although described as “a partnership in the truest sense”(Je___ 2008), the customer “didn’t see it as a

partnership”(Mi) in which they participated but rather as “the partnership which the company ran”(Mi). This was illustrated by the description that the industry partners were all represented on the Partnership Board and that key customer stakeholders are “also represented”(Case Study M, The Partnership: Industry Partners 2011)

Even having “spent a great deal of time, we only scratched the surface for the customer to realise it was a partner”(Mi). This was further complicated by the customer characteristics such that “calling the customer ‘a partner’ didn’t work. It was amorphous with no singular view”(Mi).

Although “the UK didn’t have the same organisational conflict of interest policies as the USA”(Mi), there were “tensions in the partnership”(Mi) and concerns over “the matter of trust when advising the customer”(Mi).

6.8.7.3 Contracts, Controls and IPR

One industry partner held the prime contract, with 15 partners and fifty or so associate organisations who were “small in the UK”(Mi), including multinational primes. The “Partnership Board meets quarterly, and provides support and guidance to the strategic direction”(Case Study M, The Partnership: Industry Partners 2011).

The HRP was “an enterprise in which commercial interests are put to one side and Intellectual Property Rights (IPR) are freely shared”(Jo___ 2008). The “inner ring of partners got access to all intellectual property (IP) irrespective of their involvement”(Mi) in a particular activity, but “had to bring background IP”(Mi) in return. The “associates only got access to IP for those activities in which they were involved”(Mi). The approach offered “the chance for an open and frank industrial discussion where MOD owns the output” (Case Study M newsletter. 2010).

The “open book”(Mi) nature of the contracting approach meant that the HRP was “behaviourally different”(Mi) and the flow-down of contracts through the HRP was felt to be “not bad”(Mi).

The HRP underwent a review after three years, which led to the renewal of the contract almost 18 months later. It was clear that this review was the focus of management attention even 18 months before the review (Case Study M: *Capability through partnering*. 2005), effectively creating a period of three years of uncertainty which “could easily have destabilised” the HRP (Je___ 2008).

6.8.7.4 Culture

“The partnership has a unique culture and behavioural ethos based on collaboration, impartiality, transparency, agility, high performance and trust” (Case Study M, *The Partnership* 2011). However, it was felt that the HRP could also be “quite political”(Mi) due to the nature of the partners and their relationship with the customer. The HRP was “in competition with”(Mi) one of its partners and another had “channel conflict’: they had to play, but it was cannibalism”(Mi) with respect to their other work.

However, of the 300 people who passed through the HRP during its first 4 years, “each has displayed the desire and ability to work together. This sense of cohesion reflects the behaviour of the partnership’s core team and they have been instrumental in creating the same values” in temporary members. This culture and these behaviours were felt to have enabled the HRP to overcome many of the obstacles faced in its development (Je___ 2008).

The HRP is considered to be the “model opportunity” for the customer and the Defence Industrial Base to “capitalise on their symbiotic relationship and demonstrate the close harmony, trust, and partnering behaviours required to deliver truly innovative support to both the warfighter and the UK’s defence industry”(Case Study M newsletter. 2010)

6.8.7.5 Resources: People

The HRP “is unique in its ability to draw on the combined expertise” of the customer-industry partnership (Case Study M, *The Partnership* 2011) and “establishes ‘best athlete’ teams” from the partnership that “combine the

breadth and depth of UK defence knowledge and experience” (Case Study M, The Partnership 2011). This provides the additional benefit that industry staff seconded to the HRP develop skills and experience (Case Study M, The Partnership: Industry Partners 2011) and are “able to broaden their understanding of how military personnel conduct their business”(Case Study M, The Partnership 2011), free from the constraints “their own companies may place on them in other partnering situations”(Je___ 2008).

HRP publications contained a regular feature covering details of new people joining the team, indicating a high turnover of seconded staff but also the recognition that staff changes needed to be communicated.

6.8.7.6 Resources: Funding

The HRP was “fully funded by the customer”(Mi) with “no industry cash contribution”(Mi). The “core customer funding was used to define”(Mi) the problem to be solved before “competing across the partnership for the work to be done”(Mi). Although the “sponsor also had to bring funding for activities”(Mi), the partnership “did work with very high quality people at less than the going rate”(Mi) and was felt to represent very good value for the customer.

6.8.7.7 Lifecycle

The original contract was, to some extent, “an experiment in experimentation”. Although the construct eliminated the risks involved in developing a new organisation, the HRP would have failed if the original industrial partners had not been supported by their industry peers (Je___ 2008, p98).

After the first 3 years, the HRP underwent a thorough review. As a result, the mission of the HRP evolved from being a customer/industry partnership “providing an experimental environment which allows our customer community to assess the benefits of NEC for its effective and timely delivery” to “serving defence as the definitive partnership providing decision support to

enhance current and future military capability”(Jo___ 2008, p100). At the same time, the business model also changed. Moving from the original single, guaranteed funding line, the HRP’s new contract had a mixed funding model, drawing some core funding from the original source but supplementing this with the potential for sponsor funding from a range of sources within the customer organisation. This “subtle but significant change was driven through necessity by the competing investment demands” faced by the customer, and although “workable”, was “quite demanding in terms of management attention”. The change provided what was described as an “opportunity’ for growth, set in the context that such growth was essential “to attain sustainable critical mass” (Jones 2008, p100). Such a sustainable business was viewed as a “necessary, but not sufficient” condition to meet the challenge laid out at the start of the new contract: for the HRP to establish itself as a UK strategic asset.

6.8.7.8 Complexity

6.8.7.9 The role of Systems Engineering

6.8.7.10 Perceptions of Success

It was felt that the HRP delivered demonstrable value to the customer by providing both a gateway to breadth and depth of expertise without company bias, and a means of delivering trusted evidence quickly (Case Study M website. 2011) and that it “came up with solutions to problems”(Mi) in a particular area, although “there have also been criticisms in the past of [the HRP’s] tempo and pace of delivery”(Je___ 2008).

In preparation for the three-year review there was an emphasis on capturing and measuring the benefits achieved for the customer, recognising that the benefits, including how they had been exploited by the customer, would be key criteria in the assessment (Case Study M: *Capability through partnering*. 2005).

Customer feedback noted that the process was “excellent and delivers real value to my programmes” and that it “adds significant value to our ability to make better decisions about how to deliver operational effect” (Case Study M, The Partnership 2011).

Industry partners derived “substantial benefit from their involvement”, including “improved understanding of the defence environment and [the customer’s] capability needs, the ability to make better investment decisions in relation to experimentation and NEC issues, improved commercial positioning and decision-making through understanding of [customer] programmes, and improved relationships with the ... customer” (Case Study M, The Partnership: Industry Partners 2011).

6.8.8 Case Study N

The HRP in Case Study N was a 3 year £1.8M Government-funded programme which ran between 2003 and 2006. This project involved seven universities, four industrial partners and four funding sources with the aim of extending the capabilities of aerodynamic prediction tools.

6.8.8.1 Objectives

The HRP involved research into “external and internal aerodynamics”(Ni) and “a number of the fundamental techniques which were relevant to both”(Ni). Its “three objectives were very clear”(Ni) and the “universities created sub-objectives”(Ni).

6.8.8.2 The nature of the relationship

The HRP was “technically driven”(Ni) with “lots of sharing of very fundamental stuff”(Ni). The “partnership was simple”(Ni) and work was only undertaken in areas where there were no commercial or legal sensitivities.

Compared to the HRP in Case Study D, “people were a lot clearer about how the different groups would interact”(Ni). There was an emphasis on

“ensuring the work was done in both areas but only sharing where there was benefit”(Ni) in doing so.

6.8.8.3 Contracts, Controls and IPR

The HRP was “highly complex commercially”(Ni) and it “took a long time to agree a contract involving two government bodies”(Ni) who “couldn’t agree on common terms and conditions”(Ni) to place on contractors. Industry contracts staff “did lots of brokering”(Ni) to resolve the issues. In the meantime there was “reasonable confidence that the programme would happen”(Ni) and the “technical people went ahead anyway”(Ni) and “started before we had a contract”(Ni).

“Quarterly reviews involved expert judgement from the customers’ technical advisers”(Ni).

6.8.8.4 Culture

6.8.8.5 Resources: People

Individuals and relationships were viewed as key to the success of the HRP. “People representing the industrial organisations had a good understanding of the academic environment”(Ni), and the “customer technical adviser was also a visiting professor”(Ni) at one of the partner universities. Both industry and academic participants “respected each other intellectually”(Ni).

Within one company, the representative had less experience in this environment but was “compliant”(Ni). “Although interested, this company probably exploited the research less”(Ni) and this may have “reflected the lower level of technical expertise of that particular industrial representative”(Ni). In contrast to the HRP in Case Study A, “the partnership was with the technical expert at the university, not the university itself”(Ni). “Having partnerships and working relationships with individuals was important”(Ni) and provided the additional benefit of “expert consultancy in times of urgent need”(Ni) from “academics with in-depth knowledge”(Ni).

6.8.8.6 Resources: Funding

Funding for the HRP in the form of “real cash”(Ni) was provided by three government bodies and industry, with each contributing “approximately 25%”(Ni).

It was noted that the “funding of universities moves with the individual whereas in industry it stays with the company”(Ni). This had implications when particular academic staff moved between institutions and the funding moved with them.

6.8.8.7 Lifecycle

In contrast to other partnerships, it was felt that the “funding was separate from operational relationships”(Ni). When the partnership first came together in 1999 there was “no money”(Ni). When it “won about £1.8M in 2001”(Ni) the “partnership was already functioning”(Ni). Since the HRP was effectively operational “before the money arrived, when the money came along they were ready for it”(Ni). It was felt that “maybe it transitioned *into*”(Ni) the funded HRP.

Academics “weren’t just doing this HRP, but other programmes too”(Ni). “A lot of relationships went back quite a few years”(Ni) and academics were “still working together three or four years later”(Ni).

6.8.8.8 Complexity

It was noted that within the HRP “complex technology was being developed”(Ni).

6.8.8.9 The role of Systems Engineering

At the outset of the HRP the industrial leadership “set out three requirements”(Ni). They “didn’t fuss too much after that, but just let the academics get on with it”(Ni).

“Work could be partitioned effectively”(Ni) such that the “academics had unique roles and weren’t treading on each other’s toes or trying to steal from each other”(Ni). With one exception, universities “worked together rather than trying to do the same thing”(Ni). “Integration responsibilities were defined”(Ni) and “meeting the objectives needed contributions from all participants”(Ni).

6.8.8.10 Perceptions of Success

The HRP proposal was “rated most highly”(Ni) of similar funding proposals. “One of the reasons was that it had actually started doing work before writing the proposal”(Ni).

People “worked together to pull research through more rapidly”(Ni) and in the end it “met all the requirements”(Ni). One senior industrial partner representative was “very impressed and became a keen sponsor”(Ni): as a result the industrial partner expanded its usual set of academic partners to new relationships developed in the HRP.

6.8.9 Case Study O

The HRP in Case Study O was a £1M, three-year bilateral arrangement between the company and a major university (Le___ 2009), which was among the top 10 in the UK for student numbers.

6.8.9.1 Objectives

There were “currently several objectives”(Oi) but a “win-win”(Oi) based on potentially complementary technical interests was the “common goal”(Oi).

The university “wanted to build up credibility, and establish a centre of excellence”(Oi) with the “aim to have a world class research centre across multiple fields by 2017”(Oi). They wanted “to be recognised as a centre of excellence by industry”(Oi) as well as “turning around underprivileged students”(Oi).

Although the stated aim of the HRP was “just research”(Oi) and the company “wanted to do good work and get leverage”(Oi), the primary driver for both company and university was described as “positive publicity”(Oi). For the company, working with the university was “an opportunity for us to demonstrate our support for research activity in the North West of England, where we employ around 15,000 people” and a way to address future skills gaps”. Underlying this was the desire to ensure the UK remained a world leader in engineering and technology (Le___ 2009).

6.8.9.2 The nature of the relationship

The partnership involved the establishment of a research centre, launched in 2009 to contribute to the university’s vision “to be recognised as a centre of excellence for research by 2017” and to be the Company’s first choice academic provider of research in this area. The centre’s mission was to “achieve step changes in the value delivered from R&D against market driven requirements by exploiting the synergies, integrating the skills and capitalising on the capabilities that exist across different industry sectors, their supply chains and universities” in the specific research area (Ge___ 2010).

It was clear that the university, and in particular its senior leadership, “wanted a long term, strategic partnership”(Oi). The aim was to move towards a centre of excellence “based on the HRP model used in Case Study K”(Oi) but it was unclear what would be offered or “sold”(Oi) to encourage other participants to join.

6.8.9.3 Contracts, Controls and IPR

The HRP was both operationally and “contractually simple: initially bilateral but expected to become more complex”(Oi). The partnership was delivered under the guidance of a company/university governance group (Le___ 2009). This “steering board was set up to enable stakeholder management”(Oi) and “prevent criticism”(Oi) from key areas within the company.

“Internal funding went through the usual company approval processes”(Oi). The “easiest option would have been to create a £1M work package but that wouldn’t have been a good idea. The better option was to ‘prime the pump’ and help the HRP to become self-sustaining”(Oi).

6.8.9.4 Culture

The university “only had one company link”(Oi) and little or no “industry experience”(Oi). “Unlike most traditional universities, who had other organisations they were involved with”(Oi), they came with “no baggage”(Oi)

Individuals within the university had a “really interesting mindset”(Oi): “bubbly but focused”(Oi), and “pragmatic” (Oi). They were very open, even offering to “jointly interview a new professor”(Oi) with industry colleagues. It was felt that they were “desperate to make it work”(Oi).

6.8.9.5 Resources: People

The HRP had very high level support. Senior figures from the company and university were “implicated”(Oi) and met on a biannual basis.

6.8.9.6 Resources: Funding

Funding for the HRP came from the “corporate sponsorship pot”(Oi) with the aim of “supporting the local community”(Oi). As the HRP progressed, there was an expectation of joint “business development”(Oi): “working together”(Oi) to secure national and European research funding.

6.8.9.7 Lifecycle

At the time of the interview, the HRP was in the creation phase. The statement of work and commercial / legal terms and conditions were “matured in parallel streams”(Oi). It was felt that there was the potential “to shape it to do what I want”(Oi). The intent was to transition over time from the bilateral agreement and to “grow to be self-sustaining”(Oi).

6.8.9.8 Complexity

6.8.9.9 The role of Systems Engineering

6.8.9.10 Perceptions of Success

The HRP was too new for success to be judged but it was noted that there were “no measures of success except programme delivery”(Oi).

6.9 International (non-UK) Case Study: P

The HRP in Case Study P was based on a 5-year contract to establish a systems engineering research centre, supported by researchers from 20 universities and research centres. It aimed to enhance the definition, synthesis, integration and test, deployment, and support of complex systems and enterprises.

The interviewees used the term ‘sponsors’ when referring to the ‘customers’ in this case study and their terminology has been retained here. The HRP had two sponsors. There were no industrial participants directly involved in the HRP.

6.9.1 Objectives

The HRP was established as a “concerted effort to look at harder problems”(Pi). Recognising the subject as “a national issue”(Pi), the sponsors “knew systems engineering research was needed”(Pi) in order to develop “a rigorous way to look at future problems”(Pi). Within this “application-oriented problem space”(Pi), there was a tendency for one sponsor to “want people to come and sort out problems”(Pi), and it was a challenge “to get the sponsor to have a long term strategic vision rather than short term needs”(Piii). However, the other sponsor wanted “a way to not only respond to ‘nitty’ problems but to broaden the understanding of systems engineering as a solution driver”(Pi). They were “more interested in the vision of taking systems engineering to the next level”(Pi).

The HRP's mission was perceived and stated in different ways by the HRP itself, the sponsor and individuals within it:

- “to enhance and enable (the sponsor's) capability in systems engineering for the successful development, integration, testing and sustainability of complex defence systems, services and enterprises” (Case Study P. 2009).
- “to research and analyse advanced and emerging systems engineering practices and relevant technologies to address the full spectrum of (the sponsor's) systems ... , from capability areas, enterprise systems, systems of systems, net-centric set of services, and interoperability down to subsystems and configuration items with the goal of ensuring consistency and systems engineering excellence throughout the acquisition life cycle” (Initiatives: Case Study P *undated*)
- “systems engineering research”(Pii)

The three objectives of the research program were to “make modest improvements to the state of the art, to maintain the competence of high quality people and to embed the concept of keeping people ‘refreshed’ as part of the corporate culture”(Pi). This drove the “notion of developing a community of systems engineering researchers”(Piv) and “engaging the broader community and getting other people to work on our problems”(Pi). It was “a way to grow and attract young people to the field”(Pi). HRP operations were focused on “performing high-impact research, building the community of researchers and putting research results to work”(Case Study P *2009 Annual Report. 2009*).

The two sponsors “came at this with different viewpoints”(Pi) and whilst their objectives were “not aligned”(Pi), they were “able to find common ground”(Pi). Although the lead university had “defined a strategic goal for the research”(Piii), it was recognised that each sponsor, university and individual

“had their own needs and expectations which needed to be honoured”(Piii). The “shared sense of purpose was growing”(Pii) and they were “finding ways to ensure alignment”(Pi), including the establishment of a forum for key stakeholders and a high-profile community engagement through conference keynotes. Overall it was felt that the HRP had “passion and a shared set of objectives”(Pi).

The sponsor and lead university went “back and forth on the development of research objectives”(Pi). The sponsor “wanted to be engaged in the discussion”(Pi) but the university was “responsible for delivery”(Pi). There was a recognised need for “a mix of near term and more strategic”(Pi) research: although focused on the future, the HRP was also ready to respond to current sponsor needs (*Case Study P 2009 Annual Report. 2009*). It was “OK to have a couple of programs which were more open-ended”(Pi), but “where you had nuggets there should be a mix”(Pi).

6.9.2 The nature of the relationship

The HRP had a special relationship with the sponsor which was characterised as follows:

- Responsiveness to evolving requirements
- Comprehensive knowledge of sponsor requirements and problems
- Broad access to information, including proprietary data
- Broad corporate knowledge
- Independence and objectivity
- Quick response capability
- Current operational experience
- Freedom from real and/or perceived conflicts of interest (*Case Study P 2009 Annual Report. 2009*).

Since the breadth and depth of the objectives ensured that no single university would have the required skills and knowledge, twenty leading institutions were brought together, giving “pervasive access” to a significant part of the nation’s systems engineering research and educational programs and creating a stable, inclusive research organisation (Case Study P 2009 *Annual Report*. 2009).

Within the HRP the lead university had the “responsibility to look after the sponsors and ‘feed’ the university partners”(Pii). The “governing twenty entities were not used to collaborating”(Piv). Usually, “two professors would work together, not two institutions”(Piv). It was necessary for the relationship to “evolve from individual to institution, and from single contact to multiple academic staff”(Piv). It was recognised that “to cause collaborative research to happen took a lot of trust building, openness and transparency”(Piv). This was “easy on paper, but hard to do”(Piv).

There was a need to “build loyalty”(Piii) among the partner universities. A key factor in this was thought to be “giving them business”(Piii) which meant that “most of the work (90%) should go to other universities rather than ‘feeding’”(Piii) the lead university. Nearly every project included multiple collaborators (Case Study P 2009 *Annual Report*. 2009). A metric had been created to monitor “the percentage of work going to other universities”(Piv) and this was “tracked internally to ensure that it was equitable”(Piii). The HRP was seen as “a collaboration, validated by ‘walking the talk’”(Piii)

There was also a desire to “find ways to partner with other organisations”(Pi). Persuading other organisations to collaborate with the lead university received some “push back”(Pi) but the “solution was to get one organisation that could see the bigger win involved, so that others would be interested”(Pi). It was recognised that “you couldn’t force them to talk to each other”(Pi). One view was “the larger the team, the better”(Pii). Recognising this as “a unique opportunity to create a systems engineering research community”(Pii) there was a desire for it to be “a bigger

collaboration”(Pii) and to “take potential competitors off the street by getting them into this team, not someone else’s”(Pii).

Roles within the HRP were evolving through time. “For some research projects, the lead university largely shaped what was in them. Others were more shaped by the sponsors”(Pii). This was felt to be a good thing, reflecting “increasing maturity”(Pii). The preferred approach seemed to be for the sponsor to “write an initial problem statement”(Pi) and then open the bid, and for the lead university to “do an initial assessment”(Pi) of proposals and “engage the sponsor in a discussion of opportunities”(Pi) but this was clearly evolving and varied between projects.

Overall, there was a recognition of the need to “maintain boundaries”(Piii) between the sponsors and universities and to “build rapport and trust”(Piii) by “honouring the sponsors’ needs to be impartial and objective”(Piii).

6.9.3 Contracts, Controls and IPR

The HRP enjoyed “special status”(Pii) within the sponsor organisations and in related organisations which enabled them to receive work without competition “if the HRP’s mission fitted their need”(Pii).

“Two types of agreement”(Pii) were in place: an “umbrella agreement containing 80% of what was needed to do the work, and specific research subcontracts”(Pii) which could be issued quickly. In addition, a “management plan established the business rules to oversee and manage the HRP”(Pi). A detailed listing of deliverables enabled the sponsors to “feel comfortable rather than just hoping for the best”(Pi), although even with this it was a challenge for the lead university with “responsibility for delivery”(Pi) to “inculcate timeliness and deliverables”(Piv). In the early stages the level of contracting activity required “regular weekly meetings between contracting people”(Pii) in the lead university and sponsor organisations. “Every time there were cross-university issues, an extra contract was required”(Pii) between them. However, several universities were “in a quiet state”(Pii)

without work or funding awaiting the removal of certain contract terms which were in conflict with their university policies.

The two sponsors were “equal partners”(Pi) who “had oversight management controls”(Pi) and each “had control over their share of the funding to prioritise work/effort and the problems to be tackled”(Pi). They “reviewed draft deliverables, which provided lots of opportunity for direction”(Pi). Although “each research team was responsible for quality”(Piii) it was recognised that the “integrity of the research had to be monitored”(Piii) by the lead university and that there needed to be “the rigour to filter out bad or mediocre researchers”(Piii), although this was seen as “the tough part”(Piii).

There were differences in contractual culture within the HRP, with one sponsor being used to “micromanaged pages and books of rules”(Piii). The lead university “established an infrastructure which supported the sponsors needs, including procedures, bookkeeping rules and on-time reporting”(Pii). Although all the partner universities “had to conform to the standard management plan”(Piv), accounting could be “slow and unreliable”(Piii) and “bookkeeping systems were not up to it”(Pii). “Invoicing and getting paid”(Piii) were non-trivial tasks. Although some people “were impeccable in the application of funds”(Piii), others were “less so”(Piii). The lead university “needed to ensure trust without being too overt and too much scrutiny”(Piii) but could not “accept mis-invoiced claims”(Piii) which were a “risk to the relationship with the sponsor”(Piii).

Four people managed the HRP: Executive Director, Deputy Executive Director, Director of Research (all part-time management roles) and a full-time Director of Operations. The management team were “responsible for the success of” the HRP mission: aligning strategy and execution with external stakeholders and ensuring research quality, managing resources and meeting contractual requirements (Case Study P 2009 Annual Report. 2009).

6.9.4 Culture

Cultural differences between the various parties were recognised. The sponsor was “trying to be transparent, viewing research as something that was very open and which benefitted from others who contributed to the problem space”(Pi). This was in contrast to many universities, where “transparent growth of knowledge was not how they would behave”(Pi). “Universities had many different needs”(Piii): there was a “sense of competition in each faculty member and the spirit of cooperation would take some doing. They flew their own university flag each waking moment”(Piv). As a result, “universities didn’t know how to team well”(Pii) and “academics by predisposition were not the best team players”(Pi). Although they would “sometimes work well together, sometimes they wouldn’t”(Pii), and “sharing data was always a problem”(Pi). This was illustrated at a research programme review where “half gave the sponsor what they wanted and the other half marketed the university instead of opening the books and showing stuff”(Pi). The challenge was “how to get them to change”(Piv).

There were also “two cultures in the sponsors”(Piii) and “a differing sense of urgency”(Piii) between them, and between the sponsors and the lead university. One sponsor was “risk averse”(Piii) and had the tendency to “put the brakes on if the pace seemed too fast”(Piii) and it was recognised that it “could derail the relationship if there wasn’t a sense of matched pace”(Piii). The sponsors “wanted to grow the investment slowly. They didn’t move quickly: it was counter to their culture”(Pii). The “cultures and bureaucracies needed to co-exist”(Piii).

The culture of the lead university was apparent. It earned trust by “people coming to respect them technically, by working pretty collaboratively and through transparent contracting”(Pii): by being “collaborative and open and flexible – increasingly flexible”(Pii).

6.9.5 Resources: People

The HRP was “totally driven by people and relationships. Like a small company, it was dominated by personalities”(Pii). Key people were identified as “great”(Piv), “incredibly good”(Pii), “a great teammate”(Pii), “marvellous at marketing”(Pii), “very good at identifying strategic initiatives”(Pi), and as having “collaborative DNA”(Pii) and a “big mind, good understanding and wide range”(Pi). A “successful mode of operation” for one individual was “continually updating himself”(Pi). This level of drive and competence was contrasted to “other people who got ideas and shopped them around lots of contacts without actually solving them”(Pi).

Within the leadership team, relationships were described as “a marvellous partnership”(Pii) and “based on personal credibility”(Piii). Leaders could “manage a group with conflicting interests and pull them together”(Piv) and there was an emphasis on “creating relationships to support collaborative thinking”(Piii).

Relationships and individual motivation were seen to be important factors. Behaviours and ways of working went beyond the “contract to collaborate”(Piii). The special relationship with the “principle academic partner had no contractual requirement but relied on integrity and behaviour”(Piii). It was recognised that having got it “contractually right, the HRP needed to build credibility and trust”(Piii). “Trust and consistency”(Piii) and “keeping people satisfied”(Piii) were important. In spite of “complicated relationships”(Piii) there was an emphasis on “keeping people happy – not because we *have* to work together, but because we *want* to!”(Piii). One interviewee summed this up by noting “I love what I do. I get paid, and it’s an opportunity to work with smart people. My expectations are met”(Piii). Nevertheless “some sceptics thought we were just playing. Doing it was what counted. Not everyone understood”(Pii).

The sponsor also recognised the “benefit of engagement”(Pi) with the HRP. Although this was a “high overhead for fairly small amounts”(Pi) of research

investment, the sponsor “got value by the overhead”(Pi). People with “responsibilities for furthering systems engineering tracked and advised on each task”(Pi) within their technical area and benefitted “because their job was to answer that problem”(Pi). However, there had been “three cycles of change”(Piii) within one sponsor and the “key people had changed each time”(Piii). New people questioned the HRP’s value and it was necessary to “send the big guy in, get in there often and become a trusted friend”(Piii) in order to rebuild the relationship each time and “convince them”(Piii).

The success of every research project depended on the expertise of collaborating researchers and was “carefully staffed” (Case Study P 2009 *Annual Report*. 2009). The process of selecting academics to tackle a particular research topic was merit-based and involved “the sponsors bringing a problem” and then “understanding who was best through personal contacts and the literature, so that peers figured out who was in the best position to do the work”(Piv). This involved “knowing the capabilities of other universities: knowing what they were capable of, but also using their contacts and pulling contacts in”(Piii). Ideally each programme had two or three, up to a maximum of five, university participants”(Pii). Selection of Lead Investigators was initially from the lead and principal partner universities and “people who were known”(Pii), but this was expanded as the programme grew and matured. The “collaboration was big enough that there were multiple source options”(Pii) and “general calls for collaboration”(Pii) were starting to be used to widen the pool further.

In spite of this there was “still a divide between those out there doing it, and those researching”(Pi) and one sponsor “had a greater need for research to be presented in layman’s language, that ordinary people could understand”(Piii). In order to meet expectations there was a need for “consistency in research output”(Piii) and “greater focus on its practical purpose”(Piii). There was also a concern that the “state of academic systems engineering was not keeping pace with industry”(Pi), although “leading

institutions kept their staff refreshed and recognised the need for today's information and understanding"(Pi).

6.9.6 Resources: Funding

Since the HRP was guaranteed only a relatively small annual amount of research funding, there was a need to "do something"(Pii) to grow by five or ten times in order to "make sense to even do it"(Pii). It was seen as "having potential"(Pi), and "aimed to form strategic relationships"(Pii) and to treble the average size of projects from the initial level. The HRP was "trying to find partners with deep pockets and big problems"(Pii). Although "legally, the HRP could take money from industry, culturally the sponsors weren't ready for that"(Pii).

"Ninety percent of the research cost paid for professors, graduate students and travel"(Pii). In scoping new work there was "generally a sense of the money available"(Pii) which enabled "probing the community to shape the scope, working backwards from the available investment"(Pii). From that it was possible to propose a sensible programme: "not crisp, but more standardised by scale as the HRP grew"(Pii).

The HRP was considered to be a "good thing financially"(Pii) for the wider systems engineering research community and there would be "a lot less spending in systems engineering research without it"(Pii).

6.9.7 Lifecycle

Creation of the HRP was a "long and difficult process which took eight years to come to fruition"(Pi). It was "hard to establish a new entity"(Pi) and it suffered an "eight year push back from a strong community who questioned the nature of systems engineering research"(Pi). One key figure within the sponsor organisation had said that having launched it, it was "up to the HRP to convince others and to grow"(Piii).

The HRP “took its shape in the proposal phase, driven by the need to win the competition”. Although there “wasn’t a pre-existing community”(Pi), the leadership team was “a known commodity”(Piii) and key participants “had an existing relationship”(Piii). Since the “Request for Proposals’ had indicated that collaboration was valued”(Pii), a small group from the lead university and principle partner “reached out to sixteen universities in a range of areas”(Pi). “Partner selection was driven by geography, with at least one partner within a 30 minute drive of key sponsor locations. The aim was to transfer talent into the sponsor’s talent pool”(Piv) as the HRP matured.

In the first year, the HRP established an infrastructure, worked collaboratively with sponsors to define its research strategy, and began critical research (Case Study P 2009 Annual Report. 2009).

The HRP was subject to a five-year review as part of contract renewal (Case Study P generic *Management Plan: Appendices A & B*. 1996) at which three questions would be asked: “was there still a need?, was the need still stated appropriately?, and was the HRP fulfilling that need?”(Pi). This would be “an opportunity to change the mission”(Pi) although “the vision was something that would stay”(Pi). Although at that stage the HRP “could be re-competed”(Pi), the aim was to have created “credibility and sustainability so that the sponsors would want to continue”(Piii). It was “up to the HRP to grow the initial concept into something continuously valid”(Piii) recognising that “university expectations would change”(Piii) and continue to change through time. Although in all the HRP had been “fifteen years in the making”(Pii) there was an expectation that “in five years we may do things differently”(Pii).

6.9.8 Complexity

“Systems engineering is a young field”(Piii) and the sponsor “had to be convinced that systems engineering research was needed”(Pii). Even then, uncertainty around the nature and principles of systems engineering research

brought complexity to the HRP's programme. Even those who "understood systems engineering"(Pi) were "very uncomfortable about systems engineering research"(Pi). The "fundamental issue remained: what should the principles be"(Pi) for systems engineering research? It was felt that "for something like systems engineering which was not research-oriented it was a challenge to identify what the research was, and what we meant by the problem"(Pi). There was a concern whether typical primary systems engineering research instruments such as surveys and workshops "were a way to do research"(Pi). There was a view that researchers would "hold lots of meetings, make assumptions from random sets of inputs and get stalled if there was not enough data"(Pi), and doubt that "what we were seeing was research"(Pi). This concern was not unique to the HRP and was compared to another context where "systems engineering research was the hardest area of the research programme to do"(Pi).

The scale and scope of the HRP added complexity, both in "trying to market nineteen partners and put together a balanced team"(Pii) and having "various people to work"(Pii) among the sponsors and potential sponsors in order to grow the HRP. The problem space was "so complicated you could only get there by collaborating"(Piii). It "couldn't be done with 'my agenda' at heart"(Piii) but there was added "complexity in unknown expectations"(Piii). The lead university "had never dealt with this level of complexity"(Pii) before.

Complexity was compounded by the fact that the charter was also "very broadly defined"(Piv) and included "any key word you could think of"(Piv). The scope was "intentionally so broad you could drive a truck through it"(Pii), but "couldn't be any other way"(Piv) to allow adaptation as understanding grew. Most similar HRPs were "based around technologies. This was the only one around a discipline: it had to be broader"(Piv) in order to tackle the complex problem space. The "cases were very difficult with so many variables, it was not easy to have an academic institution come in and work with the sponsor"(Pi). "The last thing we needed was to let researchers get

into programmes and mess them up. They shouldn't have had to bother the programmes to do research"(Pi).

6.9.9 The role of Systems Engineering

The role of the HRP was seen as "putting together tangible systems to conduct research to enhance the sponsor's mission"(Piv). It was felt that systems engineering had been used "to the extent that you could apply systems engineering to an existing adaptive system"(Piv). There had been "lots of thinking on organisational structure and system dynamics"(Piii) and a "flowchart of relationships"(Piii) had been developed. There was "lots of management involvement"(Piii) and "typical management tools"(Piii) had been used "to look at internal and external strengths, and to align the management plan to the sponsor's research strategy"(Piii). The need for a systemic balance in the HRP was understood and it was recognised that for the HRP to be effective the key players "all had to pull at exactly the right tension"(Piii). "If they were all aligned, the HRP would lift. If they didn't consider expectations, the emergency brake got pulled"(Piii). "Sponsors and universities needed to be aligned, and pace and objectives needed to be aligned"(Piii).

"Organisation for long term flexibility"(Piii) was seen as important, which demanded a "robust architecture"(Piii) and "an organisation structure to navigate changing leadership"(Piii). However, "management techniques were used to build the business, but not to analyse it"(Piii) and there was scope for "using business tools more systemically"(Piii). It was "probably a systems process to draw clarity to success and failure based on understanding risks and expectations"(Piii).

In architecting the research programme the HRP "went through a 'crawl' phase, taking a few steps and falling now and then"(Piv). "Our lesson was that we needed some time to assemble what the strategic initiatives should be - top down and bottom up – to form the key strategic initiatives"(Pi). It was

hoped that “over time it would focus on key strategic initiatives, recognising that that knowledge just wasn’t available up front”(Pi). One sponsor “laid out a broad set of problems, chopped them up into areas and picked research foci in those areas, both in an integrated and modular way. Depth in one area was considered good, and integration was even better. The other sponsor was asked to identify those areas where they could derive value and where they could contribute”(Pi). This was a “really productive approach, which created several discrete active projects which could build towards a grander area”(Pi).

Systems engineering had been used to “identify the problems”(Pi) and “to develop the research agenda”(Pi), and a “roadmap of research going forward”(Pii) had been created. Roadmapping was “likely to get used more”(Pii) as it “allowed the universities to be paid to frame the work”(Pii) and was “a community activity, engaging researchers, users, potential funders and adopters in building and vetting white papers”(Pii). “Pathfinder projects” were used to create research roadmaps to tackle very hard, very important problems over a 3-5 year timescale, identifying promising research with the potential for major impact (Case Study P *2009 Annual Report*. 2009).

Nevertheless, the sponsors still “struggled with getting the academics to understand what the problem was and why it was an issue”(Pi). It “took forever to get over that”(Pi) especially as they were “mostly individual technologies people”(Pii). However, projects which were “easily relatable”(Pii) meant that “in some areas they had been largely focused on point solutions but were now thinking about the overall picture”(Pii). The “oldest programme was most coherent”(Pii) while “other areas were less mature”(Pii).

6.9.10 Perceptions of Success

The HRP was felt to be a “good marriage”(Pii) with “impressive breadth”(Pii). A “very good team”(Pii) had “created credibility for systems engineering

research”(Pii) and was “seen as a national asset”(Piii). One interviewee was “not totally convinced that the university partnerships were going to be successful”(Pi), in spite of the 90% rule “which was how collaboration was made to work”(Pii), but “still had high hopes”(Pi).

The culture and relationships which were such a strong characteristic of the HRP were seen to be key to its success. One individual felt that they “would be successful if relationships were good after five years”(Piii) and they had made “no mistakes”(Piii), and noted that they were “looking to build relationships, develop a vision and create emotional ties – like Kennedy and space”(Piii).

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7 SYNTHESIS OF CASE STUDY RESULTS

7.1 Introduction

Drawing on the wealth of data in Chapter Six, Chapter Seven now integrates the case study findings by identifying common and contrasting messages across the sixteen case studies. This was done by reviewing the text of each case study in detail and highlighting key messages, and then combining messages across all the case studies, one theme at a time. New messages were added to each section as they were identified, whilst common messages were simply updated with additional data and case study references. As with the pilot study, the analysis of the text was done manually in order to identify related issues which would not have been apparent simply by identifying the same word or phrase in different passages.

The ten themes from Chapter Six were found to overlap in some areas (for example Resources: People and Culture) and similar issues were identified under different theme headings. Within Chapter Seven, these issues were brought together and the original ten theme headings only retained in a supporting role to give structure to the chapter.

Where specific message have been derived from a particular case study this was noted in parentheses thus (X). Absence of a particular case study reference does not imply that the issue was not relevant to that case study, but that no explicit evidence was obtained.

7.2 Common and contrasting messages

7.2.1 Objectives

7.2.1.1 Clear, agreed, focused goals

Some HRPs had a very clear, simple goal with significant benefits which enabled the partners to 'rally together', and which gave clarity to the required programme (B, G, I, J, N). In one long-lived case this purpose had been reviewed and revised over time (J).

7.2.1.2 Clear Boundaries

Clarity regarding what was in or out of scope for the HRP was a key element for some HRPs (G, I, K). Others found this clarity very difficult and boundaries were unclear (A, C, D). In one case the loose definition of the boundary was identified as deliberate, in order to give the HRP flexibility in dealing with the breadth of the topic (P).

7.2.1.3 Different Benefits

In HRPs which shared a common objective, it was considered acceptable for the direct benefits to different partners to be different (B, E, F). This is slightly different to the concept of stakeholders who had different objectives which were not aligned, but nonetheless understood each other's needs and were able to find common ground (A, P).

7.2.1.4 Idealistic Objectives

In one case the objectives were idealistic and there were no effective plans to deliver them (A).

7.2.1.5 Agreed goals but unclear function

Although the overall goal was agreed for some HRPs, the actual function of the HRP was unclear in terms of 'what it would do' to meet that goal. This

made it difficult to demonstrate progress (C, D) and to be clear about the business needs that were being addressed (D).

7.2.1.6 Contract in conflict with objectives

In two HRP the contracts were not aligned with the vision, such that contract performance alone would not deliver the objectives (A, F). This problem was particularly acute on programmes where there was limited management discretion over how funding was spent (F).

7.2.1.7 Structural Effects

In one HRP the management structure and approach resulted in competition between its research themes and a dilution of the objective, such that although the objective was understood at a management level it was lost by the time it reached researchers (E).

7.2.1.8 Teaming an objective in itself

For several programmes, simply forming and working within a team on the topic was important (D, E, M, O, P). In some cases this was a political demonstration of 'the correct behaviours' (E, O); in others, it was a way of 'taking the competition off the streets' (J, P).

7.2.1.9 Low-TRL Programme

Several programmes deliberately constrained themselves to low TRL (up to TRL 4-5 for demonstrations) in order to avoid competitive pressures close to product development maturities (B, E, K).

7.2.1.10 Consolidated Technical Programme

Levels of integration of the technical programme varied. One HRP only shared information between partners where this was perceived to be of benefit (N). Several HRPs had no consolidated technical programme and it was therefore difficult to see how the programme would deliver the intended

objectives (A, F). Lack of clarity in the overall objective meant that one HRP could not evaluate the alignment of research projects and struggled to retain control of the overall programme (D).

7.2.1.11 Focus on Industrial Exploitation

Despite working at relatively low TRL levels, a number of HRPs were focused on the longer term business opportunities from exploitation (B, E, I, K). This was seen as a joint responsibility between researchers and business sponsor in one HRP (D). Another HRP instigated a bi-annual review in which industry's plans for exploitation could be challenged by researchers (G). There was evidence that the customer (or equivalent) implicitly carried the responsibility for ensuring research exploitation (E, I).

7.2.1.12 Focus on Academic Exploitation

One HRP found that it was possible to derive good academic publications from industrially-beneficial work such as demonstrations (G).

7.2.1.13 External Dependencies

Several HRPs were heavily dependent on external factors to achieve their objectives. The achievement of those objectives was not in the control of the HRP (C, F). This also manifested itself in reliance on engagement with the customer (E, P). The extent to which the customer was engaged in the programme was significantly higher in one HRP (P) than the others.

7.2.2 Nature of the relationship

7.2.2.1 Leading by example

Where HRPs were run through a prime contractor, there was an expectation that the organisation would not abuse its privileged position but would if anything subordinate its objectives to those of the HRP (E, F, P). Such organisations had responsibilities to both the customer and research

suppliers. One HRP made it clear that partnership was not defined by the contract, but by behaviours (P).

7.2.2.2 Government partners

Several HRPs had government bodies as partners. The nature of the relationship and the closeness of government participation were constrained by competition rules and the need to retain perceptions of fairness (A, C, E, F, M, P). In some cases the organisations in prime contract roles had expectations placed upon them regarding their access to and understanding of government needs and their ability to communicate and address these through the research programme (E, F, P).

7.2.2.3 Government funding agencies

Funding agencies were involved in a number of the HRPs, but having approved the funding proposal their role was largely as 'banker'. The nature of the relationship varied from the agency being largely ignored after the money was secured (A) to the agency only being interested in spend and milestones rather than the quality of the work (G).

7.2.2.4 Competitors can be partners

In one HRP, the industrial participants were largely competitors. After a difficult start the group developed robust and effective relationships with a delivery focus (B). Competitor companies also participated in a number of other HRPs where the development of a relationship of trust was critical to success, and where work had to be architected in a way which addressed intellectual property and other legal concerns (J, K, M, N). Other HRPs involved universities who were in competition with each other (G, I, N, P). In general, conflict was tackled by ensuring research programmes did not overlap to eliminate the need to cooperate in these areas.

7.2.2.5 Management control

HRPs applied different approaches to management control and the extent to which management intent was implemented through a formal technical and project management structure. Some HRPs expended significant effort on management control (A, D, E, F, P), whilst others allowed much more independent action (J). Higher levels of control caused a cultural clash and operationally difficult for some of those being managed, but met the expectations of those funding the programme. Researchers in several HRPs felt that, at times, there was too much emphasis on budgets and milestones and inadequate technical leadership (D, E, F). This balance got worse close to review points in some HRPs (D); in another it got better with a change of personnel (F).

Some HRPs attempted a more engaging management style (E, G). One found that the scale of the partnership made this challenging (E).

7.2.2.6 Missing layers

In one HRP, there was clearly a strategic intent for partnership and individual researchers worked well together. However, there were 'missing layers' at an operational management level where partnership practices were not implemented (A).

7.2.2.7 Maintaining the relationship

Even where the existence of the team itself was seen as part of the objectives of the HRP, deliberate efforts to nurture the team were not always adequate (A) although some HRPs were better at this (E, P). In one long-standing HRP, the internal culture had developed to such an extent that it was self-sustaining and resisted external influence (J).

7.2.2.8 Intra-partner relationships

Several HRPs suffered from dysfunctional relationships between different stakeholders *within* one or more of the partners. This made it very difficult for relationships *between* the partners to be effective (C, D, F, M)

7.2.2.9 Multiple related programmes

In some cases HRP partners were involved together in several related programmes or initiatives in similar topic areas creating dependencies, managerial and technical overlaps and potentially conflicts (A, I, L).

7.2.2.10 Loose consortium

Whilst most HRPs had a relatively stable membership (A, B, C, D, E), others were more open and continued to add members over time (F, K, M) making management of a coherent whole more challenging.

7.2.2.11 Expectations of transition

Several HRPs had established expectations that the relationship would transition and grow, either through the involvement of additional partners or the attraction of other sources of funding. One had achieved this (K). Most did not have credible processes and suitable business models in place to make the transition happen (A, F, O). In a couple of instances, the preparations seemed more promising but these were at an early stage and the effectiveness had yet to be demonstrated (M, P).

7.2.3 Contracts, Controls and IPR

7.2.3.1 Partners in name only

Most HRPs were run in the spirit of partnership, but with a formal contract in place which established a customer/supplier relationship (D, E, F, G, M, P). One HRP was established under the umbrella of another organisation which had since disappeared. It was felt that it could continue without a formal

agreement although this did affect the visibility at senior levels in the partner organisations (C). Another HRP was established as a 'true democracy' with partners voting on how shared funds would be spent (K).

7.2.3.2 Complicated agreements

Most HRPs had extensive and complicated contracts or agreements (A, B, E, F, H, M, N, P). Agreements involving more than one government entity seemed to be particularly challenging (B, N, P). Several agreements had large numbers of signatories which made both change and exit difficult (B, F, M). Considerable effort went into the development of commercial and legal frameworks although there were questions as to whether the results of such careful negotiations would ever be needed (A, E).

In contrast, one HRP ran on the basis of a lightweight, three-way contractual and financial structure but this caused difficulties as it gave the main stakeholder no control over spending (D). Another was bilateral and 'simple' (O). A third HRP was formed and received funding months before any commercial negotiations took place (L). The earliest HRP in the study had no formal agreement whatsoever (J). Whilst this did not appear to be a problem for the HRP, it was a source of concern for commercial managers in the partner organisations.

Strained relationships between commercial managers within the different partner organisations were not uncommon (E, F).

7.2.3.3 Scale

Several HRPs had scores if not hundreds of contracts in place to cover ongoing research (E, F, P). Even with standard contracts this was a significant commercial burden. Negotiation of standard contracts was also a significant effort in itself. Management of the bidding process for research work was also a challenge. The commercial, financial and project management effort required in these HRPs was significant and one HRP found the associated resources inadequate (F).

7.2.3.4 Reuse

Several HRPs emphasised the reuse of management assets such as contracts, IPR agreements, reporting structures and financial planning models (E, F). In one case these not only saved time in preparation, but also in negotiation between partners for whom agreement terms were already familiar (E). In another, the lack of an adequate agreement led to significant rework which could have been avoided (F).

7.2.3.5 Intellectual property rights

One HRP implemented an IPR agreement which was seen as unfair and caused resentment (A). Several HRPs noted the importance of fair agreements: one implemented separate IPR agreements for each project and ensured that there was a spread of participation (B). Management of IPR for integration activities was a concern for one HRP (E); another one proactively tackled the issue of IPR leakage through academic publications by instigation an effective industrial review process (I).

The balance between the IPR which was protected for HRP participants only, and that which was made openly available, was an issue for all HRPs. It was unclear how such decisions were made in a structured and controlled and controlled way (L).

7.2.3.6 Room for uncertainty

Several HRPs felt that there was a need for flexibility in the programme to accommodate uncertainties in the research area and the need for understanding to develop through time. One achieved this by establishing a very broad scope (P): others found themselves overly constrained (D, F).

7.2.3.7 Risk Management

In competitive HRP space, defining the risks was very important (B). The lack of responsibility for risk management was noted as a weakness in one HRP (D).

7.2.3.8 Common processes

Most HRPs operated some form of joint or common commercial and project management processes (A, E, F, M, P).

7.2.3.9 Metrics

Several HRPs used metrics to assess performance (A, D, F). There was a tendency to select simple, familiar metrics which were easy to collect rather than those which necessarily reflected the HRP's objectives (A, F). There was a risk that metrics were a distraction and became the target in themselves rather than reflecting the success of the HRP (A).

Others felt that after several years of operation the HRP had reached the point where key performance indicators may be useful, but these had not been implemented (C).

7.2.3.10 Independent leadership

Several HRPs had independent leaders in a variety of roles (A, E, F, K). One HRP had given its independent technical director the final authority over programme selection and the ability to terminate underperforming work (E). Similar authority existed within the management team of another HRP (P).

7.2.4 Culture

7.2.4.1 HRP Culture

Even within individual HRPs there were a range of views about culture. Some felt that all HRP participants had similar cultures by virtue of their engineering, systems engineering or similar backgrounds and experience (A, C, E, J). Others felt that the cultural differences between industry, academia and government were significant (A, F, G, P). Some HRPs suffered from the range of cultures within the participant organisations, including that in other functions such as commercial management, and particularly where the

dominant stakeholders changed over time, introducing different cultures (C, D, E, F, I, L). Cultures in the HRPs evolved (B, G, M) and some HRPs developed their own culture (J, M).

Several HRPs identified the need to change culture within their own organisations and those of their partners (D, G, F, I, P). The academic culture of competition rather than collaboration was specifically highlighted as needing to be changed.

7.2.4.2 Closed communities

Several HRPs benefitted from building on existing relationships, but there was a risk that this alienated newcomers (D). A mix of 'old and new' was felt to be needed (E).

7.2.5 Resources: People

7.2.5.1 Individual leaders are key

All HRPs, but especially those where competitors were involved, relied heavily on the quality of their leaders. These individuals demonstrated leadership skills at several levels in the organisation. Those who did a particularly effective job stood out for praise by their peers (B, C, E, G, P). In others, the leadership team was commended for working well together (F, P). Other leaders were noted as less effective and this was seen as damaging to the HRP (A, D).

7.2.5.2 Credibility is critical

Whether in industry, academia or government, the credibility of key figures was critical. For research leadership this implied technical credibility in all the partner organisations, with individuals needing sufficient technical competence to collaborate effectively with experts in the field and establish common ground (A, D, F, I, N, P). Inexperienced or less competent staff were felt to reduce the potential for research exploitation (N). In

management and strategic roles, individuals needed influence to bring resources to bear and the skills to facilitate collaboration (A, C, D, F, M). These skills were thought to be naturally developed through the typical career path of such individuals (E).

7.2.5.3 Partnerships are between people, not organisations

Several HRPs noted that although partnership agreements may exist at the organisational level, the true partnership operates – or not – between individuals (A, D, E, J, N, P). Turnover of senior stakeholders had to be managed and relationships re-established (P). Turnover of individuals within the HRP and the introduction of inexperienced staff were disruptive in several HRPs (A, D, F), but managed in another as a route for staff development (M). Relationships often survived beyond the formal end of an HRP (D, N).

7.2.5.4 Resources are scarce

A number of HRPs struggled to adequately resource the partnership with the necessary skills and experience (A, B, D, E, F, H), particularly with UK nationals (E). Many individuals had several part-time roles in different HRPs or similar programmes (C, E, F); some were simply 'overloaded' (F).

Several HRPs were specifically targeted at developing relevant skills in industry (A, M), academia (E, I, P) and government (F, M, P).

7.2.5.5 Integrated programmes need different resources

HRPs which sought to establish integrated research programmes needed both research skills and integration skills (E, I).

7.2.5.6 Individuals may be disruptive

Several HRPs singled out specific (different) individuals who had been disruptive and required a disproportionate amount of management attention (E, G). In such cases it was felt that one such individual could be

accommodated, but more than one would be seriously detrimental to the programme.

7.2.6 Resources: Funding

7.2.6.1 Running on a shoestring

Several HRPs were run on very low levels of overhead for management and integration (A, E, D, F, I, M). Central funding (A), 'Contribution in Kind' (E, F, M), investments by universities (D, I) and the goodwill of individuals meant that costs were kept artificially low and not sustainable in the long term. This had a direct impact on the ability of the HRPs to become self-sustaining (A, F).

7.2.6.2 Strategic vision must be funded

Several HRPs were funded from research funds with little or no funding for other activities. Objectives which went beyond research could not be funded (A, F, P).

One HRP had to win research funding on a tactical basis which did not align with its strategic vision. Delivery of the vision inevitably required some direct research funding (A).

Funding was an enabler for the community (P), enabling research organisations to work with universities (E), but the relatively small scale of the investment limited the effectiveness of one HRP in respect of its broader ambitions (F).

7.2.6.3 Innovative research needs long term funding

Short term funding pressures affected the ability to conduct more innovative research in several HRPs (D, G, I). Annual funding cycles prevented the instigation of certain types of research, e.g. PhDs (G).

7.2.6.4 Exploitation must be funded

A number of HRPs were unable to exploit the research outputs due to lack of funding (C, E, F). A funding pathway for the research is necessary from initial idea right through to exploitation.

7.2.6.5 Good leverage means shared influence

Several HRPs traded off control of the HRP's programme for funding leverage from other partners (B, K). This added complexity and delays to the programme.

7.2.6.6 Sustainable HRPs need to grow

Several HRPs had the objective to become partially or fully self-sustaining (A, F, K, M, O, P). Some of these established a significant business development activity to support this (K, M, P).

7.2.6.7 'Smorgasbord' management

Both companies and universities took income from a number of sources, including one or more HRPs, in order to construct an internal programme of related work (E, G).

7.2.6.8 Programmes may be terminated or have funding breaks

A number of HRPs had potential break-points in the programme at which funding could be terminated. Whilst this happened in only one of the HRPs studied (D), the risk of losing funding drove behaviours in several others (E, F, I). One HRP suffered an interruption in funding between programme phases whilst the results of the previous phase were evaluated (B). Most partners sustained a level of effort from internal funding during this hiatus to prevent the programme from collapsing.

7.2.7 Lifecycle

7.2.7.1 Inspiration

A number of HRPs were formed as a result of inspiration and conceptual agreement between senior figures in the partner organisations (A, D, F, L, O, P). In a number of cases, the detailed planning and what was implemented were somewhat short of the original vision (A, D, F).

7.2.7.2 Formation of team

HRPs formed teams in different ways. Some based the HRP on existing and proven relationships (A, G, I, L, N), even where these were with 'known' competitors (B). In one case, its success in winning funding was attributed to the fact that the HRP was already operational before the proposal was written (N).

Others ran an open competition for the leadership (K, P): some selected most or all of the academic participants before defining the research programme (D, P). Team selection had both technical and political drivers (B, E, P).

7.2.7.3 No instant formula

Several of the HRPs had a long gestation period, typically years, between concept and implementation (A, D, P). Most HRPs then took 1-2 years to become established, build relationships, properly understand the problem space, implement processes and start to manage research at the expected scale (A, B, C, E, H, P). For researchers, the initial focus was to establish fundamental research progress in their area of expertise (I).

In a number of cases, detailed planning of the research programme was not done until after contract award, at which point there were significant time pressures and the programme creation seemed rushed (D, E).

7.2.7.4 Different time constants

HRP partners had different time constants. For academia this was several years, largely driven by the duration of a doctorate. For industry, yearly changes to budget and direction were not uncommon (A). The timing of annual budgeting cycles was also different, with industry, academia and government each working to a different financial year. Launching an HRP at the 'wrong' time of year caused difficulties in academic recruitment (E).

7.2.7.5 Continued evolution

HRPs are complex evolving systems. Membership, ways of working, technical emphasis, delivery focus, funding models and even mission statements can change through time (A, E, M, O). However one HRP was unable to get support for a planned evolution from an initial capability to full capability (F).

7.2.7.6 Fixed duration

With only two exceptions (J, P), all the HRPs studied had a fixed duration after which they would terminate. Most also had intermediate review points after 2-3 years (5 years for P) at which they could be terminated early if necessary. Although some reviews focused on the need and whether or not the HRP was fulfilling that need (A, G, P), the remainder appeared to focus more on research content and progress.

Despite the cost, effort and time delay of establishing an HRP and regardless of ambitions in a number of cases to establish a 'centre of excellence' (A, E, F), there were no provisions for contract extension. Funding cycles were felt to drive an artificial lifecycle for HRPs (E), and this was supported by the one *unfunded* HRP which had survived for over 30 years (J). Rolling contracts were felt to be better suited to research in this environment (E, F).

7.2.7.7 Reviews are disruptive

Although it was almost unknown for an HRP to be terminated early, a number of HRPs described the disruption to their planned programme caused by uncertainty and the need to 'demonstrate success' in the run-up to a formal review (B, D, E, I, M). Some HRPs redirected effort from fundamental research to demonstrations (D, I). Another HRP found its interim review less distracting, but had confidence that the programme would continue (G).

7.2.7.8 Risk management

A number of HRPs implemented risk management processes during the bid cycle and during the establishment of the HRP (A). However, emphasis on risk management reduced with time, with the exception that HRPs subject to interim reviews conducted risk mitigation in the run up to the reviews (M)

7.2.8 Complexity

7.2.8.1 Nature of work

For several HRPs the research itself was complex: the technology was complex (N) or the variables and relationships were not well understood (A, C, E, F, P). One HRP noted that the lack of understanding of the problem meant the complexity was underestimated (F).

Several HRPs suffered from the fact that the research area was too esoteric and not close enough to product, making it difficult to achieve clarity of scope and priorities, and making research difficult to exploit (A, D, P). Some tackled this directly by focusing on a particular application (E) or 'Grand Challenges' (I). Exploitation was considered to be complex by some (F).

7.2.8.2 Many stakeholders

Most HRPs had many stakeholders: not only those with direct roles relating to the HRP such as funding stakeholders (B, E), but also those simply in

positions of influence in one of the partner organisations (A, C, E, F). One HRP felt it was less complex, having only one customer stakeholder (I). Stakeholders were 'stovepiped' (C) and changed over time.

7.2.8.3 Technical and management structures

Several HRPs devised complex structures to partition work in order to manage the scope, protect intellectual property, remove competition, distribute work or meet other requirements of the funding body or customer (B, D, E, F, P). Some had several layers of contracts and managing the multiplicity of contractual relationships was complex (E, F, P).

7.2.8.4 Complex, integrated processes

Incompatibilities between the extant processes of partners meant that joint HRP processes were complex (A). Aligning the funding from different bodies added financial complexity (B).

7.2.8.5 Multiple related HRPs

A number of partners participated in multiple related HRPs at the same time. Whilst this provided greater leverage for funding, the relationships between them were complex (A).

7.2.9 The role of Systems Engineering

7.2.9.1 Systems engineering used

Although only one HRP was actually 'systems engineered' in itself (A), several applied systems engineering to the research programme (B, E) or to the delivery of tasks (J). One had applied systems engineering to the 'existing, adaptive system' and considered structure, dynamics, relationships and the overall 'systemic balance' (P). Another HRP prided themselves on having taken a 'whole system approach' to the problem domain being tackled (B).

Several HRPs used systems engineering processes and techniques (A, B, D, E). These included developing an operational concept (B), requirements definition (B, D, G, N), requirements analysis (function & non-functional; viewpoint analysis), Quality Function Deployment, synthetic environments (A, E), modelling and operational analysis (E). One HRP used trade-off studies on emerging concepts and would have liked the resource to do more in order to guide the research programme (E). Another identified the potential value of using systems techniques to monitor the HRP success over time (P).

Roadmapping was specifically identified as a critical technique to express requirements, conduct gap analysis and plan exploitation across different HRP participants (C, P). Conducting roadmapping as a community activity was felt to be very powerful (P).

The quality and appropriateness of requirements varied. One HRP found them particularly bad (D). Another noted that access to the customer and user was inadequate to get a sound understanding of the requirements (E). A third noted the balance between needing requirements and over-specifying the solution, and the importance of alignment to business need (G). This was consistent with the struggle to get researchers to understand the real problem (P).

7.2.9.2 Systems thinking

Several HRPs which did not use systems engineering processes felt that systems thinking was naturally applied to the HRP by those involved (C, J).

HRPs used systems metaphors to describe the nature of the HRP (A, E, F) and to support logical thinking (E).

7.2.9.3 System boundary

One HRP felt that there was inadequate understanding of the overall problem domain: in effect the systems boundary had not encompassed important factors (A). It was felt that the systems engineering had 'failed' and the

solution had been devised before the problem was understood (A). In several cases, critical dependencies were identified but not managed as part of the system (A, F); in others the organisation flaws were boundary issues (E). Some HRP's failed to establish an agreed system boundary altogether (A, D).

7.2.9.4 Early systems engineering

One HRP felt that the early systems engineering was effective (A) but that there was a discontinuity between concept and implementation.

7.2.9.5 Architecting

One HRP identified requirements but failed to implement a robust architecture of people, processes, technology and control structures to meet them (A). In another, the customer had already specified the architecture at the tender stage without reference to the necessary functionality, and this was found to be lacking in a number of areas (F). Two HRP's deliberately architected the work programme to separate competing academic partners (I, N). Another noted the importance of developing a robust architecture to provide long-term flexibility (P).

7.2.9.6 Integration

Although some HRP's felt that academic researchers would not typically be interested in integration and links within the programme (E), others deliberately placed that expectation upon them (G, P). Some HRP's incorporated an 'integration layer' to bring together all the programme elements as a coherent whole (B, N). Integrated demonstrations played an important role in a number of HRP's (B, E, G). One HRP used a top-down and bottom-up approach of vignettes, capability challenges and generic system concepts in order to achieve an integrated programme (E). Another HRP found the unplanned integration of its diverse programme difficult (F).

7.2.9.7 Demonstration

Several HRPs developed demonstrations to show off the maturity of their research (B, D, E, G, I). These were planned in advance but some seemed to require additional unplanned effort which was diverted from other work (D). Proper planning and management of demonstrations by competent staff was seen as a key enabler: several HRPs chose to use experienced industry staff for this role (B, E), whilst others provided support for an academic lead (G, I).

7.2.9.8 Methodological rigour

Two HRPs expressed concern at the lack of methodological rigour with which systems engineering research data was collected and analysed (D, P).

7.2.9.9 Review processes

Most of the HRPs were subject to standard, systems engineering-based lifecycle review processes in one or more of the partner companies. One HRP expressed concern that the scale of these reviews was out of proportion to the value of the HRP contract (F).

7.2.10 Perceptions of Success

7.2.10.1 Measures of success

One HRP was considered 'best in class' for collaboration and working together and attributed its success to its focused goal (B). Another intended to judge success by the 'quality of relationships' after five years (P). However, for most HRPs, the measures of success tended to focus on the delivery of the HRP's research programme (A, B, D, E, F, G, I, N, O).

Metrics were used to manage a number of HRPs (A, B, E, F), although it was often not clear that target figures, even if they were achieved, equated to the achievement of the HRP objectives. One HRP was considered successful

having delivered more benefit than promised in 'all the different forms required' (B).

7.2.10.2 Networking and relationships

A number of HRPs considered the relationships and networks that were formed to be important in themselves (A, B, C, E, J, M, P), although one struggled to demonstrate more tangible results (C).

7.2.10.3 Bigger political objective

Most of the HRPs attracted a level of senior management attention which was out of proportion to the financial values involved (A, B, C, D, E, F, O). This seemed to reflect the fact that the HRPs had broader value in terms of intangibles such as relationships, IPR risk and future work. Such 'hidden' objectives were likely to have been influencing factors in the creation of HRPs but were typically not formal measures of their success. Evidence suggests that such strategic drivers were unlikely to justify HRP survival unless the primary declared objective was also met.

Several HRPs had aspirations to become a centre of excellence and a national asset (A, E, F, J, K, M, P). At the time of writing only two felt this had been achieved (J, P), although others retained this aspiration.

7.2.10.4 Academic publications

HRPs generally delivered good numbers of academic publications and the quality was good (D, F, G). Two HRPs deliberately facilitated the academic publication process (G, I). One HRP won a number of awards (G).

However, the unsuitability of the outputs from academic research for a wider audience was a common theme, and two HRPs specifically noted the inaccessibility of academic reports for government audiences (F, P). This was a measure of dissatisfaction rather than of success.

7.2.10.5 Following fashion

One HRP had been based around a problem context which was a 'hot topic' when the HRP was conceived but ceased to attract as much attention by the time progress was reviewed a few years later (D). This was cited as one of the reasons for early termination of the HRP.

7.2.10.6 Fragile success

Several HRPs had been unable or were unlikely to meet their full aspirations (A, E, F). Having got most of the 'basics' right, one HRP was trusted and had been given 'the benefit of the doubt', but remained finely balanced between acceptable performance and 'going badly wrong' (A).

7.2.10.7 Articulating the benefits

Several HRPs struggled to capture and measure (M) or articulate (A, D) the benefits of their existence. This is, in systems engineering language, the validation of the HRP: not only delivering the elements of their research programme but making a difference.

7.2.10.8 Exploitation

For most HRPs the ultimate measure of success was the exploitation (B, C, D, E, F, G, I) or commercialisation (K) of the research. Routes to exploitation were identified by several HRPs (B, G): others expressed frustration that the lack of planning (D) or funding (C, E) for such routes meant that research was 'wasted'.

Ironically, successful HRPs were likely to lead to further funding of the research area, although this would often require the re-formation of the HRP, or the creation of a new one (B, G).

7.3 Conclusion

In this chapter, eighty more detailed ‘messages’ were drawn from the research data across the case studies. Whilst the ten themes were retained for traceability, they no longer added value, as practical issues crossed multiple themes.

All sixteen case studies contributed to these messages. The non-UK case study, P, was included in this analysis and did not stand out as facing particularly different issues. This very limited sample suggests that these are not UK-specific issues, but rather a characteristic of the domain and the relationships therein.

The research now moves forward to consider the implications:

- first, the Implications for Theory are discussed in Chapter Eight, in terms of the body of literature reviewed in Chapters One to Four, and the models presented in Chapter Five;
- second, the Implications for Practice are addressed in Chapter Nine.

8 IMPLICATIONS FOR THEORY

8.1 Introduction

Having drawn together common and contrasting messages from the research findings, Chapter Eight now reflects on the implications: in terms of the themes from the literature reviewed, the systems approach and models used, and the research methodology.

8.2 Implications for themes from the literature

Reflecting upon the experiences of the sixteen case studies in the context of the literature review in Chapter Four, the following observations were made:

8.2.1 Traditional Systems Engineering

8.2.1.1 Requirements

Expressing objectives in terms of fashionable ‘buzzwords’ gave the HRP a limited ‘shelf-life’. It is essential to get beneath popular expressions to understand what they really mean, and agree objectives at that level (Case Study D).

Fundamental changes in requirements, i.e. those which were not technical but were political or organisational (perhaps resulting from the change of a key stakeholder), were not tracked through to implementation, but needed to be (Case Study F).

8.2.1.2 Architecture

In some cases the architecture of the research programme needed to protect a ‘no man’s land’ between research tasks to prevent friction between potential or actual ‘competitor-partners’ (organisations working together

within the HRP but commonly competitors in other contexts) working on similar or related topics (Case Studies B & D).

For an integrated research programme, work should be partitioned as far as possible with integration in mind. This implies partitioning along logical lines which allow interfaces to be clearly articulated and specified, and where issues such as IPR can be explicitly addressed (Case Studies B & E).

Where appropriate, the HRP was intended to grow. It was necessary for the architecture to enable the function of *growth* alongside other functions. This has structural and resource implications as well as affecting mindset and strategy (Case Study P).

Harmony (per Boardman): the complete HRP architecture including structure, controls, contract etc should be in harmony with the objectives (Boardman 2010) (Case Studies A, D, F).

“Think about the end before the beginning” (the motto of Omega Alpha, the Systems Engineering honour society). Identifying the scope of demonstrations can be used to define the problem space to be addressed by research (Case Study G).

Integration, verification and validation are important for the research programme as a whole (Case Studies D and F).

8.2.2 Systems Science

The ability of the partners to perform in the culture of the HRP is impacted by their ‘home environment’ culture: for example an organisation which is metrics-driven will struggle to judge and reward success without the achievement of metrics (Case Study A).

Interviewee views on good or bad HRP characteristics varied widely, and as such the ‘success’ of an HRP was difficult to judge. Different partners may

have different 'true measures' of success, even where the formal measures are agreed in advance (Case Study D).

8.2.3 Technology Management

Individuals within the HRP needed the skill and competence to derive research questions from business requirements. This was non-trivial and required an understanding of both research and business. Decomposing the requirements too far constrained the potential solutions (Case Study D).

It was important to know the skill base of people involved in the HRP, without going too far and allowing considerations of the 'team' to dominate research direction. An iterative process evolving both team and research topics seemed an ideal way to develop the research programme (Case Studies B, D, P).

'Research exploitation' was an essential phase of the HRP lifecycle which needed to be planned as part of the programme. Within a defence environment, careful selection of demonstrations enabled them to be acceptable to academics whilst enabling them to be read-across to other applications of industry or government interest (Case Study G).

8.2.4 Project Management

Some HRPs had an underlying function to win more funding, thus perpetuating the research programme whether or not the HRP continued over time (Case Studies A, F and P). This business development function not only needed resourcing, but if successful would introduce further work to be managed within the programme.

Different funding routes for HRPs meant that aligning funding and project control mechanisms was not trivial. There was a need for the contract architecture to be robust (Case Study D) and to manage commitments and concessions made during project initiation (Case Study L).

The HRPs were subject to a balance between stability and change: what to one participant was 'designed to change' was seen by another as 'ongoing messing' (Case Study A). There was a need for the project management function to accommodate and facilitate necessary change.

HRPs were subject to different lifecycles: those of the HRPs themselves, and the lifecycles of each research area through from idea to exploitation. Project managers needed the ability to coordinate lifecycles without confusing them. The boundary between the 'implementation' phase of the HRP lifecycle and its operational sustainment phase was typically fuzzy (Case Study E).

Each partner had their own 'environment', changes in which (such as a change in strategy or tactics which led to the redistribution of resources) could affect the HRP. The resultant transition or change in one of the HRP 'partners' could have a huge impact on the other partners, especially if it was the customer / owner or leading partner who was affected (Case Study F).

The principle of successful programmes resulting from 'systems engineers and programme managers who are joined at the hip' applies equally to HRPs (Case Study E). HRPs benefited from a combination of effective project management with strong, integrated technical leadership.

8.2.5 Knowledge Management

The concept of HRPs as a knowledge management mechanism did not come through strongly in the case studies, and management of knowledge within the HRPs varied. In some HRPs, the same people were involved at both strategic and tactical levels. Although good for communications this would risk distorting relationships, particularly at the tactical level (Case Study B).

Those responsible for operating an HRP were often different to those who established it. Tools and mechanisms such as Rich Pictures would be valuable to effectively communicate objectives and context (Case Studies A, E and F).

8.2.6 Management Science

The issue of clear, shared objectives was important for a number of HRPs and it appeared that the strength of the common goal may have affected how much diversity the partnership could tolerate. Drawing from Adair (Adair 1983) it would appear that at least one of Task/Individual/Team drivers may be needed to motivate effective participation (Case Studies B & J).

It was clear that different partners had different levels of involvement and commitment to the HRP, and that their degrees of motivation would therefore be different (Case Study F).

One key characteristic of the HRP was the closeness of the partnership, which could be likened to the tensions & forces between the elements in a mechanical mass-spring system. These provided forces for change to, and within, the HRP (Case Study C).

HRPs needed leaders: both high level sponsors (for whom the HRP was only a tiny fraction of their responsibilities), and lower level programme managers who needed leadership qualities to succeed (Case Study D).

Individuals in HRPs needed the credibility which came from power. Resource, position, expert and personal power were all legitimate and valuable power sources within HRPs (Case Studies A, B, C, D, E, G & P).

Conflict was observed when the implementation of the HRP violated the norms in the partner organisations, particularly with regard to the 'imposition' of tight project controls in academic environments (Case Studies D, E & I)

HRPs were hard to establish and compromises had to be made – as if to overcome 'static friction' in the partner organisations. However, once it was 'moving', insufficient effort went into redirecting the HRP to its original intent (Case Study A).

8.3 Implications for Systems Models

The models presented in Chapter Five have been reviewed and updated where necessary to reflect the learning from the case studies.

8.3.1 HRP Lifecycle Model

The generic HRP Lifecycle Model was found to be applicable across the case studies, and provided a common language for understanding the evolution of HRPs. However, a common message was that the lifecycle was essentially artificial and driven largely by funding. HRPs which existed independent of funding or which managed to secure additional funding from other sources were less susceptible to this lifecycle. Figure 8.1 proposes a revised model in which the role of funding in the lifecycle is explicitly recognised.

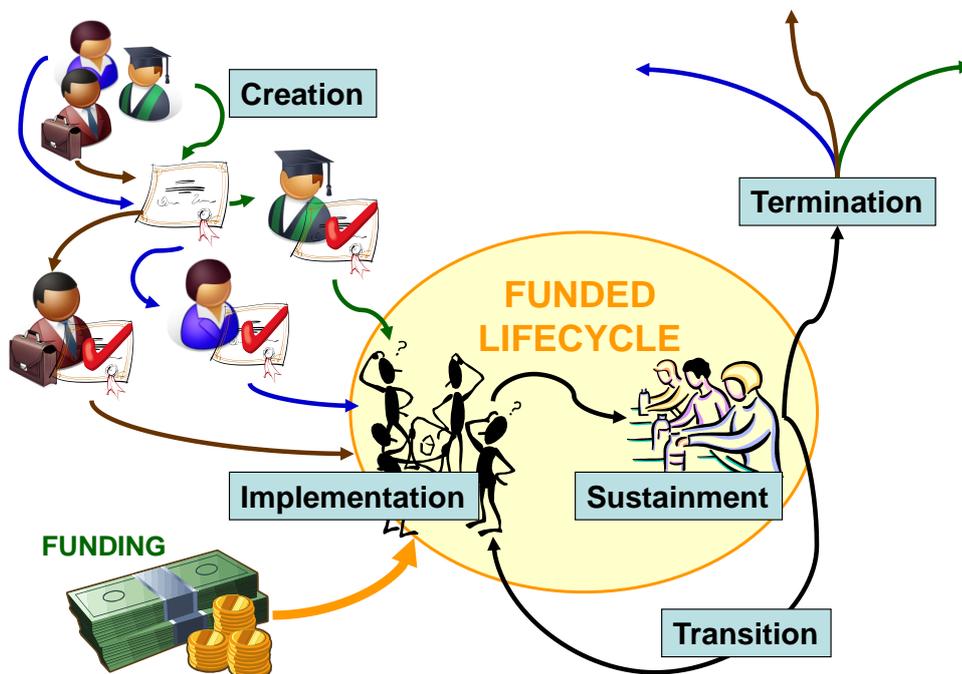


Figure 8.1 Revised HRP Lifecycle Model

The revision reflects the additional 'input' of funding at the point of implementation, and the fact that when the 'Funded Lifecycle' is complete the HRP must undergo transition or termination. Although transition to a new operating model during the funded lifecycle is theoretically feasible, in practice this is likely to be constrained by the funding contract and any other agreements that are in place.

8.3.2 Generic Conceptual Model

It is clear from Chapter Seven that many themes run across HRPs, but also that there are many different perspectives on what constitutes success. It is suggested that HRPs generically have multiple purposes applicable to them. Each one will have a greater or lesser emphasis depending upon the stakeholder, the particular 'make-up' of the HRP, its technical domain and the point in the lifecycle. Some will be stated explicitly, whilst others will only exist in the minds of the stakeholders. For example:

- To undertake research
- To develop academic capability
- To develop industrial capability
- To establish or maintain a network
- To demonstrate 'good citizenship'

The revised generic conceptual HRP model is at Figure 8.2.

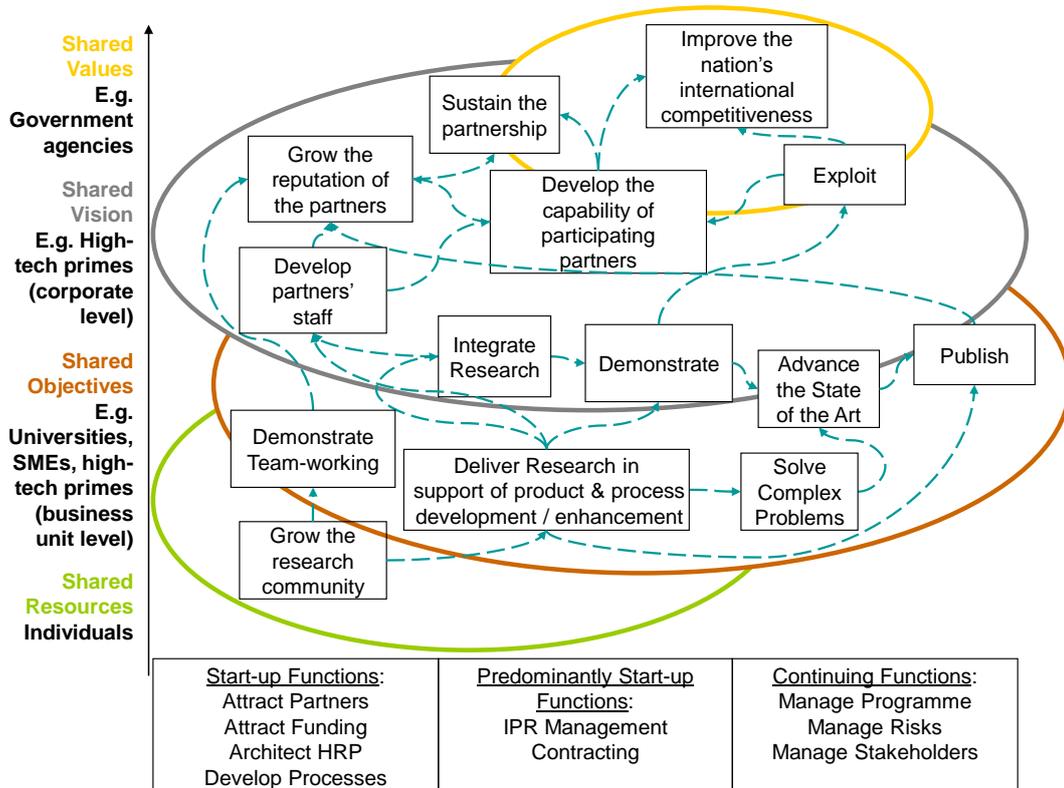


Figure 8.2 Revised Generic Conceptual Model

The principle changes from Figure 5.2 are:

- The addition of ten supporting functions during start-up, predominantly at start-up but continuing at a lower level through the programme, and throughout the programme.
- The removal of promotion of the discipline, knowledge dissemination, education and training, and consultancy which do not form part of the objectives of most HRP.
- Changing the ‘Community of Practice’ to the ‘research community’.
- The addition of research integration, demonstration, exploitation and publication to reflect the focus of most HRP.
- The addition of ‘demonstrating team-working’ as a function for all organisations involved in the HRP.

The four coloured ellipses were used in the Pilot Study to indicate the interests of different stakeholder types. In the revised model this has been refined to not only reflect interest but also potential involvement, with the foreground ellipse indicating the primary driver. So, for example, integration and demonstration would typically be led at a corporate level by 'high-tech' prime contractors familiar with systems integration, whereas publication will be dominated by universities. The interest of government agencies in sustaining the partnerships has been de-emphasised and the focus has shifted towards exploitation. This is particularly true of agencies and departments responsible for industry and defence and those responsible for supporting regional development.

The generic model reflects the major purposes commonly exhibited by the HRPs studied. It is therefore intended as a start point to consider the purposes of any given HRP, recognising that the specific purposes in any given instance may be more or less extensive than the model.

8.3.3 Academic Motivation Model

Evidence from the case studies reinforced the findings of the pilot study, in that the collaboration in those HRPs where the academic 'survival' cycle was explicitly supported was perceived as more successful by all parties. There were no changes to the model in Figure 5.3.

8.3.4 Systems engineering approaches in defence

Although the original model in Figure 5.4 suggested that 'softer' systems methodologies are likely to be more applicable for complex enterprise-type problems, it was apparent from the case studies that where objectives and requirements can be agreed, the basic principles of traditional SE could be effective for certain elements of developing and maintaining HRPs. Figure 8.3 shows the revised model with the addition of shading between the two parabolas, indicating that even within the complex problem space on the

right-hand-side of the diagram there are some aspects which are fairly deterministic, and consequently susceptible to traditional hard systems approaches.

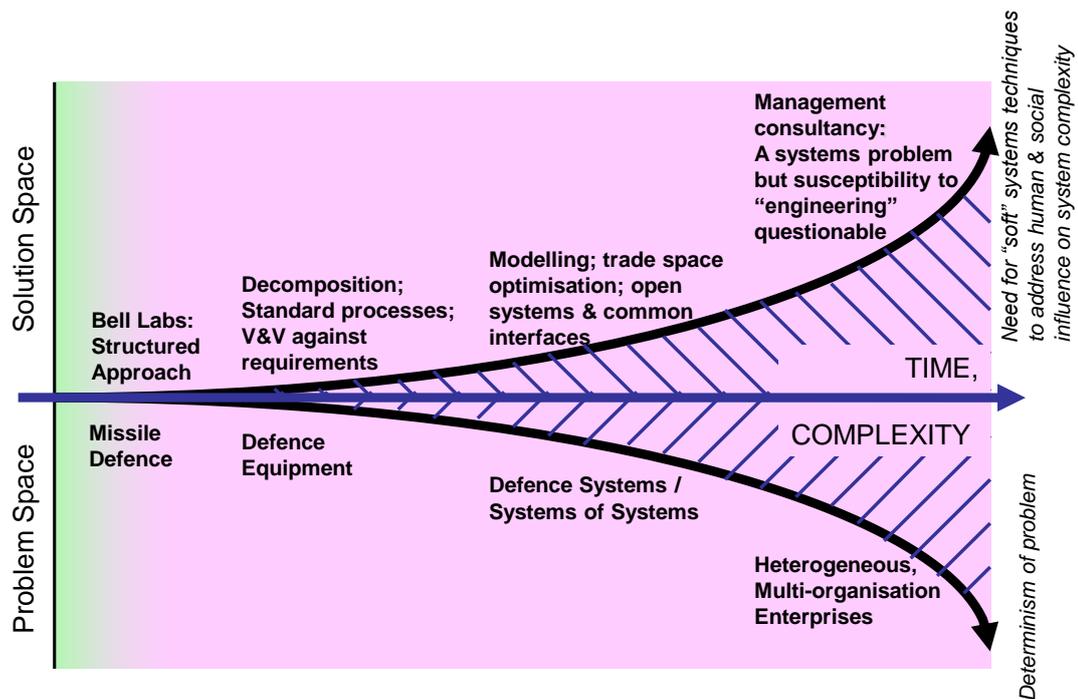


Figure 8.3 Revised Systems Engineering Approaches in Defence

8.3.5 System of Systems Methodologies (SOSM)

Evidence from the range of case studies suggests that HRP are typically pluralist. However, evidence from the pilot study indicated that SSM was unlikely to be acceptable as a working methodology for those involved in the development and operation of HRP. These two positions are in conflict if the SOSM model in Figure 5.5 is correct. Resolution of the conflict may be achieved, not by changing the model, but by dividing the problem space between the *creative establishment* of the partnership, and the *engineering* of the HRP.

In establishing an effective partnership there is necessarily an activity by which a common understanding is achieved and shared objectives agreed. Often this is not done explicitly, if at all, and it may be done only at some later date when problems have emerged. However, this is essentially a pluralistic activity for bringing together the views and needs of two or more partners, which is susceptible to SSM if done early enough, enabling participation in the process of debate around what is systematically desirable and politically or culturally feasible. What is clear is that the potential for such debate is much greater in the formative stages of an HRP, reducing drastically once legal agreements are in place, and that subsequent intervention is likely to be resisted.

Having established shared objectives and perhaps articulated a shared culture for the HRP, the use of hard systems thinking is appropriate for more deterministic problems. Managing requirements, architecting both the organisation and research programme, and planning the integration, verification and validation of the work becomes a tractable problem which is essentially unitary. It is believed that if the two activities are divided in this way, then the model remains valid.

8.3.6 Conceptagon

None of the case studies had applied systems engineering to the development and operation of HRPs to the point where it was possible to use the Conceptagon to assess completeness. However, the need for a balanced approach to meet conflicting demands was apparent across the case studies. Consideration of the model in Figure 5.6 is likely to be useful in the planning, development and ongoing operation of HRPs. There were no proposed changes to the model.

8.3.7 Action Centred Leadership

Evidence from the case studies suggests that the Action Centred Leadership model is valid for HRPs, and that a balanced approach which considers the needs of task, team and individual is likely to be most effective for HRPs. There were no suggested changes to the model in Figure 5.7.

8.4 Implications for Methodology

8.4.1 Holistic Approach

Although the three core ‘sub-systems’ of the research (research context, systems theory and research methodology) have been treated separately, it is clear that the three are in fact highly interrelated as illustrated in Figure 8.4 (Valerdi, Brown et al. 2010).

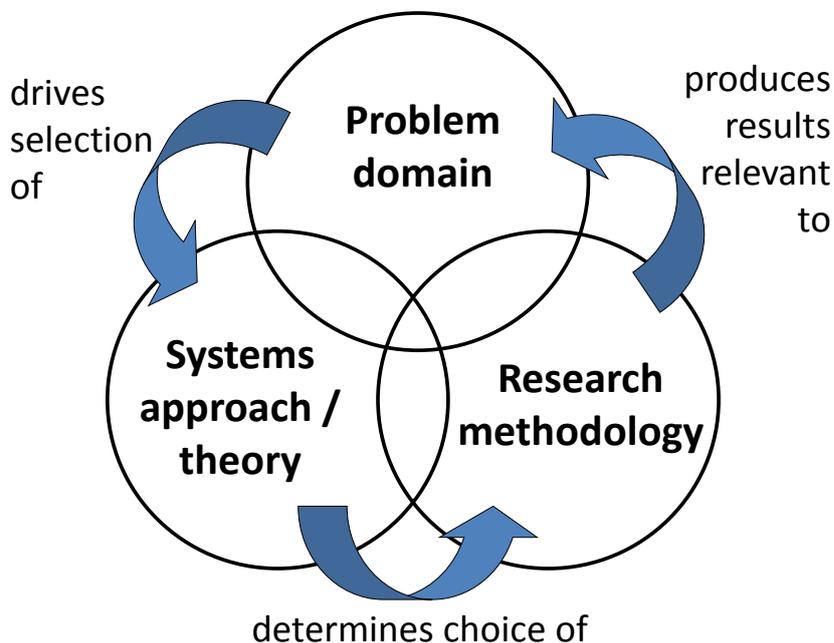


Figure 8.4 Holistic research approach

In adopting a holistic philosophy for any systems engineering research:

- the systems approach or theory should be consistent with the problem domain and context
- the methodology should be philosophically consistent with the systems theory or approach, and
- the research output should be relevant and useful in the problem domain.

8.4.2 Issues of Transition and Incommensurability

Although Jackson's SOSM goes some way to characterise problem contexts in terms of complexity and the heterogeneity of participants (Jackson 2003) and thus enables the selection of an appropriate systems approach, experience from the case studies suggests that this provides an incomplete solution. Effective HRPs are those which succeed in transitioning from the pluralist to the unitary context, enabling the diverse participants to work together towards a common goal. If research into HRPs is to remain consistent with the context, this implies a transition from an interpretive to a realist paradigm as the HRP becomes increasingly homogeneous. Since the paradigms are incommensurable, such a transition would normally be considered impossible.

If the transition between paradigms is to be resisted, then either an interpretive or realist philosophy must be maintained throughout. Authors are clear that SSM cannot be used as intended within a realist paradigm (Checkland 1981; Jackson 2003). A question remains over how and indeed whether hard systems engineering techniques can be used within an interpretive methodology. This is a significant philosophical and practical issue which will not be resolved here, but should be the subject of further consideration and study as the systems engineering research discipline evolves.

9 IMPLICATIONS FOR PRACTICE

9.1 Introduction

As noted in Chapter Five, intervention in the normal sense was not possible in these case studies. Instead, the decision was made to make provision for intervention in the HRP community through the development of guidelines for those developing, implementing and operating HRPs. The intent is that these guidelines be used at a time which is convenient in HRP development, rather than at a time which was convenient to the author but would be disruptive to the HRP.

Chapter Nine therefore provides

- Ten principles related to the context, to assist in the understanding of the nature of HRPs.
- Ten practices, for using systems theory in the establishment and operation of HRPs.

For each principle and practice, the Chapter Seven ‘messages’ from which they are derived are noted in parentheses.

9.2 Ten Principles of HRPs

9.2.1 Principle 1: Exploitation

(See 7.2.1.11; 7.2.10.4; 7.2.10.8)

Even when working at relatively low TRL levels, HRPs are fundamentally created for exploitation. Exploitation may be into products and processes (for industry & government) or additions to the academic body of knowledge which then act as foundations for future work. Most HRPs are likely to need both forms of exploitation. Exploitation must be supported, planned and resourced.

9.2.2 Principle 2: Multiple Purposes

(See 7.2.1.1; 7.2.1.3; 7.2.1.8; 7.2.10.1; 7.2.10.3)

HRPs often have multiple purposes. Clarity of goals, whatever they may be, is important. The relative emphasis between different purposes may vary between different stakeholders and change with time. Even where the stakeholders share a common objective, the benefits to each may be different.

HRPs need to be capable of delivering all their purposes. Even for a team responsible for delivering a research programme, teaming can be important in its own right: either to be seen as a 'good citizen', to learn from peers and others in the supply chain, or to 'take competitors off the street'.

HRPs sometimes have bigger political objectives which may not be articulated. The presence of such 'hidden' objectives may be indicated by a level of senior management effort and involvement which is out of proportion to the monetary value of the HRP. Reputation, future business and wider relationships may all be at stake. However, although politics may launch an HRP, genuine understanding, agreement and tangible outputs are necessary to keep it afloat.

9.2.3 Principle 3: Traceability 'top-down'

(See 7.2.1.4; 7.2.3.9; 7.2.6.2; 7.2.7.1; 7.2.10.3; 7.2.10.6)

For an HRP to be integrated, traceability from the vision to research programmes must be top-down not bottom-up, in order to ensure that what is implemented is consistent with the original vision. Whilst an understanding of the possibilities is necessary to create the top-down picture, it is inadequate on its own. It is relatively easy to suggest that research makes a 'contribution' to solving a problem, but much harder to demonstrate that all the elements are in place for the problem to be solved. Top-down traceability will help to identify objectives which are idealistic and unachievable, and ensure that all elements necessary to achieve the strategic intent are funded.

Performance measures must be developed in the same way to ensure that they truly indicate progress towards the HRP's objectives.

9.2.4 Principle 4: Harmony

(See 7.2.1.6; 7.2.3.1; 7.2.3.9)

The business model must reflect the aim of the HRP and, since most HRPs are implemented through a contractual framework, commercial and legal arrangements must match its function and objectives. Successful completion of the contract should equate to achieving the HRP's strategic objectives. Performance metrics should measure progress towards those objectives.

Arrangements for both foreground and background IPR must be well-informed and made in the context of exploitation strategy. Relevant experts should be involved early before commitments are made and expectations set.

9.2.5 Principle 5: Robust architecture

(See 7.2.1.7; 7.2.2.6; 7.2.9.5)

The HRP must be architected, and the HRP architecture must reflect its function. It is not adequate to simply define requirements. The architecture, which should address people, processes, technology and control structures, should be robust to changes in individuals within the HRP, in external stakeholders and in the environment.

9.2.6 Principle 6: Balance

(See 7.2.2.4; 7.2.2.5; 7.2.3.5; 7.2.4.2)

HRPs must be balanced, but each one faces a large number of 'balance' choices. These choices should be made consciously rather than by default.

For example:

Broad publication	vs	IP protection
Publishing academic papers	vs	Exploitation on product
Cheaper 'temporary' academic resource	vs	Building long term academic capability
New knowledge & innovation	vs	Application & delivery
Funding research	vs	Funding other functions e.g. business development
Advancing the knowledge	vs	Sharing the knowledge through teaching and consultancy
Programme management	vs	Technical leadership
Architecting for research depth and academic focus	vs	Architecting for application and industrial exploitation
Top-down management control	vs	Leadership freedom to determine programme
Partitioning (for sensitive issues, reduced overhead)	vs	Integration (for an integrated programme, better exploitation)
Breadth & depth of coverage from lots of partners / universities	vs	Number of interfaces, interactions, communications
Effort for contract development and refinement	vs	Risk if something goes wrong
Financial leverage from additional industrial partners	vs	Programme control
Known partners who get up-to-speed quickly	vs	New partners who bring new thinking
Short term delivery	vs	Major advances in knowledge
Costs of developing integrated processes	vs	Costs of operating disparate processes and managing process interfaces
Working with friends	vs	Working with competitors to tackle major national issues.
Task-driven, contractual 'certainty'	vs	Flexibility to tackle uncertain problems

9.2.7 Principle 7: Not simply money

(See 7.2.2.3; 7.2.2.9; 7.2.6.1; 7.2.6.3; 7.2.6.5; 7.2.6.7; 7.2.7.4; 7.2.8.5)

HRPs seldom stand alone in the research environment. HRP partners will often have involvement in several related programmes, creating dependencies, overlaps and potential conflicts which must be managed. Good leverage on a programme means involving partners who will add complexity, dilute control and potentially introduce delays.

Customers differ in their desired levels of engagement and need to be treated appropriately. Budget rules and financial cycles have to be accommodated. Launching at the wrong time of year will affect recruitment. Spending may be constrained within financial years and short term funding models may restrict the ability to undertake more innovative research. 'What money can be spent on' may depend on exactly where it came from.

HRPs typically run on artificially low overhead levels which are unsustainable in the long term.

9.2.8 Principle 8: People and Culture

(See 7.2.2.1; 7.2.2.2; 7.2.2.7; 7.2.4.1; 7.2.5.2; 7.2.5.3; 7.2.5.6; 7.2.7.2)

Since HRPs rely so heavily on the active and willing involvement of participants, the leading organisations must be committed to everyone getting benefit, both in terms of meeting 'survival' needs and gaining 'reward'. Organisations with a 'prime contract' position within the HRP are responsible for ensuring its culture and leading by example. Early changes in influential people are very disruptive to cultural stability and should be avoided wherever possible: repeated changes may mean that the culture is never established. Investment in nurturing the team is unlikely to be wasted. Partnerships are defined by behaviours, not contracts.

Individuals can be highly influential, and they must be credible in their respective field to be effective. Disruptive individuals demand

disproportionate management attention and can damage the effectiveness of the HRP. Each individual will have different views: effort is needed to challenge & test assumptions and to see that task, team and individual needs are met.

Relationships are between people, not organisations. They may be influential in the establishment of the HRP and will often out-live it. However, the constraints on some individuals such as government employees must be respected. The longevity of relationships is one possible measure of HRP success,

9.2.9 Principle 9: HRP partners are heterogeneous

(See 7.2.2.8)

Organisations participating in Heterogeneous Research Partnerships are, themselves, often heterogeneous. Stakeholders within the partner organisations can be diverse, dispersed, have different priorities and drivers. It is important to understand the robustness or fragility of each the partners' representation, and the extent to which one individual represents a 'corporate voice'. It may be valuable to understand stakeholder 'maturity', in terms of commitment to the HRP and ability to coordinate internally. Dysfunctional relationships within a partner organisation can make it difficult for relationships between the partners to be effective.

9.2.10 Principle 10: Evolution

(See 7.2.2.10; 7.2.2.11; 7.2.6.6; 7.2.6.8; 7.2.7.3; 7.2.7.5; 7.2.7.6; 7.2.10.8)

HRPs do not stay the same. They have a lifecycle and the world changes around them. Those that are too sensitive to their environment will perish. The strongest HRPs evolve and thrive. Evolution may involve new partners, new funding routes, new technical emphasis or new ways of working, and the transition may be largely unfunded.

The establishment of an HRP comes at a high price in terms of money, resources and time. Many take years from conception to birth and may exist for only a few years. This is hugely wasteful of both time and effort, when provision could be made for successful HRPs to survive, evolve and grow. However, establishing a long term HRP requires a different mindset. Expectations of transition and growth must be planned and resourced, and treated like any other objective of the HRP.

9.3 Ten Practices for HRPs

Whilst there is no assumption that HRPs are systemic, evidence from the case studies suggests that they would benefit from the application of holistic thinking and systematic processes.

9.3.1 Practice 1: Establish HRP system boundary

(See 7.2.1.2; 7.2.1.13; 7.2.9.2; 7.2.9.3)

The HRP system boundary is unlikely to coincide with existing organisation boundaries but must be established early, and both technical and organisational scope defined. Any lack of clarity or difference in opinion or interpretation needs to be addressed, and any deliberate ambiguity understood and managed. External dependencies must be identified and monitored. Heavy dependencies on external factors can be a recipe for failure. Internal dependencies must be managed as part of the HRP. Boundary issues are a common cause of problems within HRPs. Even where systems engineering processes are not considered appropriate, systems thinking is a valuable aid in the development of HRPs - and nowhere more so than in establishing HRP scope.

9.3.2 Practice 2: Determine HRP functionality

(See 7.2.1.3; 7.2.1.5; 7.2.9.1)

By definition, HRPs involve research. However, HRP requirements may be much broader and/or deeper. The HRP may intend to conduct research, or just manage or coordinate it. Other functions may include programme management; capability development in industry, government or academia; teaching or training; and business development in order to grow. All the expected functions of the HRP, including the support functions necessary simply to sustain itself, need to be identified. Where stakeholders have different objectives or needs, these should all be reflected in the overall functionality

9.3.3 Practice 3: Architect the HRP and research programme

(See 7.2.1.9; 7.2.2.4; 7.2.3.3; 7.2.3.8; 7.2.7.4; 7.2.8.3; 7.2.8.4; 7.2.9.4)

Determine the architecture to deliver the functionality. Architect the intent - to meet ALL the requirements, not just those of the 'customer' or lead organisation, and not just those relating to research. Determine the 'best' research partitioning and integration given the particular set of political, organisational and technical factors. Make external dependencies explicit and plan for them. Define the interfaces to the outside world. If the intent is for integration and joint work, enable them. Partition work where necessary to avoid competitive issues between partners. Include and fund integration, demonstrations and joint publications in the agreement and the work breakdown structure.

Establish common processes where necessary and identify and resolve incompatibilities between partners' extant processes where these are adequate. Recognise difference in annual and multi-year cycles between partners from different sectors. Acknowledge and plan for the scale of the HRP. An HRP with hundreds of contracts faces different architectural challenges than one with only few.

9.3.4 Practice 4: Standardise and Reuse

(See 7.2.3.4)

Start with a standard contract and only modify where essential. Re-use IPR agreements, reporting structures and financial planning models. Use 'use cases' to explain the vision and how the HRP is intended to work to those establishing its legal and financial framework. HRPs are expensive to establish, operate on low management overheads and are relatively short-lived. Where necessary, invest wisely in their commercial infrastructure.

9.3.5 Practice 5: Plan Integration, Verification & Validation

(See 7.2.1.10; 7.2.5.5; 7.2.9.6; 7.2.9.8; 7.2.10.7)

Plan integration, verification and validation from the start: integrating and 'proving' a research programme retrospectively can be very difficult. This applies to validation of all the HRP's outputs including, for example, best practice guides and demonstrations. Determine what is necessary to convince stakeholders of success and who the 'approval authority' will be. Be prepared to meet both academic needs for rigour and industrial needs for applicability. A programme which is hard to define in simple, unambiguous terms will always be hard to 'sell'. Resource appropriately: integrated programmes need individuals with integration skills.

9.3.6 Practice 6: Demonstration and exploitation

(See 7.2.1.11; 7.2.1.12; 7.2.6.4; 7.2.9.1; 7.2.9.7; 7.2.10.4)

Roadmapping is a key tool, both at an individual project level and across the HRP. Plan for quick wins on the road to long term capability, since both are important. Plan to demonstrate research outcomes from the start. Fund and resource the planning as well as the demonstration. Plan exploitation of the demonstration through academic publications. Plan and secure funding for longer term exploitation. Responsibility for exploitation must sit at the highest level in the HRP and inevitably be managed across the HRP boundary.

Plan to exploit the HRP itself. It represents a significant investment of time, effort and money in building relationships and intellectual capital. Challenge the assumption that the HRP will terminate. Without losing focus by creating an open-ended programme, consider what could be achieved by extending it and avoiding the re-start costs and delayed start of a new programme.

9.3.7 Practice 7: Manage risk, manage stakeholders, through life

(7.2.2.2; 7.2.3.2; 7.2.3.7; 7.2.7.7; 7.2.7.8; 7.2.8.2; 7.2.9.9; 7.2.10.5)

Assign responsibilities within the HRP's leadership team and manage risk at a strategic level through life, to address topics such as HRP resourcing, funding, stakeholder change, review and termination. Where HRPs involve competitors, risk management is all-the-more important. In other cases commercial agreements and review processes should be proportionate to risk and should not add an unjustified financial burden to the partners or the programme. Both contractual negotiations and programme reviews are sources of stress and disruption to the HRP: such disruption should be as much as necessary, but no more.

Key stakeholders are a primary source of complexity and risk: not only those with roles relating to the HRP, but also those in other positions of influence. Managing them requires more than just maintaining a list. Understanding them, how they are changing and what matters to them is critical to HRP risk management. Avoid following the latest fashion, even when there is high level sponsorship, unless the work is expected to complete in a relatively short timeframe. There is a particular need to understand Government stakeholders: their role in the HRP, in influencing more widely, their access to data and ability to share it.

9.3.8 Practice 8: Leave space to manage uncertainty

(7.2.3.6; 7.2.8.1)

In the systems domain, the *System Readiness Level* (SRL) matters. High TRL technologies integrated in a new problem space are no longer 'close to market'. It is important to leave flexibility in the programme to manage the uncertainty in 'systems space'. The problems are complex, relationships are complex: solutions are also likely to be complex and not fully understood at the outset. In complex, poorly-defined research areas significant effort may be needed to converge on research goals in order to be able to justify the value of the programme and demonstrate benefit to the stakeholders.

9.3.9 Practice 9: Use leaders, grow leaders

(7.2.3.10; 7.2.5.1; 7.2.5.2)

HRPs are difficult and complex to lead and manage. To be successful they need good leaders at a number of levels. Leaders must be able to cope with technical, organisational and political complexity and take unpopular actions such as terminating poor work. Good people lower in the HRP hierarchy will grow to be future programme directors or members of a strategy board and should be nurtured accordingly.

The maturity of the HRP's research topic helps to determine the skill requirement. Mature technology research needs to be led by a technical expert capable of engaging at a deep technical level and understanding the technical progress being made. Poorly defined, innovative research needs a creative but credible team player capable of motivating and coordinating a diverse community and getting them to converge on effective solutions.

9.3.10 Practice 10: Grow the community

(7.2.5.4; 7.2.6.2)

HRPs are typically established in discipline and domain areas where skills are not ubiquitous. Many HRPs struggle to resource their programmes from both academia and industry. Individuals may be overloaded with part-time roles in several HRPs. Growing the community should be a deliberate, planned and integrated part of the HRP. Technology, integration and partnership skills can be developed in academia, industry and government. To be effective this should be architected as part of the programme and funded accordingly.

9.4 Opportunities for Intervention

The original intention described in Chapter Three was to undertake this research following an Action Research methodology which would, by definition, have involved intervention in the problem domain. Although such a methodology was not feasible, the principles and practices described herein do offer the community of HRPs (both existing and planned) an opportunity to review and improve their approach based on lessons learned from others.

Within industry, where the approach to establishing HRPs is typically most structured, the Principles and Practices should be embedded within guidance for those establishing and operating HRPs and within formal programme review checklists, thus providing a ready reference for those with, and without, previous experience in this area. Since the heterogeneity of organisations in both government and academia is likely to make such a formal approach more difficult, the guidance should be shared freely with those sectors. This will aid the development of a broad, mutual understanding between the sectors which can only be of benefit to both current and future HRPs.

10 ACHIEVEMENTS AND FUTURE WORK

10.1 Introduction

In Chapter Two, the set of functions for this research were derived from the research requirements that had been identified. Table 10.1 below shows how and where the research has addressed these functions.

Table 10.1 Requirements Validation

Research Function	Validation Method	See:
Understand HRP context and operation	Literature Review	Ch. 1
Link HRP context and operation to systems techniques	Case Studies	Ch. 5,6,7
Understand HRP lifecycle and link to systems techniques	Case Studies	Ch. 5,6,7
Create / interpret new knowledge	Case Studies	Ch. 7,8,9
Systematically acquire / understand knowledge	Literature Review + Case Studies + Modules	Ch. 1,3,4
Understand boundaries of SE discipline	Literature Review	Ch. 4
Extend the SE discipline	Case Studies	Ch. 8,9
Identify potential systems techniques	Literature Review	Ch. 3, 4
Develop SE techniques for SoS	Case Studies	Ch. 8,9
Develop SE techniques for humans in the system	Case Studies	Ch. 8,9
Apply SE to research design and content	Pilot Study + Case Studies	Ch. 3, 5
Design research	Pilot Study + Case Studies	Ch. 3, 5
Design research to give initial insight beyond UK	Case Study Selection	Ch. 5
Understand research techniques	Literature Review + Course Module	Ch. 4
Match research output to business need	Principle & Practices	Ch. 9
Publish research	Published Papers	App. 2

In Chapter Three, it was identified that there were three distinct but interrelated research subsystems, reflecting the three perspectives of the problem context, systems approach and research methodology. Chapter Ten first addresses the limitations of the methodology employed and then returns to this framework as it draws together the conclusions of the research in terms of both achievements and future work, and then considers the wider implications for SoS.

10.2 Review of Research Methodology Employed

10.2.1 Sample constraints and limitations

The decision was made to limit the sample of UK case studies to those in the defence domain, and involving the sponsoring company. Although this limited the breadth of HRPs that could be studied and thus the scope of direct applicability of the research findings, it provided the significant benefit of increasing the consistency of the data, both in terms of the typical terminology used, and in avoiding any potential data sensitivity or competition issues between interviewees.

10.2.2 Data collection and analysis

Whilst the intent was to maintain an interpretive philosophy throughout, the research methodology became a compromise between the need to collect interpretive data and the need to deliver an output of value to the research sponsor: in this case, the Principles and Practices.

Extraction and translation of the data from interviews and other sources was carried out manually in order to identify similarities and differences in words and meaning which would not have been identified by a computer. In fact, the identification of themes was in large part attributable to the author's significant experience both in the sponsoring company and working in this domain. Whilst this was not as rigorous or repeatable as 'automatic' computer-based methods, it enabled a much more coherent picture to be

formed. Ultimately, the conclusions are largely insensitive to the intermediate analysis steps and will be tested - not by academic measures of validity - but by usage in the HRP community.

10.3 Heterogeneous Research Partnerships

10.3.1 Achievements

HRPs are a fairly common instantiation of a predominantly social SoS, but one which is poorly represented in the literature. Each year, significant sums of money and levels of effort are invested in collaborative research delivered through HRPs: however, for them to be acclaimed as an unmitigated success is rare. This research has not only provided a better understanding of the domain by exploring and characterising HRPs, but has presented principles and practices to enable those involved in their development and operation to be more effective in their collaborative endeavours. There is an indication, on the basis of one case study, that these principles and practices may also be of value outside the UK.

10.3.2 Further research

This research has taken a holistic, high-level view of the specific context of HRPs. There is scope for research at a more detailed level which might consider:

- Different structures for the HRP organisation and research programme, in terms of both their effectiveness and the process by which they are derived as part of the HRP implementation.
- The impact of different management and leadership styles within HRPs, which may also consider how appropriate leaders are developed.

- The extent to which investment in integration (including management, coordination, joint publications, demonstration and reporting) of the research programme across an HRP delivers tangible benefits.
- Whether intensive preparation for interim reviews, which is not uncommon but is viewed as highly disruptive to the research programme, actually makes a difference to the review outcome.
- The possibility of reducing the annual cost to the community of establishing HRPs by adopting longer-term programmes without relinquishing control of purpose or quality.
- Whether a generic standard HRP contract (or suite of possible contracts) could be developed collaboratively by the community in order to significantly reduce the commercial burden of establishing new HRPs.

Additionally, the context of the research could be expanded to explore:

- Whether the principles and practices identified are equally applicable to other settings such as non-defence industry; commercial organisations; non-governmental organisations; and multi-national partnerships in both culturally similar (e.g. 'western') and culturally-diverse (e.g. global) situations.
- How 'shared purpose' might be established within heterogeneous partnerships and how this could be developed as a fundamental systems engineering concept for human-centric systems.
- The relevance and value of concepts such as 'open systems' and 'systems of systems' as mechanisms to identify inherently uncertain system problems, and to enable the development and application of systems approaches which are well suited to this class of problem.
- What learning processes operate within HRPs, and in particular how individuals and organisations develop the competence to enable them to contribute effectively as HRP participants.

10.4 Systems Engineering

10.4.1 Achievements

The focus of this research was on the *application* of systems engineering and not on systems engineering per se. It has enabled the development and refinement of a number of generic models to assist in the establishment and operation of HRPs. Furthermore, it has explored the issues associated with addressing both unitary and pluralist aspects of the problem domain and the challenges that this presents in the adoption of an appropriate systems approach which crosses the boundary between ‘hard’ and ‘soft’ systems.

The principles and practices developed bear a striking similarity to the systems engineering principles identified in “Creating Systems That Work” (Elliott, Deasley 2007). In particular, both emphasise the importance of designing and managing balanced commercial, contractual and personal relationships alongside technological issues, and note that failures often occur at artificially-imposed boundaries where conflicts may exist between the different perspectives. However, *Creating Systems That Work* does not explicitly tackle the issues of inherent uncertainty and complexity which characterise both HRPs themselves, and a number of the research findings:

- Although *Creating Systems That Work* recognises the existence of multiple stakeholders, it assumes that a single, articulated and well-understood purpose can be ‘debated, defined, revised and pursued’ for the system and that individual perspectives must be ‘managed and consistent’. This research notes that for HRPs, there may be multiple intended and equally valid purposes even *within* each partner organisation. This research challenges current systems engineering practices to improve the ability to establish and maintain agreed shared purposes in such pluralistic environments.
- *Creating Systems That Work* focuses on technical systems with defined and bounded scope. However, HRPs have been found to exhibit

characteristics (e.g. senior management involvement) which belie their monetary worth: in effect they may be likened to an iceberg in which only a small proportion of both the requirements and costs are visible. Success of HRPs is often measured by factors completely outside their control, such as their ability to deliver research which is subsequently exploited. However, good HRP design demands that expectations which may never be articulated be accommodated, and that invisible costs are nonetheless prevented from spiralling out of control. The ability to do this requires domain experience in organisational systems, much as *Creating Systems That Work* notes that other systems engineers need domain experience in the design of technical systems. The principles and practices identified herein aim to recognise this domain of organisational systems and capture some principle elements of domain expertise.

- *Creating Systems That Work* notes that investing in people is part of system development, suggesting that ‘people requirements’ are part of the system requirements. However, the transient and evolving nature of HRPs demands that an ‘open system’ approach be taken, focusing on the admittedly undefined and uncertain need for overall capability in the community rather than limiting the consideration to current contracts.

10.4.2 Further work

This research has highlighted a particular issue facing the systems engineering of SoS with significant social aspects, namely the need to transition between those systems methodologies better suited to social issues and those better suited to hard systems problems. It is far from clear that soft systems approaches can properly embrace hard systems engineering techniques for ‘sub-problems’ which are deterministic by virtue of their limited scope or duration, for example. There is significant scope for work at this boundary to develop both methodologies and specific techniques which would support practitioners working with this class of problem.

10.5 Research Methodology

10.5.1 Achievements

In order to be effective, systems engineering research must integrate systems engineering with a range of research traditions and paradigms to create outcomes which meet a purpose. This research identified the importance of consistency between problem domain, systems approach and research methodology in order for the research to be philosophically valid and the purpose to be met. It contributes to the limited body of methodologically-explicit systems engineering research by adopting an interpretive methodology using qualitative methods.

10.5.2 Further Work

One of the significant challenges facing systems engineering research is the lack of a methodological body of knowledge for the discipline, from which students and researchers can draw in order to inform their work. It is unclear whether this shortfall reflects a lack of rigour in the research itself, or simply a cultural norm that the reporting of research methodology is unimportant for a practitioner discipline. In either case, the paucity of methodological literature for systems engineering research is felt to be harmful for the academic discipline, as illustrated in Figure 10.1 (Brown 2009). In a research discipline dominated by industry funding and practitioner researchers, deliberate effort is required to address issues of methodology and ensure that this body of knowledge is developed.

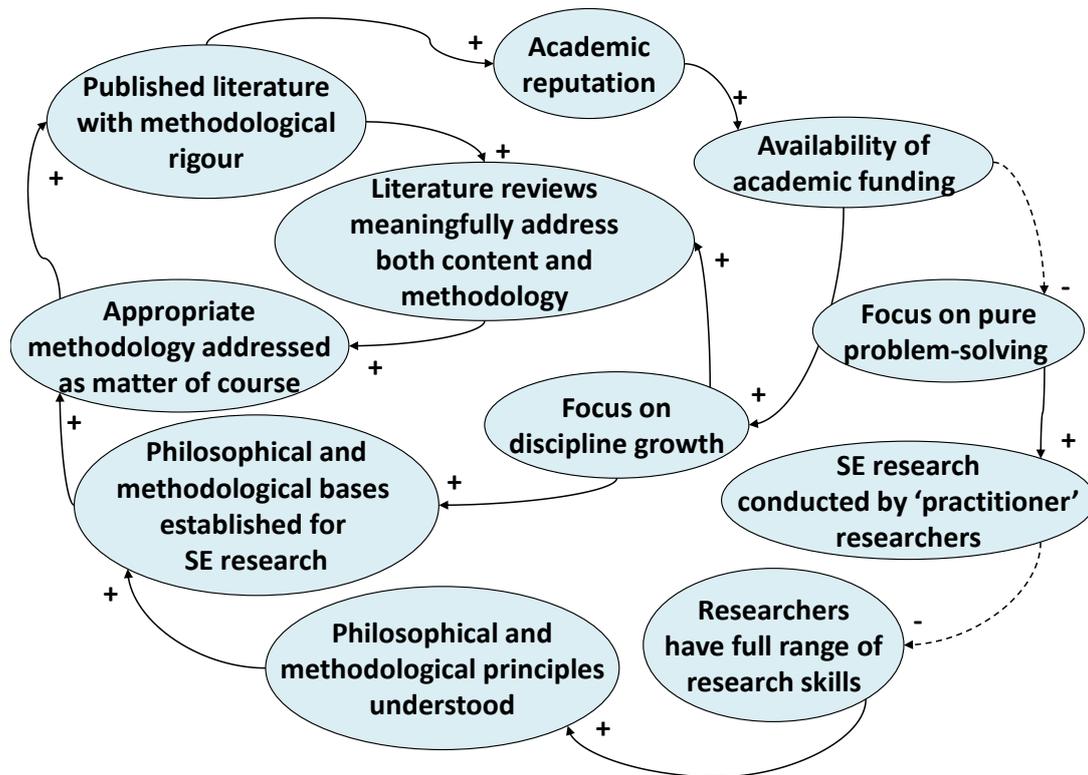


Figure 10.1 Methodological Rigour in Systems Engineering Research

Whilst methodological rigour will generally benefit the discipline of systems engineering research, this research has also identified a specific problem which is related to the need to transition between interpretive and realist methodologies to address the different aspects of system of systems problems. This is a fundamental philosophical issue for the academic community of systems engineering researchers to address.

10.6 Wider implications for systems of systems

The aim of this research was to explore potential systems engineering approaches to the human and social aspects of those SoS where these are significant factors, by focusing on the specific context of HRPs. The work cannot be considered transferable to all such 'social' SoS, since homogeneous SoS (where values, beliefs, culture and doctrine are common) will face fewer challenges in agreeing objectives and working towards a

shared goal. For other heterogeneous SoS, however, there are lessons which can be learned from this work which may be of value. In particular, the ability to implement the systems approaches necessary to expose critical issues for 'pluralist' or heterogeneous problems may be constrained by contractual agreements, operating norms and political sensitivities. Such constraints make it incumbent on the customer or lead organisation to initiate this exploration of issues and purposes at the earliest possible opportunity in SoS development, and to ensure that the outcomes are embedded in the formal contractual and organisational structures as these are defined. By so doing, they will enable a significant advance in an area of SoS engineering which, thus far, has been largely overlooked.

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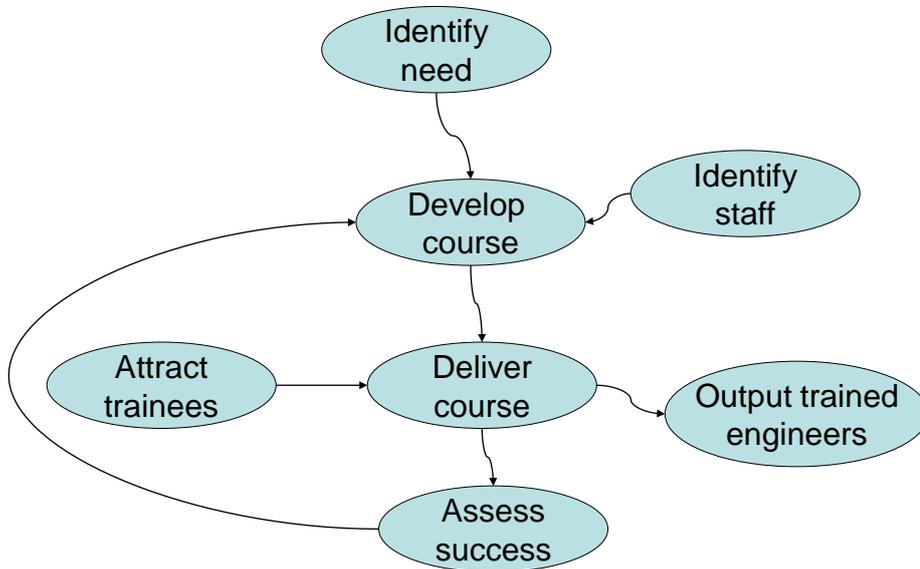
APPENDICES

APPENDIX ONE

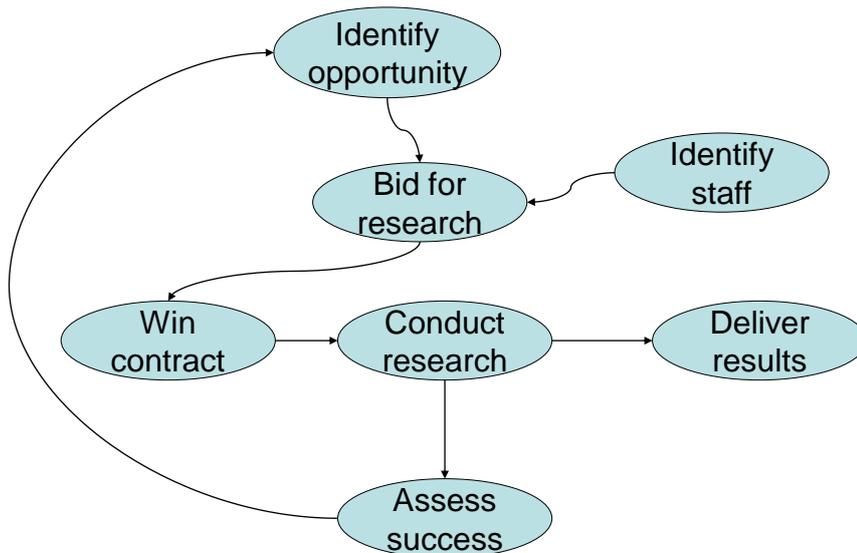
PILOT STUDY CONCEPTUAL MODELS

AND ROOT DEFINITIONS

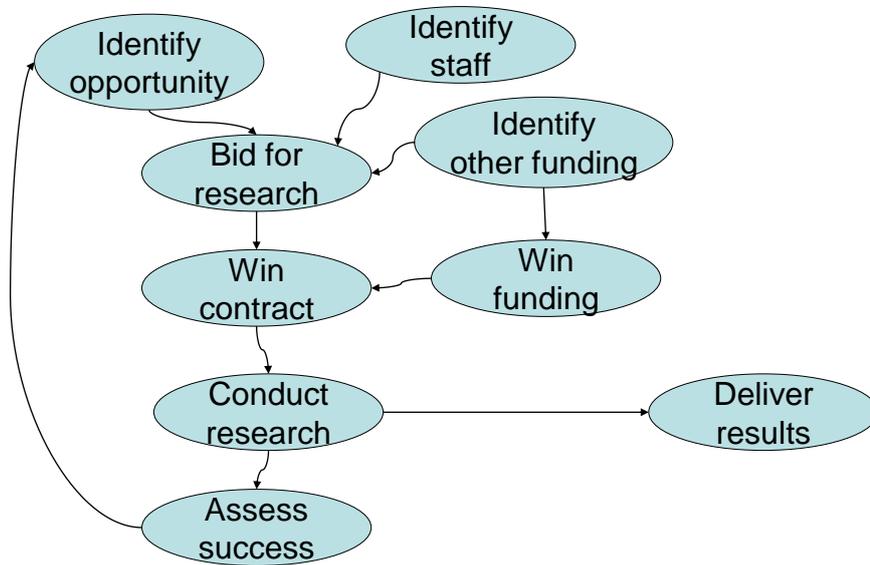
A: Educate & train systems engineers



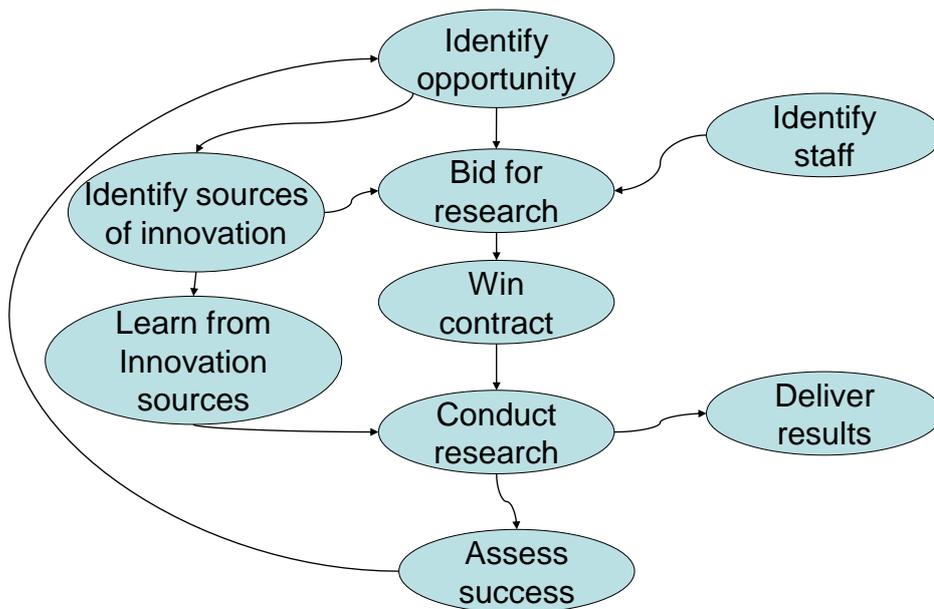
B: Deliver fully-funded research (to defined requirement)



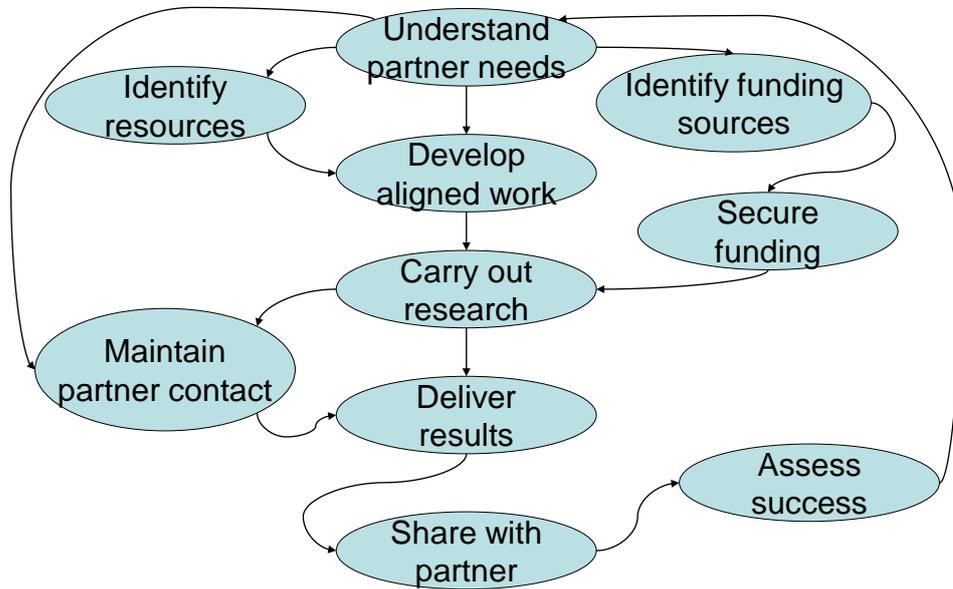
C: Deliver part-funded research (to defined requirement)



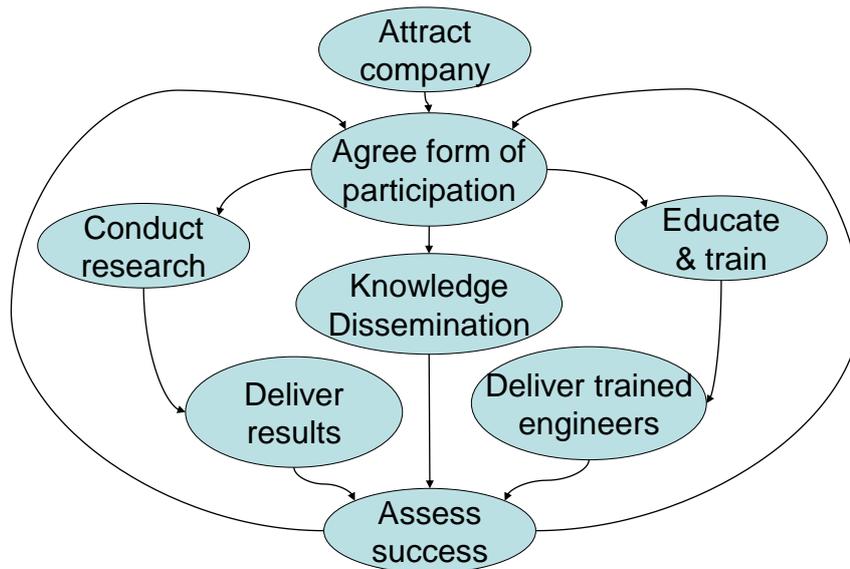
D: Deliver innovative SyE research



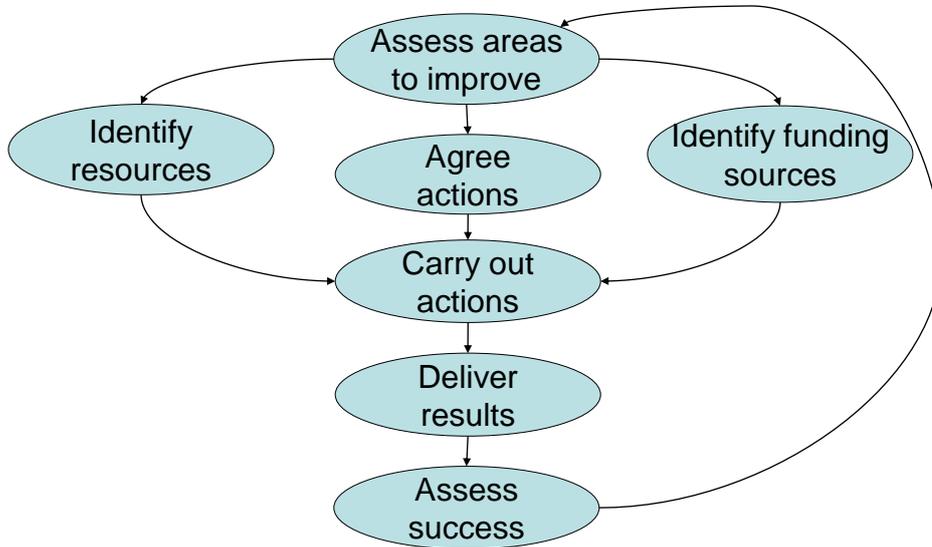
E: Deliver aligned research



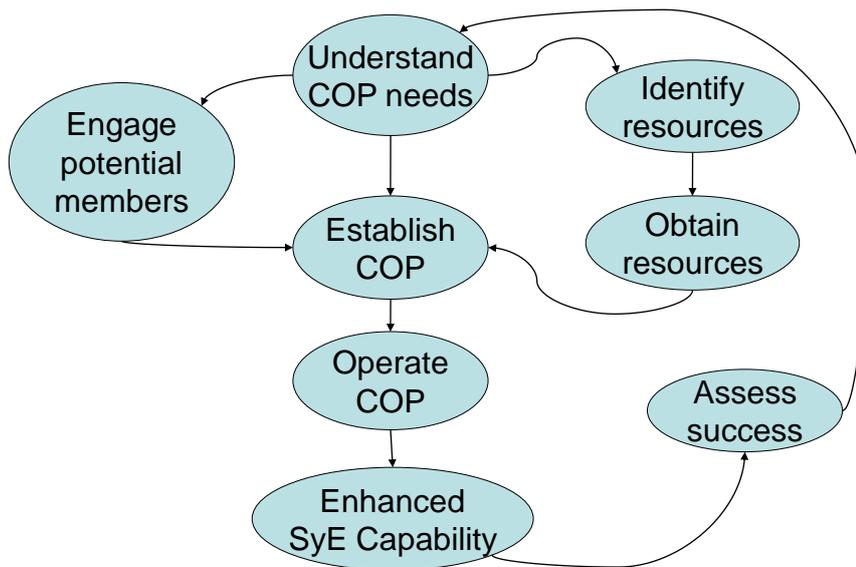
F: Develop the SyE capability of a participating company



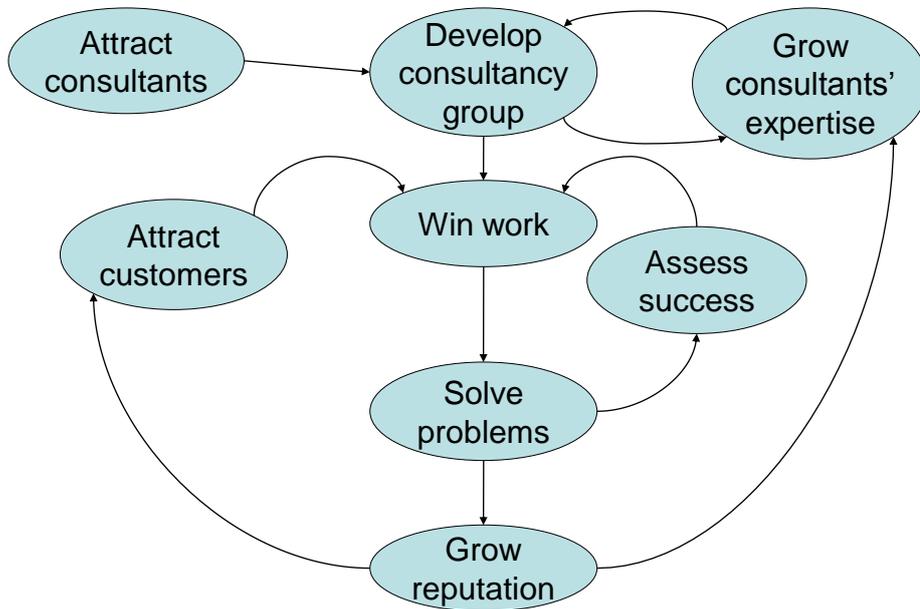
G: Improve Regional and the UK's international competitiveness



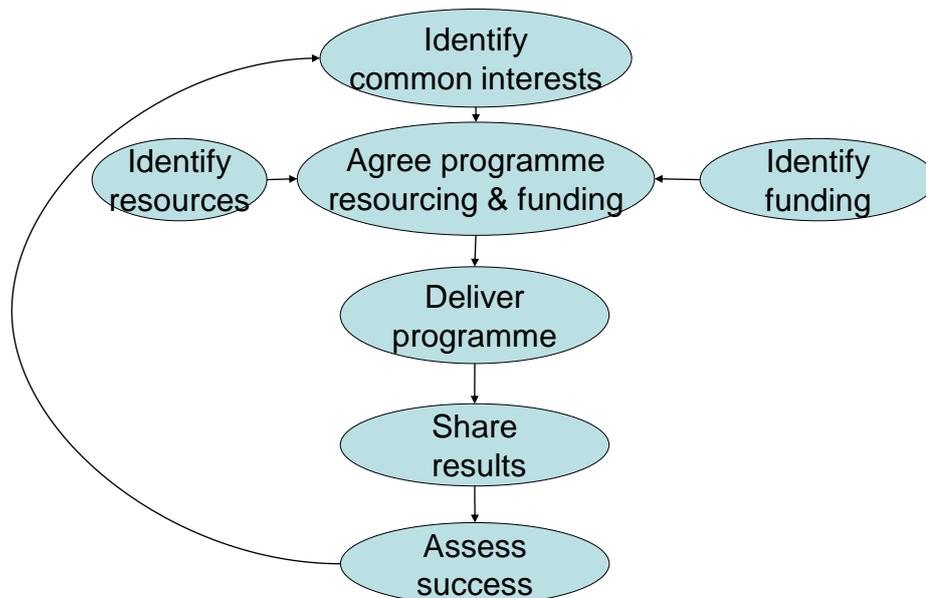
H: Establish & operate SyE Community of Practice



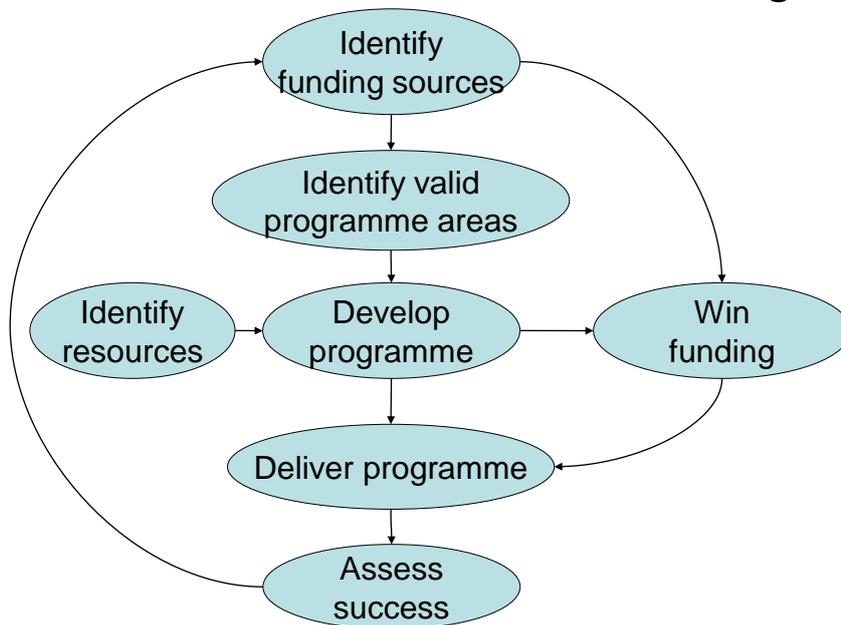
I: Provide SyE Consultancy



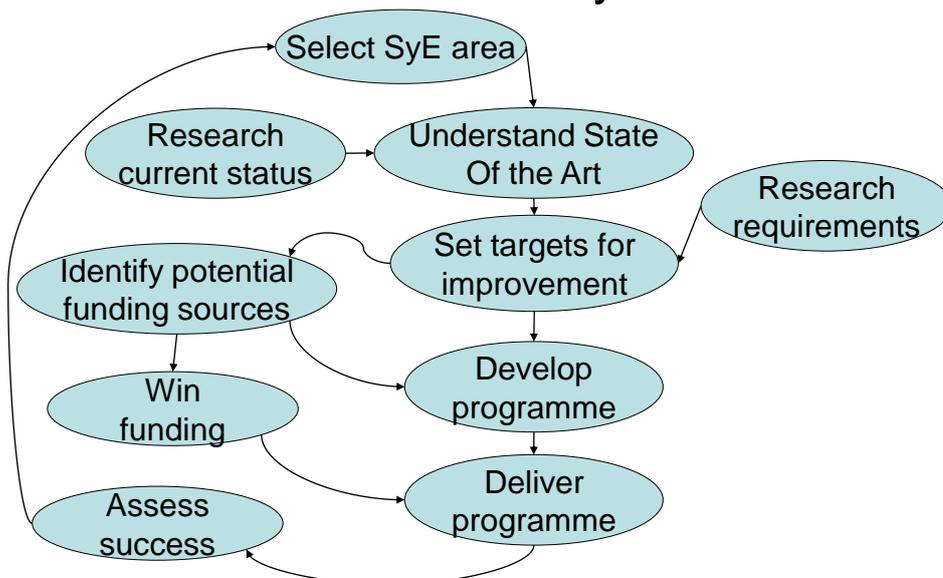
J: Engage partners in joint research



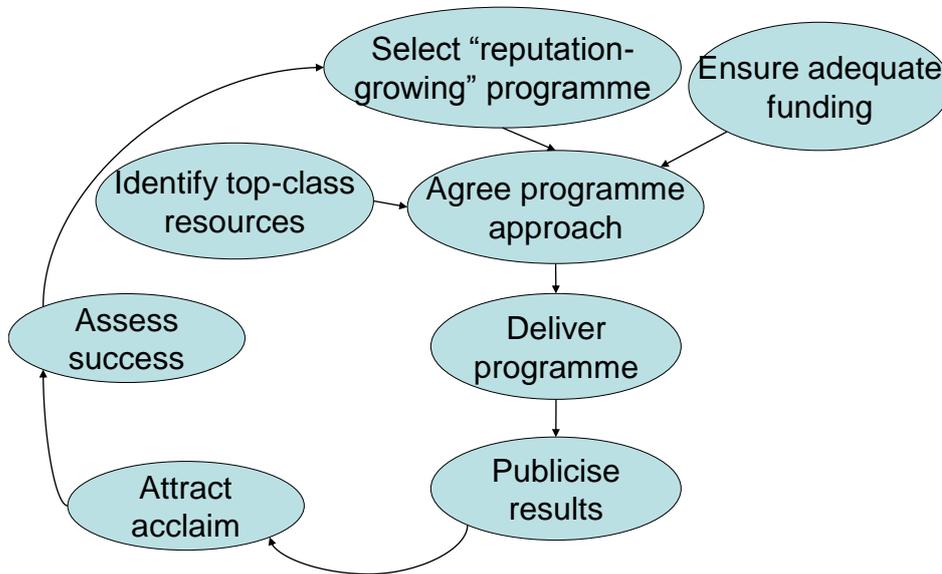
K: Attract & direct external funding



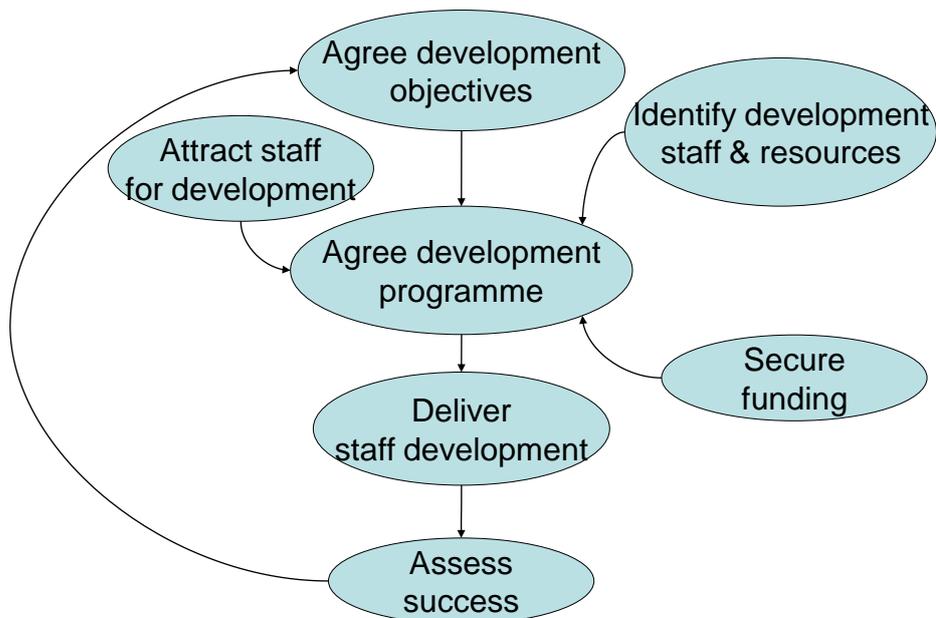
L: Advance the State of the Art in areas of SyE



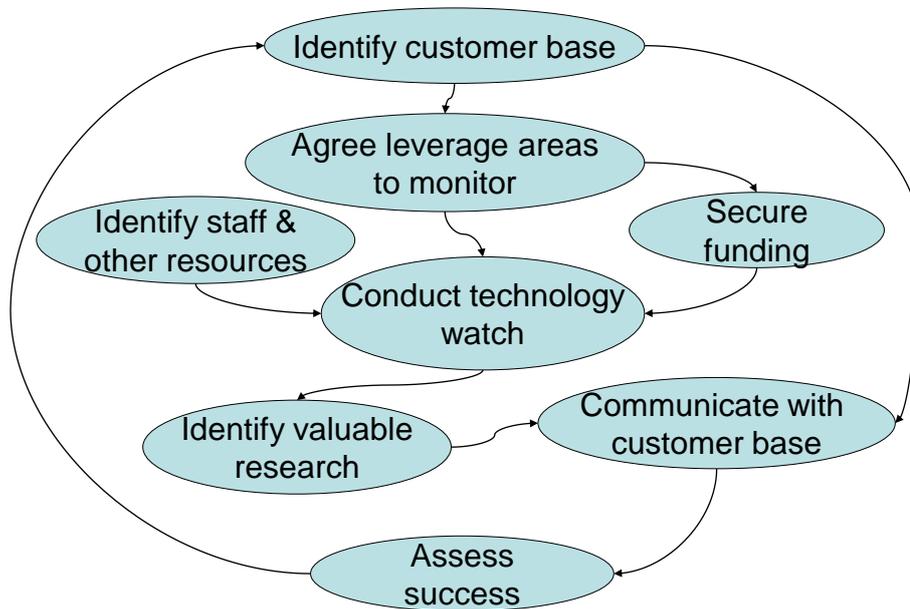
M: Grow the reputation of HRP partners



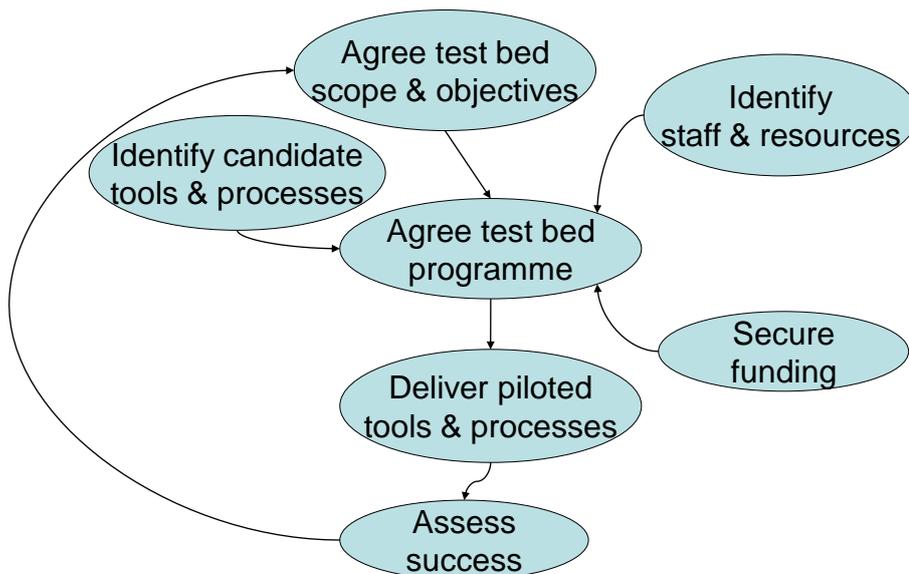
N: Develop partners' staff



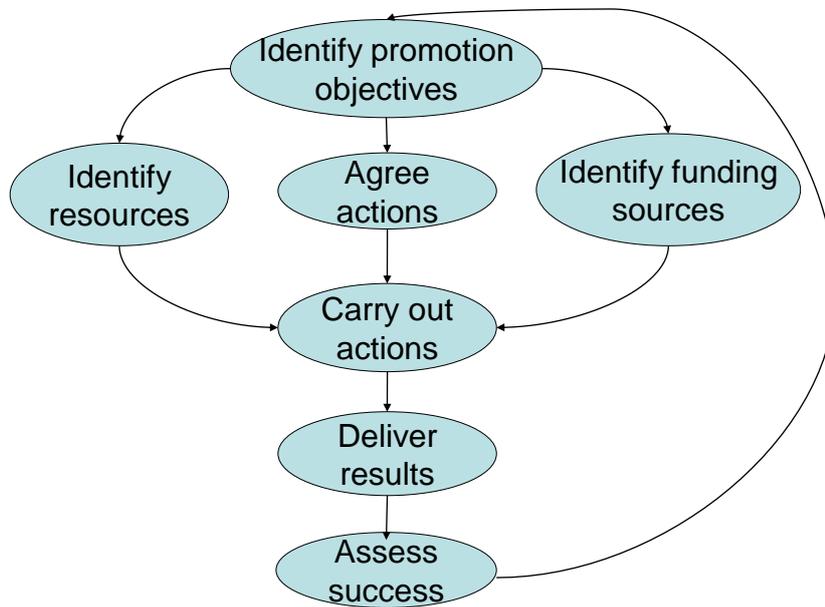
O: Leverage Other Research



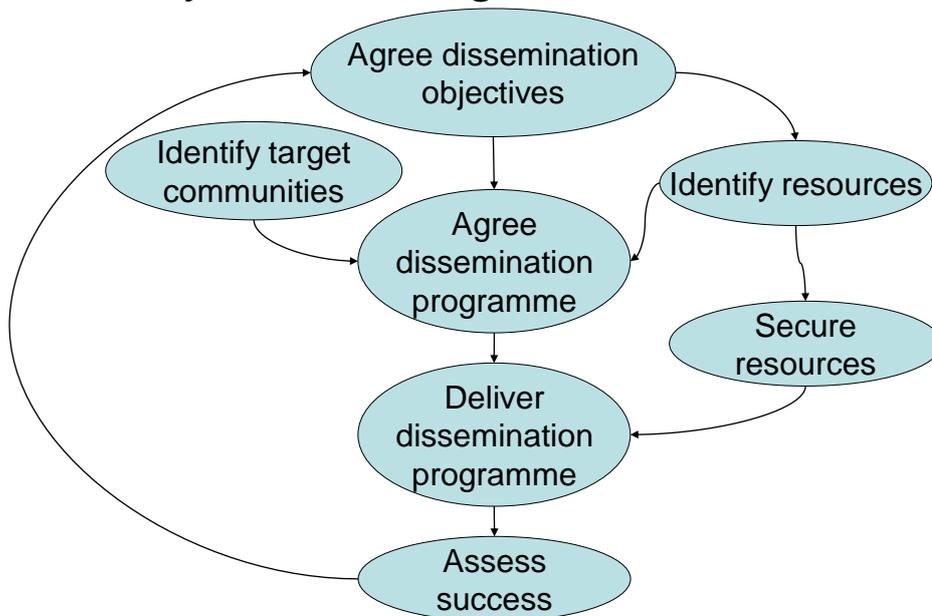
P: Provide a test bed for SyE tools and processes



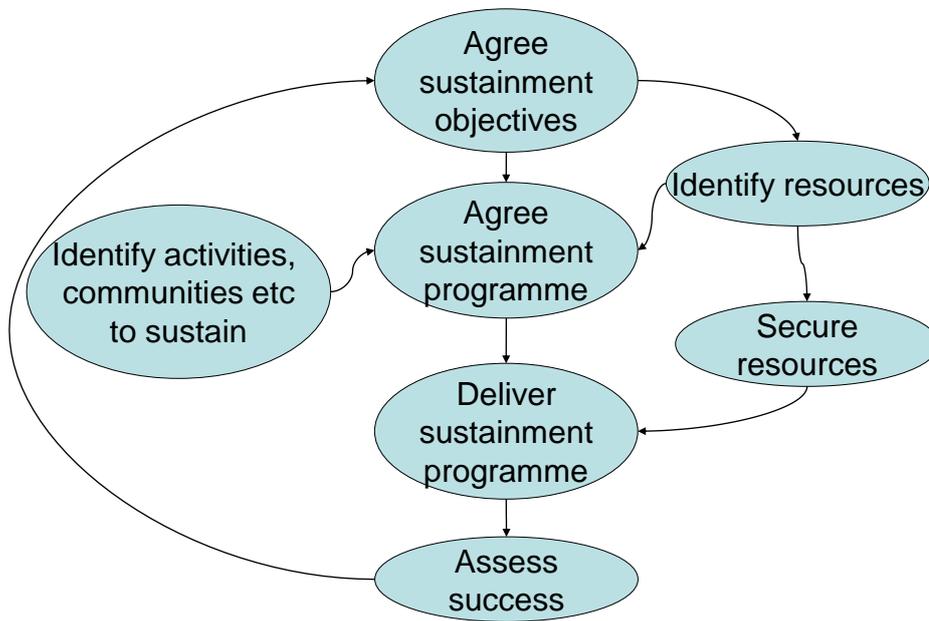
Q: Promote Systems Engineering



R: SyE Knowledge Dissemination



S: Sustain the HRP



ROOT DEFINITIONS

	Owned by (O)	Operated by (A)	To (T)	For (C)	W (worldview)
A	University Department	Academic and administrative staff	Educate and train systems engineers By Developing, promoting and running profitable education and training programmes in systems engineering	Industry and commerce in the UK	In order to grow the systems engineering resource to meet society's needs
B	Industrial Partners	Industrial partners staff and/or academic staff	Deliver fully-funded research (to defined requirement) By Bidding for, winning and delivering programmes of work which are defined and fully funded	The funding industrial partner	Industrial partners have sufficient funding for the work that they need to do
C	Industrial Partners	Industrial partners staff and/or academic staff	Deliver part-funded research (to defined requirement) By Bidding for and winning external funding, and delivering programmes of work defined and partly funded by	The funding industrial partner and other funding body	Industrial partners have insufficient funding for the work that they need to do; external sources of funding are available.

	Owned by (O)	Operated by (A)	To (T)	For (C)	W (worldview)
D	Industrial Partners	Industrial partners staff	Deliver innovative SyE research By Bidding and winning programmes of work which are defined and fully funded; identifying and drawing upon other relevant but unrelated work; delivering innovative results.	Industrial Partners	Research with outside influences is essential for the HRP to be considered a world leader; this provides the technical leverage of the HRP.
E	University Partner	Academics	Deliver aligned research By Assessing partner needs, developing aligned work, seeking and securing funding, delivering the research and sharing results.	Any HRP partner	Aligned research provides automatic industrial relevance & support, and strengthens the partnership.
F	University Partner	Staff from university and all participating companies	Develop the SyE capability of a participating company By Conducting research and undertaking education, training & knowledge transfer activities	Any participating company	SyE capability is grown through research, education and knowledge transfer.

	Owned by (O)	Operated by (A)	To (T)	For (C)	W (worldview)
G	UK Government	Leading SyEs from around the UK	Improve Regional and the UK's international competitiveness By Conducting government-sponsored research, education, training and knowledge transfer.	UK industry & commerce	Better SyE leads to improved competitiveness
H	Partners	Partners systems engineers	Establish and operate SyE Community of Practice By Providing a suitable environment and facilities	HRP Partners	A SyE COP will provide enhanced SyE capability to HRP partners
I	University Partner	Leading SyEs from around the UK (& potentially overseas)	Provide SyE consultancy By Establishing and marketing a consultancy capability, solving problems and growing the group's reputation.	UK & potentially international industry & commerce	There is a market for SyE consultancy; consultancy will underpin other aspects of the HRP business model; the HRP can attract suitable consultants.
J	Partners	Partners staff	Engage partners in joint research By Facilitating an understanding of shared interests and a cooperative approach to research	Partners	Joint research will be of greater benefit to the partners

	Owned by (O)	Operated by (A)	To (T)	For (C)	W (worldview)
K	The partners	Industrial partners' staff and academic staff	Attract and direct external funding By Developing research to match funding opportunities.	Company and University partners	Targeted research bidding can be used to control funding streams
L	The partners	Leading SyEs from Industrial partners and University partner.	Advance the State of the Art in areas of SyE By Understanding the state of the art in selected areas, targeting research at high-value problems and delivering results.	The partners	The partners will accept some latitude in research programmes in order to make significant breakthroughs.
M	The partners	Partners' staff	Grow the reputation of HRP partners By Being highly visible and delivering world class research (&/or education, knowledge transfer) in high profile areas	The partners	Visibility of world-class research, education, etc will have a positive effect on the reputations of the partners.
N	The partners	Industrial partners' staff and academic staff	Develop partners' staff By Exposure to research and teaching in an academic environment	Individual development of the partners staff	Exposure to the HRP environment is beneficial for development.
O	The industrial partners	Industrial partners' staff and academic staff	Leverage other research By Conducting technology watch in agreed leverage areas	The partners	Greatest and most cost-effective advances in SyE research will be made by building on existing work.

	Owned by (O)	Operated by (A)	To (T)	For (C)	W (worldview)
P	University Partner	Industrial partners' staff and academic staff	Provide a test bed for SyE tools and processes By Establishing a funded test bed programme with agreed scope and objectives, delivering piloted tools and processes.	Partners	A permanent test bed facility is a critical resource for systems engineering research and will enable a wide range of problems to be tackled quickly, efficiently and cost-effectively.
Q	Partners	Industrial partners' staff and academic staff	Promote systems engineering By Agreeing promotion objectives and actions, securing funding and resources, delivering results.	Society (employers, potential systems engineers, users of engineered goods & services)	Systems Engineering is fundamentally "good" but is under-represented in education, research and the workforce at large.
R	Partners	Industrial partners' staff and academic staff	Disseminate SyE knowledge By Agreeing dissemination objectives and actions, securing funding and resources, delivering results.	Systems engineering society at large	Sharing of systems engineering best practice among both partners and competitors strengthens the discipline overall.

	Owned by (O)	Operated by (A)	To (T)	For (C)	W (worldview)
S	Partners' senior management	Industrial partners' and academic senior staff	Sustain the HRP By Agreeing sustainment objectives and actions, securing funding and resources, delivering results.	Partners	Independent of its outputs, the existence of the HRP as a partnership is, in itself, a good thing for the partners and the HRP should therefore be sustained.

APPENDIX TWO

PUBLICATIONS

The following conference papers were published by the author during the period of doctoral research:

BROWN, S.F., 2007. The application of systems engineering to the management of nationally-important research in a multi-enterprise context. STEVENS INSTITUTE OF TECHNOLOGY, In: Conference on Systems Engineering Research 2007, CSER 2007.

BROWN, S.F., 2008. Enhancing the Partnership through SSM, 6th Conference on Systems Engineering Research, 4th-5th April 2008, CSER 2008.

BROWN, S.F., 2009. Naivety in Systems Engineering Research: are we putting the methodological cart before the philosophical horse? 7th Conference on Systems Engineering Research, 20-23 April 2009, Loughborough University.

BROWN, S.F. and RAGSDELL, G., 2009. Systems Engineering meets Knowledge Management: Introducing a 'System of Knowledge Management Approaches', INCOSE 2009: 19th International Symposium, 20-23 July 2009, International Council on Systems Engineering.

DIXON, K., BROWN, S.F. and KEIRL, J., 2007. Integrating the Intelligent Enterprise, INTERNATIONAL COUNCIL ON SYSTEMS ENGINEERING (INCOSE), In: INCOSE 2007, 24 - 28 June 2007, International Council on Systems Engineering.

VALERDI, R., BROWN, S.F. and MULLER, G., 2010. Towards a framework of research methodology choices in Systems Engineering, STEVENS INSTITUTE OF TECHNOLOGY, In: Conference on Systems Engineering Research, 17-19 March 2010, CSER 2010.

The following figure illustrates their role in the evolution of the research.

