Commercialisation Models

A review of the literature on existing commercialisation models, other research into success factors in commercialisation, their possible relevance to Australia's defence business environment and how they might shape a survey questionnaire for the Australian defence community

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While a number of commercialisation models have been developed around the world to facilitate the exploitation of Intellectual Property (IP) derived from R&D in high-technology sectors such as Information & Communications Technology (ICT) and Bio-technology, none have been developed specifically for the defence sector.

To some extent this is because defence R&D has historically existed in something akin to a command economy: defence forces have tended to specify equipment or capability needs (often expressed as emerging threats to which counters are required) and then fund the necessary R&D by a government research organisation or a private company. Defence-related R&D has not always resulted in IP which can be exploited profitably in the non-defence sector, and this is rarely, if ever, an explicit goal of government-funded defence research (Trenberth 2004) (UKMoD 2007). Therefore, defence-related R&D is not generally stimulated by commercial market drivers and so the expression 'commercialisation' has not been applied widely to the exploitation of IP generated in government-owned defence research establishments or by private sector companies or research facilities using government funding.

However, the expression 'commercialisation' is synonymous with 'product innovation', a process with which defence forces, defence research establishments and private sector defence industries are only too familiar. Regardless of the source of the original IP, it is a reasonable proposition that the process of turning it into an effective, useable defence product (a weapon, or other piece of equipment, a service or process) has much in common with the commercialisation, or product innovation, processes adopted by private sector firms operating in commercial markets. For the purpose of this monograph the two expressions will be used interchangeably.

There is some convergence between the defence and commercial markets also: over the past decade defence forces have begun exploiting commercially-developed high technology products and processes, particularly in the ICT and biotechnology sectors. Whereas defence research once led civilian research in the ICT area particularly, the opposite is now true. Therefore the defence community – defence forces, as well as specialist defence manufacturing and systems integration companies – is increasingly adopting products and processes that have already been commercialised from civilian-developed IP. The commercialisation of ICT-related IP is a fairly generic process, and therefore specialist models are not necessarily required for defence-related applications.

But the demands of military operations – in particular for reliability under extremely stressful operating conditions, as well as for security, along with some unique applications and functions that have no civilian or commercial equivalent – mean there is still a sub-set of these and other high technology industry sectors that exists solely to develop products and processes for the military, and to support and enhance these once in service.

Increasingly, combat effectiveness and decisive military advantage are enhanced through the leverage afforded by ICT-related capabilities grouped under the general heading Network Centric Warfare (NCW). These include radios (both secure and non-secure), Tactical Data Links (TADIL), routers, satellite terminals, encryption and security devices, and computerised command support and decision support systems, all of them designed, to a greater or lesser extent, for deployment aboard ships, aircraft or vehicles into a combat zone.

The NCW domain also embraces sensors and weapons and the fusing of the whole into a smooth-functioning network where information can pass rapidly between 'nodes' (often people, sometimes computers, sensors or 'effectors' such as missiles). Such a network has many similarities with civilian IT networks developed for the banking and financial services, airline and travel industries.

Much of the investment in defence-related Science & Technology (S&T) across the western world at present focuses on the NCW domain. However, there remains considerable S&T investment in 'traditional' defence-unique areas such as ordnance, ballistics, rocketry, high-speed aerodynamics and ballistic protection which have little or no direct relevance to the civil economy.

The unique nature of the defence market, which in most countries is dominated by a single government customer, means that sometimes the route to market doesn't follow roadmaps developed for the commercial sector, and companies face a different set of business and financial risks and challenges.

In particular, at the leading edge of operational capability, defence is a high-risk/high return business: Defence forces, and therefore defence contractors, deliberately court high levels of risk in seeking a capability edge over adversaries. This is in contrast with the commercial sector where customers and suppliers both seek to eliminate or reduce risks as far as possible.

Notwithstanding, any examination of the factors which affect the successful commercialisation of defence-related IP in Australia will benefit from an examination of successful commercialisation models developed for and adopted by commercial research and technology players. And given the essentially high-technology nature of the defence market generally, whether for ICT products or other technologies and capabilities, it's reasonable to hypothesise that a successful ICT commercialisation model from the civilian world can be modified to accommodate the unique features of the defence market.

The literature contains several examples of commercialisation models developed for and applied successfully in commercial high-technology markets. There is also a body of literature based on research into the distinguishing characteristics of successful technology innovators and factors determining, or at least strongly associated with, commercialisation success. Only a tiny minority of this literature specifically addresses the defence domain.

It is reasonable to hypothesise that a defence industry survey based on a study of commercialisation models and success factors in the non-defence sector will identify certain factors unique to the defence sector which in turn will help define a model for the successful commercialisation of defence-related IP.

Categorisation of models

The commercialisation models described in the literature fall generally into two broad categories. The first is the 'Linear Model' (sometimes referred to also as a 'Process Model') which sets out a linear, step by step process. In some cases such models include parallel streams of complementary activities which should be undertaken concurrently in order to maximise the chances of a successful commercialisation.

The second category is the so-called 'Functional Model' which aggregates important activities and describes relationships between them, without necessarily prescribing steps to be taken down a particular path.

The Linear Models, with a few exceptions, are generally presented as block diagrams. In some cases, these represent a sequential process, in others a set of relationships between elements of the commercialisation process. Commercialisation is indeed a sequential process but typically requires the innovator to repeat many iterative 'loops' before it is concluded successfully.

These models amount to 'check lists' (in different forms) of specific tasks to be completed, and technical, market and business conditions to be satisfied or goals to be met on the commercialisation path. They represent a distillation and fusion of expertise in the research, product development, marketing and business development domains. They highlight the importance of processes 'downstream' from the original invention or idea and the broad range of skills which must be deployed to create a successful venture based on a new piece of IP.

The blunt message for researchers is that having a good invention is not enough: successful commercialisation requires a good business plan and a good business team.

Many of these models focus on the process of 'venturing' – that is, establishing an all-new business to commercialise a new piece of IP; many such models have emerged from the academic world where a significant proportion of IP commercialisation involves venturing in some form by academic researchers, with or without the support of their parent organisation.

The pattern in established industry sectors, however, is for a more iterative approach based on the creation of a new product, process or service by an established company, either through ‘importing’ IP (for example, by licensing) or development of IP generated in-house. Subsequently, existing products, process and services are enhanced, upgraded, expanded and adapted to match evolving customer demands. This involves the development and extension of a product, process or service developed from the original IP into a new or enhanced offering.

This commercialisation process is more representative of the majority of such activity undertaken within manufacturing industry, whether for defence or other applications. However, many of the technical, market and business factors identified and addressed in models designed for venturing purposes are still highly relevant here also.

While Linear Models list specific activities and tasks, they have no predictive power in themselves. However, they almost all at various points require innovators and entrepreneurs to make honest assessments of future market conditions, project schedules and cash flows, and product or organisational attributes which to some degree predict, or point to the likelihood of, commercialisation success or failure.

The literature also includes a body of research which has successfully identified key factors associated with successful commercialisation, whichever process (IP licensing, venturing or in-house development) is adopted. These factors include the size and technology orientation of the commercialising companies, the urgency of the demand ‘pulling’ the IP down the commercialisation path and the Technology Readiness Level (TRL) of the IP being commercialised. This research, when applied to new commercialisation programs, has a predictive function; therefore it is a reasonable hypothesis that this can also be applied in turn to existing commercialisation models to identify, shape and guide commercialisation opportunities.

A sub-set of the body of literature identifying commercialisation success factors consists of research to determine features of a national innovation system associated with high levels of commercialisation success. This research seeks to quantify relationships between private and public sector investment in R&D and education, numbers of people involved in R&D and commercialisation, as a proportion of the workforce at large, and other similar relationships.

Linear Models

One of the best-known examples of a Linear Model is that developed by Dr H. Randall Goldsmith (Goldsmith 1995).This integrates the technical, market and business elements of the commercialisation process into a matrix of concurrent and sequential activities and decision points.

The Goldsmith Model is one of three Linear Models studied and compared by Rosa and Rose in their 2007 report for the Science, Innovation and Electronic Information Division of Statistics Canada, “Report on Interviews on the Commercialisation of Innovation” (Rosa and Rose 2007).

TECHNOLOGY COMMERCIALIZATION MODEL COMPONENTS:	TECHNICAL	MARKET	BUSINESS
CONCEPT PHASE			
STAGE 1 INVESTIGATION	TECHNICAL ANALYSIS • Define Concept • Confirm critical assumptions • Survey state of the art • ID critical barriers • Evaluate applicability • Determine technology	MARKET ASSESSMENT Conduct market overview • ID pricing structure • ID market barriers • ID risks • ID distribution channels • ID trends and competitors	VENTURE ASSESSMENT • Estimate profit potential • Conduct self, enterprise and commercialization assessments • ID professional needs • ID capital needs
DEVELOPMENT PHASE			
STAGE 2 FEASIBILITY	TECHNICAL FEASIBILITY • Develop working model • Test technical features • Assess preliminary manufacturability • Conduct manufacturing assessment • Assess safety & environmental features • Finalize designs	MARKET STUDY ID and quantify: • Market size • Customers • Volume • Prices • Distribution • Competitors	ECONOMIC FEASIBILITY • Formulate financial assumptions • Develop *pro forma* • ID seed capital • Form advisory team
STAGE 3 DEVELOPMENT	ENGINEERING PROTOTYPE • Develop Prototype • ID materials and processes • Conduct tests • Develop manufacturing methods	STRATEGIC MARKET PLAN • ID marketing team • Define target market • Select market channels • Field test	STRATEGIC BUSINESS PLAN • Decide venture or license • Finalize intellectual property • ID management team • Select organization structure • Write business plan
STAGE 4 INTRODUCTION	PRE-PRODUCTION PROTOTYPE • Develop production prototype • Determine production process • Select manufacturing process • Design field support system • Demo product features	MARKET VALIDATION • Establish market relationships • Conduct limited sales • Analyze sales • Survey customers • Refine marketing	BUSINESS START-UP • Establish business functions • Hire staff • Execute contracts • Secure first-stage financing
COMMERCIAL PHASE			
STAGE 5 GROWTH	PRODUCTION • Prepare commercial design • Establish quality control • Construct facilities • Conduct full-scale production • Finalize internal distribution system	SALES & DISTRIBUTION • Expand distribution • Analyze competitor response • Assess customer satisfaction • Assess distribution satisfaction • Refine product features	BUSINESS GROWTH • Monitor enterprise position • Hire and train personnel • Execute contracts • Arrange 2nd & 3rd stage financing • Institute vision, mission, and management policies
STAGE 6 MATURITY	PRODUCTION SUPPORT • Maximize production • Establish after market support, repairs and spares • Warranty service • Implement training program	MARKET DIVERSIFICATION • Develop market retention • Establish market scan • ID new markets • ID new products	BUSINESS MATURITY • Establish SWOT • Invest profits • Monitor product life cycle • Monitor business trends • Monitor management technologies • Implement innovations

© H. Randall Goldsmith, Ph.D.

Figure 1: The Goldsmith Model

The Goldsmith Model (see Fig.1) covers the entire process, from the first idea, through development, creation and start-up of a spin-off company and then the exit strategy for the inventor and investors. A 'check list' rather than a 'block diagram' type of model, it describes concurrent 'streams' of technical, market and business activity, each stream conforming to six sequential stages: Investigation; Feasibility; Development; Introduction; Growth; and Maturity. These streams, in addition, are broken into three sequential phases: the Concept Phase; Development Phase and Commercial Phase; in a slightly different version of this model presented by the US Department of Energy (Lux and Rorke 1999) these phases are titled Innovation, Entrepreneurial and Managerial.

The model is intended to be followed as a series of sequential steps, working from left right and top to bottom; the process does not advance from one Stage to the next, or from one Phase to the next, until the technical, business and market issues dominating that stage have been sufficiently addressed and resolved. Goldsmith himself describes it as a 'tactical model' designed as "a framework to help… develop progress measures, identify information and technical assistance needs, project development costs, and forecast financing requirements," (Goldsmith 2003). He does not characterise it, therefore, as a prescriptive set of instructions.

It has been noted that often inventors and R&D facilities progress well down the left hand column before giving any serious thought to the issues addressed in the other two columns. Goldsmith's model is designed to provide a 'reality check' which ensures all aspects of the process are given due consideration.

Rosa and Rose contend Goldsmith's model is more suitable for commercialising totally new ideas and not suited to incremental innovation, or the enhancement or upgrade of existing products, services and processes. They also contend the model isn't sufficiently flexible to accommodate feedback nor the re-ordering of steps where circumstances dictate this is necessary or desirable, especially in an incremental innovation program.

This seems to reflect a mis-reading of Goldsmith's intentions and a broader misunderstanding of the commercialisation process generally. Following the Goldsmith model, there is no reason why the process cannot return to an earlier stage when some unexpected obstacle or development is encountered: commercialisation is very rarely an unbroken, linear process and most models acknowledge this fact. And the Goldsmith model can be applied to incremental innovation by simply ignoring or modifying elements relating specifically to a new business start-up.

Goldsmith's model has no inherent predictive power, and Goldsmith himself cautions that following the model slavishly is no guarantee of success. But it does require the team conducting the commercialisation process to seek information and make informed judgements on risks and rewards at each critical point in the process – the predictive power of this model lies entirely in the integrity of the work done by those following it.

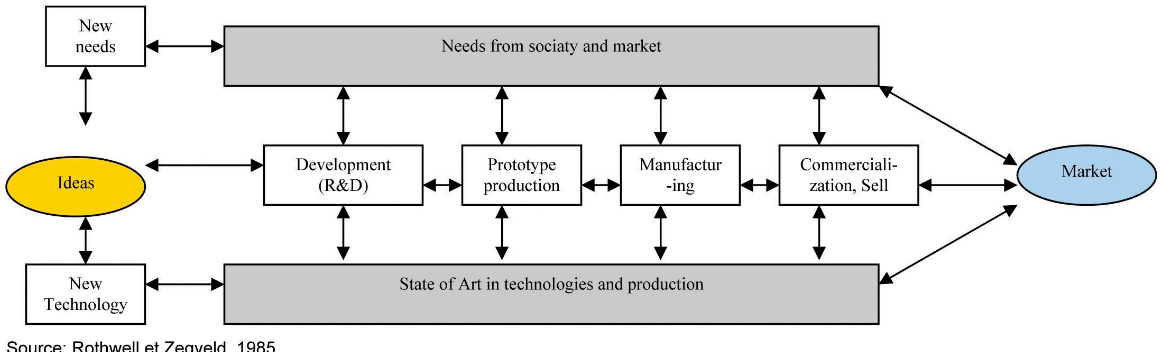


Figure 2: The Rothwell & Zegfeld Model

The Rothwell & Zegfeld model (Rothwell and Zegfeld 1985) is the second Linear Model examined by Rosa and Rose (see Fig.2). This is a 'block diagram' model, with the blocks describing the relationships between the components of the commercialisation process and how they interact with each other. Like Goldsmith's model this one is sequential, but it places the technical 'stream' at the centre of the process, its path to market influenced by emerging and evolving market needs on the one hand, and by the evolution of technology on the other. 'Business' issues are implied but not addressed specifically in this model, and the detailed 'check list' of technical, business and market factors is absent.

Again, this has no predictive capabilities but instead requires innovators to inform themselves and make their own judgements on which actions, or conditions, are most likely to result in success.

The third Linear Model examined by Rosa and Rose is the Andrew & Sirkin model (Andrew and Sirkin 2007) which presents in graphical format a curve of a typical commercialisation project's cumulative cash position plotted against time (see Fig.3). Cash, on the vertical axis, is presented as a simple positive or negative value, changes in value resulting from changes in the cash flow of the business, from negative to positive. The horizontal axis represents the sequential stages of the commercialisation process, from idea generation, through commercialisation to realisation.

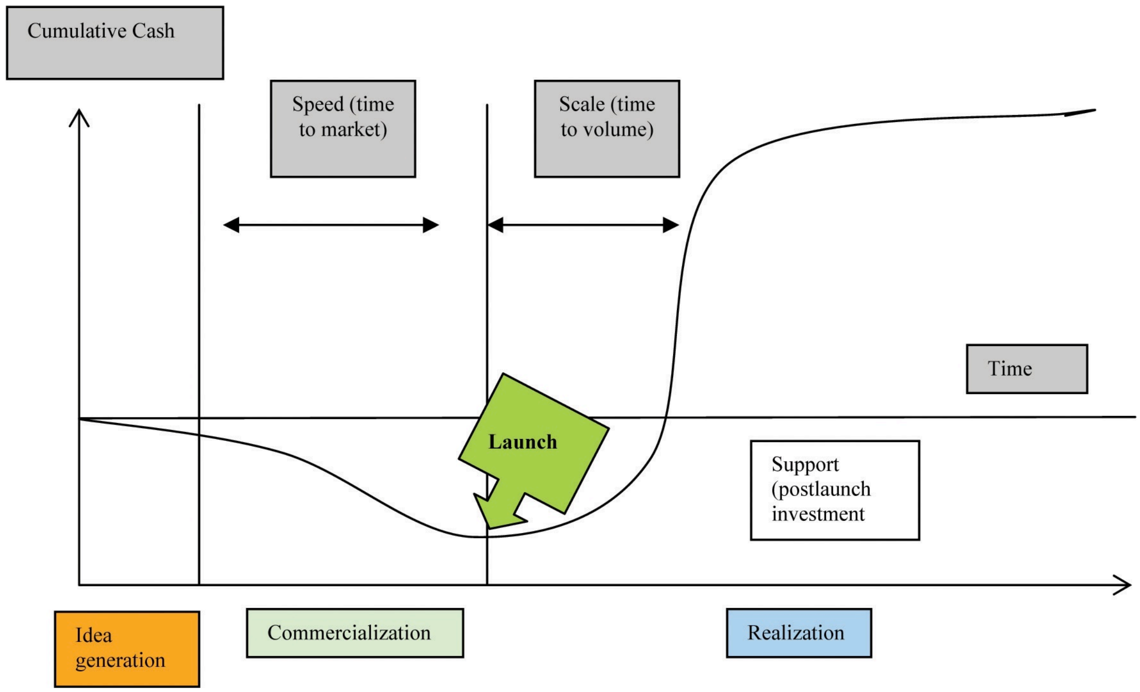


Figure 3: The Andrew & Sirkin Model

During the idea generation phase cash flow is negative; this negative flow increases sharply through the commercialisation process to the point of product or service launch, at which time the cash flow becomes positive. The project's cumulative cash position doesn't, however, become positive itself until sales have offset the initial investment.

The Andrew and Sirkin model is very useful in demonstrating the importance of speed to market to minimise the cumulative cash loss prior to launch, and then the equal importance of speed in achieving volume sales in order to achieve a profitability threshold rapidly and recoup investment. It also highlights the importance of product support post-launch: advertising, marketing, technical support and product enhancements. This resonates with research described below which identifies factors contributing to successful product innovation.

While this model doesn't set out prescribed steps, it does focus the innovator and investor on the economics of the commercialisation project and forces them to answer the simple question: is it worth the time, money and effort?

This question is addressed also in the Commercialisation Progression Model (Smith 2002) developed for the Australian Institute for Commercialisation (AIC) whose principal stages reflect the needs of the investor and entrepreneur: research; Pre-Seed; Seed; VC-Invested; Sustainable. The paper describing this model also notes what the author terms 'The Commercialisation Chasm' which lies between the Pre-Seed and Seed funding stages. Coincidentally, or not, this is the point at which the language, skills, values, interests and beliefs of the innovators on the 'upstream' side of the process yield to those of the 'entrepreneurs' on the downstream side.

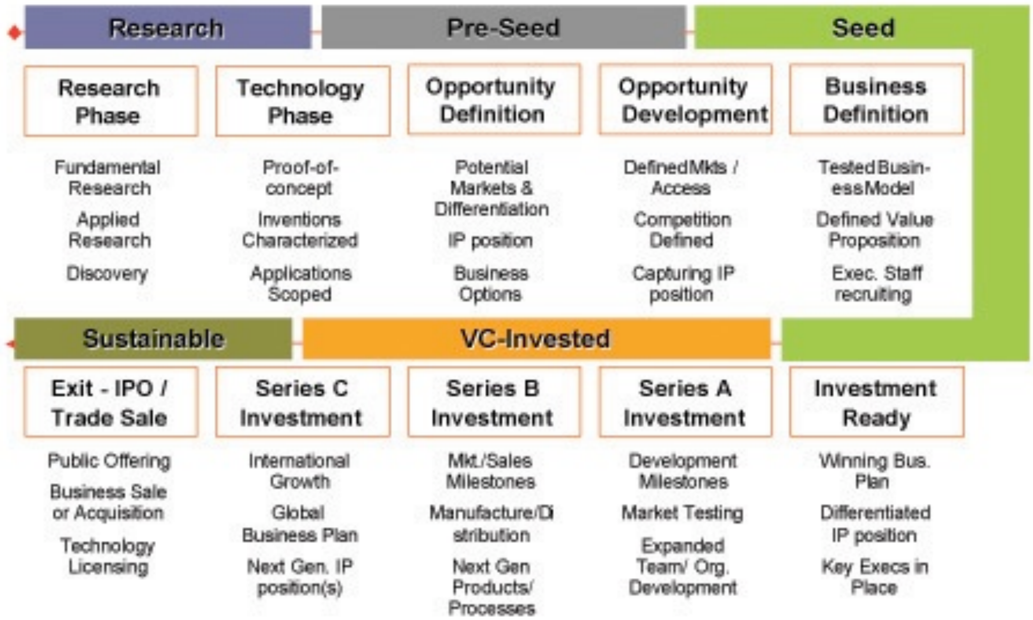


Figure 4: The AIC Commercialisation Progression Model

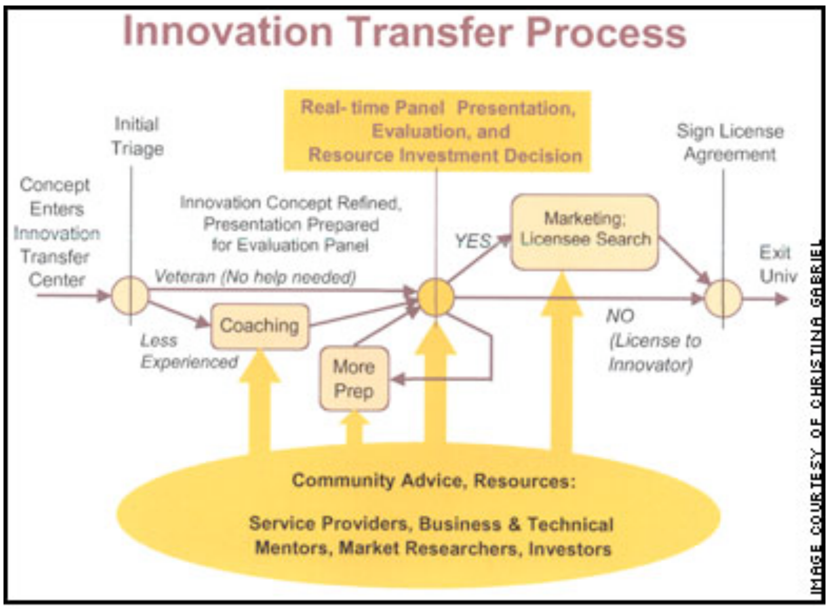
The AIC model (Fig.4) is based on data derived from a 1998 study of 266 companies in the United States by the Industrial Research Institute (www.iriinc.org). This study found that a field of 3-4,000 promising ideas may for various technical and commercial reasons be whittled down to result in a single commercial success.

Smith's paper setting out the Commercialisation Progression Model emphasises also the need for a fairly fine screening process as part of the Pre-Seed stage. This in turn has several phases, beginning with the Technology Phase, in which ideas are assessed and possibly combined or re-shaped in a series of increasingly fine filters, and then passing through the Opportunity Definition and Opportunity Development Phases. As literature cited elsewhere in this monograph shows, the idea screening stage is a vital component in the commercialisation process.

The AIC model accommodates a critical shift in emphasis as the filtering process takes effect. In the early stages of the process, ideas are subjected to ruthless scrutiny and weeded out rapidly. Ideas which cross that Commercialisation Chasm to achieve Seed and VC (Venture Capital) funding are, by definition, good enough to be worth nurturing rather than culled. As survivors pass through the model the emphasis progressively shifts from 'filtering' out weaklings to 'failure avoidance' and the protection and nurturing of promising ideas.

This is the first model to identify explicitly the need for predictive tools to guide the efforts and resources of innovators and investors by helping identify the technical and market-related features of a promising idea which would help it across the chasm. Such tools would provide a useful predictive function for the model.

Carnegie-Mellon University describes this ruthless filter as ‘Initial Triage’ in its linear Innovation Transfer Process (Carnegie Mellon University 2002). This process is what the University terms an Interactive Model, designed to accommodate mentors and experts appropriate to the proposed commercialisation and is deceptively simple (Fig.5): it has three basic steps, and an iterative loop at the critical decision point. Its intent is to help a university researcher determine the commercial prospects for an idea by involving financial, technology and marketing experts at an early stage, developing the idea and then presenting it to potential licensees or investors. If the process doesn’t result in a successful commercialisation the IP is then licensed to the innovator.



A diagram of the new Innovation Transfer Process.

Figure 5: The Carnegie Mellon Innovation Transfer Process Model

This model doesn’t prescribe a sequence of commercialisation steps, focusing instead on assembling the right advisers and mentors for a given proposal and allowing them to generate the right commercialisation strategy. Again, the explicit emphasis is on spinning off a new venture, either by venturing or through IP licensing, rather than the iterative enhancement of an existing product or service.

The University of Queensland’s commercialisation arm, UniQuest Pty Ltd, has also developed an eight-stage model (Fig.6) describing a sequential process designed to take the inventor and entrepreneur from the basic idea to the eventual exit strategy from a successful start-up (UniQuest 2008).

The UniQuest Process

	Commercialisation Stage	Research Stage	What's Involved
1	Research & Discovery	Fundamental	Research
2	Disclosure	Fundamental	Innovation disclosed to university commercialisation office
3	Evaluation	Fundamental	UniQuest evaluates the research for its commercial potential and develops a commercialisation plan.
4	IP protection & packaging	Fundamental	The IP is suitably protected and "packaged" for commercial opportunities
5	Proof of concept	Pre-clinical/ prototyping	Demonstrating that the innovation "works" or can be scaled up to industry capacity
6	Commercial pathways & resourcing		Commercial pathway chosen and financing sourced to grow the business – start-up company or IP licensing. Business plan developed, executive & marketing staff employed
7	Value-adding through to an exit	R&D/clinical trials	Continued R&D to refine product and develop additional product family members. Market and consumer testing
8	Exit		Realisation of capital value of the venture for inventor and investors. IPO or trade sale, or royalty stream coming on-line

Source: UniQuest Pty Ltd - http://www.uniquest.com.au/index.php?sectionID=106

Figure 6: The Uniquest Model

Again, this is a Linear Model and UniQuest cautions, in language commonly associated with credible commercialisation models or services, "While represented as a linear process, not all commercial ventures proceed from stage one to eight. For example, unexpected research outcomes may send a venture back to an earlier research stage or a change in market conditions may force a re-evaluation of the venture."

This model also places emphasis on the 'front end' R&D in a commercialisation program and less on the downstream elements of the process, whereas most of the models examined earlier place relatively greater emphasis in the downstream processes.

Functional Models

Rosa and Rose distinguish Linear Models from so-called Functional Models which don't prescribe a sequence of steps but, rather, describe a set of relationships which must be supported and conditions which must be satisfied in order to maximise the chances of a successful commercialisation.

The Canadian Expert Panel on Commercialization developed a Functional Model and published it in 2006 (Industry Canada 2006); this describes the various components of the commercialisation process and their relationships to each other, without overlaying them upon a linear, time-based process (see Fig.7). This model places ideas at the heart of the process in an iterative cycle which innovators, entrepreneurs and investors follow through the Technology ('R&D'), Business ('Firms') and Market elements of the process.

It acknowledges that ideas can emerge at any stage in the commercialisation process or product lifecycle; and also that several iterations of this cycle may be required in order to refine ideas and business models before a successful commercialisation is possible. Ideas can include all-new products or services, or incremental enhancements of existing ones, or new applications for existing products or services, and the steps necessary to adapt these to a new marketplace.

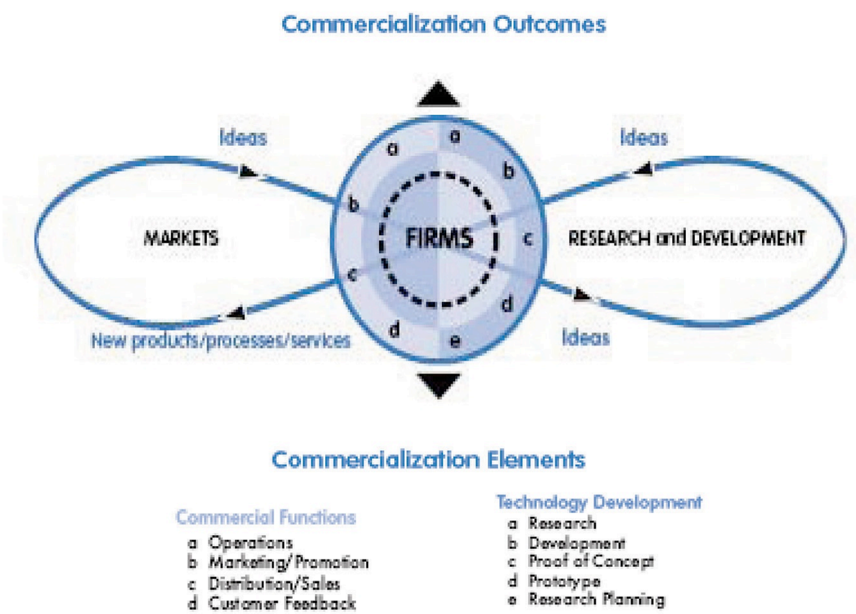


Figure 7: The Functional Model
Source: Canadian Expert Panel on Commercialisation

The paper setting out this model, like the Goldsmith and Rothwell-Zegfeld examples, identifies and embraces some key commercialisation project elements, including: R&D; prototyping; finance; skills and human resources; Intellectual Property (IP); manufacturing; sales and marketing; and customer feedback.

Predictive Models

None of the models described thus far offer any guarantee of success. They describe in various ways the key elements of the innovation and commercialisation process, their relationships to each other and the steps and precautions any prudent investor would take in starting up a new business based on a new product or service. They do not predict, or guarantee, outcomes.

These models identify, to varying degrees, the need to create or seek out the conditions or combinations of circumstances most likely to result in a successful commercialisation; but they do not describe explicitly the conditions and circumstances most closely associated with successful commercialisation, nor the qualities and attributes of the individuals and organisations involved and their potential impact on the outcome.

An analogy would be a pilot's manual for an aircraft. Theoretically, a complete novice with poor eyesight and motor skills could follow the instructions, step by step, and fly an aeroplane successfully but trained pilots would easily predict that attempting such a thing will almost certainly result in disaster. So it is with commercialisation: while in theory anybody could follow one of the models described above, history demonstrates that there are certain attributes of individuals and companies involved in the process of innovation, and the markets in which they operate, which make some more likely to succeed than others.

The value of the models would therefore undoubtedly be increased by the inclusion of techniques or knowledge which helps innovators, investors and entrepreneurs predict outcomes, or assess the likelihood of certain outcomes, with greater certainty.

Commercialisation – the literature

Data which could help create such a 'Predictive Model' has been gathered by researchers in a variety of studies across the world. However, only a few researchers have sought explicitly to develop a predictive tool from their research; the majority have focussed on identifying factors associated with commercialisation success and, in a relatively few cases, identifying factors associated with failure.

Sohn and Moon (Sohn and Moon 2003) used a Structural Equation Model (SEM) to develop a predictive Technology Commercialisation Success Index (TCSI). This employs the American Customer Satisfaction Index (ACSI) to measure the success of the commercialisation projects examined in the research. Their objective was to develop a means of forecasting commercialisation success rates and so identify the optimum commercialisation strategy for various combinations of technology (or IP), IP transferor and IP transferee.

The success of the commercialisation process was measured across 284 commercialisation projects using the ACSI model to assess variables such as customer expectations, customer perceptions of quality and value for money and customer dissatisfaction as measured in the number of complaints received.

The linkage of customer satisfaction, at one end of the innovation process, with the technology transfer mechanism close to the start of this process may appear tenuous: other researchers (see below) generally argue that internal company processes following the initial technology transfer have the greatest effect on the commercialisation outcome. But it could be argued that companies which are inherently better equipped to execute these processes proficiently (allowing for differences between technology types and marketplaces) will tend to make the correct choice of IP and commercialisation opportunity automatically.

Sohn and Moon identified a number of measurement and latent variables which they integrated using an SEM to develop the TCSI. These included the experience of the researcher, the management of the transferee, its marketing and production skills, its ability to make a product offering of superior price and quality, its export orientation, and external factors such as government policy and its broader effects on the R&D and business climate.

They found the most successful commercialisations involved established companies which spend over 2.5 per cent of sales on R&D. For software and systems development projects established companies were found to be more successful than start-ups; but for straight manufacturing projects (eg of semi-conductors) start-ups could also be successful.

Sohn and Moon subsequently developed a Decision Tree of Data Envelopment Analysis (DEA) of environmental variables representing the characteristics of technology providers, technology receivers and the technology itself (Sohn and Moon 2004). Their findings include a higher likelihood of successful commercialisation where a high technology product or process is developed by an independent researcher for commercialisation by a company employing 100 or more people which spends 2.5 per cent or more of its revenue on R&D.

Interestingly, the lowest chances of commercialisation success are associated with research by a university or research institute in order to develop a finished product. Similarly, if IP developed in a joint research program is transferred to a company with a low R&D expenditure (< 2.5 per cent of annual sales) the commercialisation has a low chance of success.

Notwithstanding some inconclusive results, these two papers independently demonstrate a high level of correlation between certain environmental factors and the likelihood of commercialisation success. These factors are the nature of the technology and the characteristics of the technology developer and technology receiver, including the size of the company doing the commercialisation, the amount of its revenue it devotes to internal R&D, whether or not the IP is derived from sole or joint research, whether the research partner is a university or another company, the level of technical sophistication of the product, and whether or not the project is government-run.

A critical figure is the 2.5 per cent of annual sales which companies should devote to R&D. Notwithstanding the fact that their research is based on Korea's rapidly-growing ICT sector, and that this figure may not necessarily be valid in other sectors, Sohn and Moon demonstrate that R&D investment is important. It should be noted that Australia's defence industry generally devotes about 0.95 per cent of sales, on average, to internal R&D. (Ferguson 2006)

This serves to illustrate that, other things being equal, there are certain intrinsic factors in the attributes of and relationships between the partners in a high-technology commercialisation venture which have a determining effect on the outcome. If applied to a commercialisation model such as those above, these factors have a potentially very useful predictive and screening function.

Reflecting some of the factors identified in Sohn and Moon's work, much of the research into commercialisation success factors suggests that while a sound idea based on solid research and subjected to a rigorous screening process is an essential pre-condition, success owes more to the business processes that follow, and the people implementing them, than it does to the invention itself.

To examine this hypothesis, Cooper examined a number of project screening criteria as part of Project NewProd (Cooper 1980) and concluded that while careful project selection was an essential condition for success, undue attention was paid to this 'front end' aspect of a project and less to the execution and delivery aspects. Furthermore, he warns, too many screening models focus on relatively less important factors in successful innovation, such as the nature of the marketplace, the business environment and the venture. However, he states a screening process is a logical and important step in the process and sets out nine criteria for selecting a new product innovation project. In descending order of importance these are:

1. Pick projects where the resulting product will yield significant and unique user benefits (avoid me too-ism)
2. Seek projects where you already know the market well and where you're likely to execute the marketing activities competently
3. Select projects with a high technical and production synergy between the product and company, and where the company has the necessary skills
4. Avoid dynamic markets with frequent changes in user needs and new products are introduced frequently
5. Look for products aimed at large and growing markets and where a high level of need exists for this type of product
6. Seek products which offer an economic advantage to the user: avoid costly products that offer no significant improvement in user benefits
7. Seek projects with a high level of marketing and managerial synergy between the project and company – financial, marketing, sales, management, distribution
8. Avoid highly competitive markets (many players, intense price and performance competition) where customers are already satisfied by competitors' products
9. Avoid projects new to the firm: new customer class, new product class, new need served, new production process, new delivery mechanism/business model, new technology, new competitors

While not all of these criteria apply to all cases, both Cooper in a separate study (Cooper 1984) and Rothwell (Rothwell 1977) emphasise the importance of an effective screening process. The benefits of such a process are highlighted by one of Cooper's findings from a review of the product innovation strategies of 122 firms: overall, the mean success rate for developed products was 67 per cent – only 17 per cent of products failed commercially in the marketplace after they had been launched. He argues that this dispels the myth in some firms that R&D expenditure and product development are unaffordable luxuries yielding low returns and that "only a fortunate few succeed in the new product game". The opposite is true, in fact: once they get to the marketplace (and many of course are aborted before launch), the majority of new products actually succeed.

However, as both Cooper and Rothwell argue, the outcome of a product innovation project is not determined by the technology, or the original idea, alone. This finding is borne out by several other studies carried out since the early 1970s. Most of these seek to identify factors contributing directly to or associated with successful innovations, or the characteristics of firms which have proven to be successful innovators.

This reinforces the suggestion that commercialisation success is really a function of the processes downstream from the original invention. Consequently, it is a reasonable hypothesis that commercialisation success depends to a significant degree upon factors such as the quality of a company's management, its internal processes, its understanding of the customer's needs, the technology it is dealing with and the market in which it is operating, and the competitive pressures it is facing.

For example Kleinschmidt and Cooper (Kleinschmidt and Cooper 1988) found that product innovation success is more likely when the company developing the product adopts an international outlook. That is, if the company designs the product for the world market and targets export markets deliberately (including carrying out market research overseas) it has a far higher chance of success both overseas and, significantly, at home in the domestic market. In Australia's very open defence market in which there are many foreign players, this may be a significant finding; it echoes the experience of a successful Australian radar and communications company, CEA Technologies Pty Ltd, whose strong commitment to the export market is based on the understanding that the Australian market is too small to support its R&D investment, while there is also "a perceived disinclination in the Australian marketplace to buy from local companies." (Gaul 2005)

One of the most detailed studies of success factors in technological innovation was Project SAPPHO (Scientific Activity Predictor from Patterns with Heuristic Origins), a two-phase project undertaken in the United Kingdom during the early-1970s. This was designed "as a systematic attempt to discover differences between successful and unsuccessful innovations." (Achilladelis, Robertson et al. 1971) (Rothwell, Freeman et al. 1974)

The technique employed in this project was that of Paired Comparisons in which a successful innovation was compared with an unsuccessful innovation competing for the same market. A successful innovation was defined as one that achieved a worthwhile market share and profit; failure, naturally is defined as an inability to achieve this. In all, some 43 pairs of successful and unsuccessful innovators were compared, 22 of them in the chemical process industry and 21 in the scientific instruments industry.

A total of 122 variables were measured and 41 were found to discriminate between success and failure, while the study also identified five key underlying factors which also discriminate between success and failure. The study also identified other factors associated with success as well as some inherent differences between the two industry sectors. These differences may be relevant in examining the prospects of large defence prime contractors and Small to Medium-sized Enterprises (SMEs) in the defence industry.

The five key underlying factors identified in project SAPPHO were, in descending order of importance:
1. Successful innovators were seen to have a much better understanding of user needs
2. Successful innovators pay more attention to marketing and publicity
3. Successful innovators perform their development work more efficiently than failures, but not necessarily more quickly
4. Successful innovators make more use of outside technology and scientific advice, not necessarily in general but in the specific area concerned
5. The responsible individuals (carefully defined by Rothwell, Freeman et al) in the successful attempts are usually more senior and have greater authority than their counterparts who fail.

These underlying success factors emerged from a multi-variate analysis of ten index variables constructed from the areas of competence identified as being associated with success or failure. These index variables (again defined carefully by Rothwell et al for the purposes of this analysis) are, in descending order of importance:

1. Marketing – a measure of the marketing effort deployed by the innovating organisation
2. R&D Stretch – a measure of the performance of the development work concerned with the innovation
3. User needs – a measure of the efficiency with which market research or other procedures have established the precise requirements of the customer
4. Communications – a measure of the effectiveness of the innovating organisation's communications network with the outside scientific and technical community
5. Management strength – a measure of the strength of the management of the innovating organisation
6. Familiarity – a measure of the extent to which the innovating organisation was familiar with technical problems posed by the innovation, and with the market
7. Techniques – a measure of the extent to which management explained the success/failure differences
8. Pressure – a measure of the competitive situation facing the innovating organisation
9. Organic – an attempt to classify the structure of the innovating organisation as organic or mechanistic
10. Risk – a measure of the degree of risk taken by the innovating organisation

This ranking represents an aggregate: for the chemical and scientific instrument sectors by themselves, the order of the first five variables differs quite significantly. The R&D Stretch occupies top position for the chemical industry, but fourth position for the scientific instruments, for example.

Rothwell et al also define the ‘key individuals’ in an innovating organisation: the Technical Innovator – the inventor or major technical contributor; Business Innovator – the individual actually responsible for the overall progress of the project; Chief Executive – the formal head of the innovating organisation; and Product Champion – who makes a decisive contribution by promoting the innovation’s progress through critical stages. In smaller firms a single individual may play some or all of these roles and make a far greater personal impact on the final outcome. In larger firms with formal, hierarchical structures and bureaucracy, each role is frequently played by a different person, highlighting the need for friction-free internal communications and processes.

Unlike Sohn & Moon, however, Project SAPPHO did not examine in detail the process of transferring IP from an outside R&D source to a firm, and the effect this process can have on project success.

A key difference between the chemical engineering and scientific instruments sectors identified in Project SAPPHO was that the former is dominated by large players with the resources to pursue what Rothwell et al describe as ‘radical innovation’; the scientific instrument-makers, by contrast, were generally low-capital small firms which, while agile and creative, also sought to minimise risk. The authors noted that whereas the major chemical companies derived a significant benefit from being ‘first to market’, among the scientific instrument makers the most successful were ‘second to market’, reflecting the risks borne by pioneering innovators.

Furthermore, Project SAPPHO identified another factor strongly associated with innovation and commercialisation success: autonomy. Successful scientific instrument makers were found to be either independent or, if owned by a local or overseas parent, were largely autonomous in their financial management, decision-making and in selecting and managing specific R&D programs. In the chemicals sector, by contrast, where companies are generally bigger, autonomy was not found to be strongly associated with either success or failure.

To some degree these inter-sector differences are reflected in the experiences of what in the Australian defence industry are termed large prime contractors (‘Primes’) and Small-to-Medium-size Enterprises (SMEs). By their very nature SMEs are generally dominated by tight cadres of individuals – innovators, entrepreneurs and engineers – and are generally regarded as being creative, flexible and adaptable organisations, though fragile and vulnerable to sudden, extreme shifts in market conditions.

Australia’s primes are typically very large companies (by local standards) employing several thousands of people and are now without exception wholly owned subsidiaries of European, British or American high technology aerospace and defence prime contractors such as Thales, Saab Systems, BAE Systems, Raytheon and Boeing. These are more bureaucratic and have formal management structures and hierarchies which mirror those of their overseas parents, and of the large chemical companies studied in Project SAPPHO.

There is one important difference, however: in Australia's defence industry much of the product innovation, including innovations which could be described as 'disruptive', emerge from the small, creative, high-technology companies making up the SME sector. New product developments, including disruptive innovations, from within the ranks of the primes are relatively rare, given their size.

A Wider Literature Review

A review of the literature shows broad agreement with the findings of Project SAPPHO across many studies, albeit using different measures and approaches to different research questions. Importantly, however, few studies have attempted to emulate Project SAPPHO and compare successes and failures in order to identify the discriminating factors.

The literature highlights important variations in the impact of specific factors on commercialisation success arising from contextual differences such as industry sectors, geographical location and whether or not the market is an essentially high- or low-technology one.

Henard and Szymanki (Henard and Szymanski 2001) conducted a meta-analysis of the literature on new product performance and successful innovation. Their review identified at least 60 empirical studies (including Project SAPPHO) documenting the statistical relationship between new product performance (or innovation success) and its proposed antecedents. The authors investigated the 24 most frequently occurring predictors of new product performance identified in these studies. In order to classify them efficiently the authors adopted a taxonomy which defined these predictors and grouped them into four separate categories: Product Characteristics; Company Strategy Characteristics; Company Process Characteristics; and Marketplace Characteristics.

Product Characteristics include price, innovativeness and perceptions of how well the offering meets customers needs; Strategy Characteristics refer to a firm's ability, through planned actions, to create for itself a competitive advantage in the marketplace; Process Characteristics refer specifically to the elements associated with the new product development process and its execution; Marketplace Characteristics describe the target market and its features.

From this list of 24 predictors, Henard and Szymanski identified the 11 most dominant drivers of product success. These are listed below in descending order of importance, along with their category:

1. Market potential (Marketplace) – anticipated growth in customers or customer demand in the marketplace
2. Dedicated manpower (Strategy) – commitment of personnel resources to a new product initiative
3. Marketing task proficiency (Process) – proficiency with which a firm conducts its marketing activities
4. Product meets customer needs (Product) – extent to which the product is perceived as satisfying the customer's desires/needs

5. Product advantage (Product) – superiority and/or differentiation of the product over competitive offerings
6. Pre-development task proficiency (Process) – proficiency with which a firm executes pre-launch activities: idea generation/screening, market research, financial analysis
7. Dedicated R&D resources (Strategy) – focussed commitment of R&D resources to a new product initiative
8. Technological proficiency (Process) – proficiency of a firm's use of technology in a new product initiative
9. Launch proficiency (Process) – proficiency with which a firm launches the product/service
10. Order of entry (Strategy) – timing of marketplace entry with a product/service
11. Technological sophistication of the product (Product) – perceived technological sophistication of the product (eg high-tech versus low-tech)

The others are also important, though their associations with successful innovation are less frequent in the literature examined by Henard and Szymanski :

- Product price (Product) – perceived value for money
- Product innovativeness (Product) – perceived newness/originality/radicalness of the product
- Marketing synergy (Strategy) – congruency between the firm's existing marketing skills and those required to execute a successful new product launch
- Technological synergy (Strategy) – congruency between the existing technological skills of the firm and those needed to execute a new product initiative successfully
- Structured approach (Process) – employment of formalised product development procedures
- Reduced cycle time (Process) – speed to market – i.e.: reduction in the concept-to-introduction time line
- Market orientation (Process) – degree of firm orientation to its internal, competitor and customer environments
- Customer input (Process) – incorporation of customer specifications into a new product initiative
- Cross-functional integration (Process) – degree of multiple-department participation in a new product initiative
- Cross-functional communication (Process) – level of communication between departments in a new product initiative
- Senior management support (Process) – degree of senior management support for a new product initiative
- Likelihood of competitive response (Market) – likelihood and degree of competitive response to a new product initiative
- Competitive response intensity (Market) – degree, intensity or level of competitive response to a new product introduction (also referred to in the literature as market turbulence)

Of that Top 11 predictors, it will be seen that the most numerous fall into the Process Characteristics category; three fall into each of the Strategy Characteristics and Product Characteristics categories; and only one falls into the Marketplace Characteristics category. Overall, 11 predictors fall into Process category; five each fall into the Strategy and Product categories, and three fall into the Marketplace category.

This reinforces the suggestion noted earlier that, other things being equal, the firm or company's internal processes play a significant role in determining new product and commercialisation outcomes. Henard and Szymanski state these encompass department interactions, the firm's various proficiencies, management support, marketplace orientation, development, marketing and the launch of new products. In other words, the research points largely to factors within the direct control of the company's management.

This in turn suggests that their findings, if applied appropriately to a commercialisation model of the type described earlier, would provide a predictive capability these models currently lack. Taking into account factors such as the type and location of the market, the type of technology involved, the level of competition, and so on, it might be possible to predict the levels of risk and reward associated with a proposed product innovation, and decide whether or not the project is worth pursuing. This would be a helpful tool at the idea/product screening stage. Or seen from another angle, it may make it easier for commercialisation organisations (for example at universities and research institutes) to identify and broker better matches between specific product development opportunities and companies, and so increase the likelihood of commercialisation success.

Henard and Szymanki have aggregated results across 60 separate studies; some of these studies, and others they did not include in their research for various reasons, draw out lessons and insights relating to specific circumstances or sets of conditions and are worth examining in more detail.

One of the studies they examined was conducted by Montoya-Weiss and Calantone in 1994 (Montoya-Weiss and Calantone 1994). This too was a review of the literature on new product performance, examining 47 studies and noting their functional perspective: R&D, Management, Marketing and others ('Varied'). They noted that the range of factors studied by researchers is actually quite narrow, and yet some of them have not been included in studies as often as one might expect. They identified 18 factors from the literature which have an impact on new product performance, but note that no single study has examined them all; they call, in future research, for broader-based studies that include all of these 18 factors, along with multiple factors from diverse categories, in order to jointly assess their impact on performance.

The 18 factors identified by Montoya-Weiss and Calantone echo quite faithfully the 24 identified by Henard and Szymanski, and underline the importance of the firm or company's organisational characteristics, skills and internal processes. These factors are also grouped in four distinct categories; Strategic Factors, Market Environment Factors, Development Process Factors and Organisation Factors. The 18 Factors and their categories are, in no particular order:

1. Product advantage (Strategic) – customer's perception of product quality, function and value for money compared with competitors
2. Marketing synergy (Strategic) – fit between company's marketing and sales resources and skills and the project's needs
3. Technological synergy (Strategic) – fit between project's needs and company's R&D and technology skills and resources
4. Strategy (Strategic) – strategic impetus
5. Company resources (Strategic) – compatibility of company resource base with needs of the project: capital, manufacturing facilities, manpower
6. Market potential (Market Environment) –market (and demand) size and growth
7. Market competitiveness (Market Environment) – intensity of competition within the market
8. Environment (Market Environment) – business environment, including risk and regulation
9. Protocol (Development Process) – firm's knowledge and understanding of marketing and technical aspects prior to project start
10. Proficiency of predevelopment activities (Development Process) – idea screening, market and technical assessment, financial analysis
11. Proficiency of market-related activities (Development Process) – market research, customer testing, advertising and launch
12. Proficiency of technological activities (Development Process) – prototyping, testing, trial production
13. Top management support, control and skills (Development Process) – management commitment and day to day involvement; key individuals
14. Speed to market (Development Process) – speed of development, timing of launch, first or second to market effects
15. Costs (Development Process) – project development costs, including R&D, production and overruns
16. Financial/business analysis (Development Process) – proficiency of these during development and prior to launch, including go/no-go measures
17. Internal/external communications (Organisation) – coordination and cooperation internally and between partners
18. Organisational factors (Organisation) – structure of new product team

It will be noted that eight of these factors relate to the Development Process category; five to the Strategic category; three to the Market Environment; and just two to the Organisation. Again, this reinforces the suggestion that a company's internal processes play a major, if not decisive, role in determining project outcomes.

In a discussion of the limitations of innovation studies prior to 1977, Rothwell (Rothwell 1977) notes that most of the factors considered in the majority of research have dealt with project execution variables and have explained success or failure in those terms. But attributing failure to 'poor or incomplete development work' fails to distinguish between incompetence and lack of resources; if the latter is the underlying cause, then the project shouldn't have been attempted in the first place and so the real cause of failure is the inappropriate choice of project – putting the emphasis firmly on idea or project screening at the very start of the process. As a corollary to this Rothwell points to the need for robust project termination criteria so that flawed projects which 'leak' through the screening process get terminated before they cost the firm too much time and money.

He also notes the absence in much research of the study of exogenous factors such as government policy or legislation – this is a critical factor in the defence industry, but most innovation studies focus instead on endogenous factors such as project execution, product development strategies and the attributes and capabilities of innovating firms.

Rothwell also points out that many studies focus exclusively on major, or radical, innovations – essentially the development of all-new products – and ignore incremental or minor innovations. He suggests more research is needed to establish whether, in some industries minor innovations are as cumulatively important in their effect as the occasional major breakthrough; and he hypothesises that the circumstances surrounding the generation of successful minor innovations are significantly different from those surrounding the generation of major innovations.

This echoes the point made earlier about the utility of commercialisation models which focus on new ventures based upon new IP, and of Johne and Snelson's research cited below. But the meta-analyses by Montoya-Weiss & Calantone, and by Henard & Szymanski, cited above, do not show that recent research has addressed many of the omissions noted by Rothwell in 1977.

Johne and Snelson (Johne and Snelson 1990) examined product development strategies, leadership and management structures and styles, and team skills in a comparison of 40 successful and unsuccessful product innovators in the United Kingdom and the United States across four manufacturing industry sectors: chemicals, food, mechanical engineering, and electrical and electronic engineering. Twenty companies from each country which operate in the same market sector were paired and compared using the McKinsey 7Ss framework for efficiency factors developed by Peters and Waterman of the management consultancy McKinsey &Company (Peters and waterman 1982).

The 7Ss are: Strategy, Structure and Systems (the so-called 'hard elements') and Shared Values, Skills, Style and Staff, the so-called 'soft elements'. Johne and Snelson summarised the characteristics of successful and unsuccessful product innovators – importantly, they differentiate between the development of new products and the enhancement and upgrading of old products: these require different management styles and oversight of resources, but these different approaches can be accommodated successfully within a single organisation.

While this study doesn't explicitly address the issue of customer knowledge and marketing, like Project SAPPHO it does find an association between the seniority and autonomy of key project personnel (the term 'intrapreneur' is used here) and sound internal processes, on the one hand, and a successful innovation on the other. Successful innovators have good internal and external communications and are organised to harness and exploit in-house R&D and absorb external IP; unsuccessful innovators are poor communicators in general, invest rather less in R&D and are not organised to harness and exploit in-house or external R&D; they tend to rely, in the main, on growth by acquisition, including the acquisition (rather than in-house development) of new product lines.

The critical issue of customer knowledge, of understanding the customer's needs and the dynamics of the marketplace in which a firm is operating, was addressed by Slater and Mohr (Slater and Mohr 2006). They identify three corporate archetypes: Prospectors, who seek to locate and exploit new product and market opportunities; Defenders, who attempt to seal off a portion of the total market to create a stable set of products and customers; and Analyzers, who try to combine these two outlooks by maintaining a stable set of customers and products while cautiously following Prospectors into newly-established markets.

On the customer side of the transaction, Slater and Mohr identify two types of market: Early Market and Mainstream Market; and within these categories, five types of customer. In the Early Market category are found Innovators – essentially technology enthusiasts motivated by the idea of being a change agent in their reference group – and Early Adopters who seek to harness innovation to achieve revolutionary improvements.

In the Mainstream Market are found the so-called Early Majority, pragmatists motivated by the revolutionary change they observe to pursue productivity enhancements and who seek relatively low-risk, proven, reliable solutions. These are probably the most numerous. Also in this category are Late Majority customers – conservative, risk-averse, price sensitive and technology-shy. The fifth customer type is the Laggard, a sceptic resistant to change, sceptical of claims that innovation can enhance productivity and deliver real benefits.

Slater and Mohr point out that customers often are unable accurately to articulate their needs and they set out a portfolio of research tools for innovators in high-technology markets who seek deep and detailed customer knowledge. These are designed to bridge the gap between what customers say and how they actually behave and include customer visits, empathic design, the lead-user process, research on customers' customers and he targeting of developing markets.

The Slater and Mohr taxonomy maps well onto defence department and defence force customers: in some areas the Australian Defence Force is an Early Adopter, being forced to depend upon technology to offset its small size and massive geographical responsibilities (eg the JORN radar system); more frequently is described as a risk-averse organisation and is therefore often characterised as an Early Majority customer. The New Zealand Defence Force, having considerably fewer resources than its Australian counterpart and a very strong aversion to cost and schedule risk, can be characterised as a Late Majority customer.

Their research also identifies archetypes recognisable within the ranks of the defence industry: in particular, they reinforce other research showing that firms able to develop truly disruptive innovations have a customer orientation focused on emerging customer requirements, rather than on mainstream customer needs. In fact, a company orientation that focuses too closely on mainstream customer needs inhibits the development of disruptive innovations. However, they point out, a single company can exhibit both orientations simultaneously, a conclusion which resonates with the findings of Johne and Snelson in relation to successful development of new products while simultaneously upgrading and enhancing existing products.

This is an issue which must be considered when setting criteria for a product screening process: too conservative a filter can result in low-risk, low-reward projects, while too liberal a filter can expose the firm to unnecessary risks.

In Project NewProd, cited earlier, Cooper (Cooper 1980) examined 195 new product cases, half of them successes, the others judged to be failures. He measured 77 variables which fell into six categories, three of them being controllable for a given project – The Commercial Entity; Information Acquired; and Proficiency of Process Activities – and three which were described as 'environmental', or non-controllable: nature of the Marketplace; Resource Base of the Firm; Nature of the Project.

His analysis identified 15 specific properties of a project which distinguished successes from failures. In descending order of importance these were:

1. Proficiently executing the launch – sales, promotion, distribution
2. A new product that better meets customers' needs than its competitors
3. A higher quality new product than competitors (quality, durability, reliability, etc)
4. Undertaking a good prototype test with the customer
5. Sales force and distribution well targeted on the right customers
6. Undertaking a proficient test marking campaign
7. Proficient ramp-up to full-scale production
8. Knowledge of customers' price sensitivities
9. Proficient execution of product development
10. Understanding buyer behaviour and customer purchase decision process
11. Product permits customer to reduce his own costs
12. Good company-product fit in sales/distribution
13. Good company-product fit in marketing skills
14. Good idea screening
15. Understanding customers' needs, wants and specifications

It could be argued that number is 15 redundant, and that this detailed customer knowledge is implicit in Properties 2, 4, 5, 6, 8 and 10. Nevertheless, most of these factors could be described as 'controllable' in Cooper's terms, rather than environmental.

Cooper also re-organised the data from the 77 variables to identify 18 Dimensions (also termed Underlying Factors) that characterise new product projects. When product outcomes were related to these 18 dimensions, 11 were immediately identifiable as determinants of product success, nine of them quite strongly. Of these the three dominant dimensions were product uniqueness and superiority; market knowledge and marketing proficiency; and technical and production synergy and proficiency, in that order.

Cooper found that the projects which scored highest in these three areas exhibited a 90 per cent success rate. Conversely, of the projects which scored lowest in these three areas, only 7 per cent were successful. However, Cooper made an important discovery: Product remains the critical variable. Even projects lacking both marketing and technical prowess achieved a 62 per cent success rate when they were based on what was classified as a unique superior product.

More generally, says Cooper, Project NewProd showed that project success or failure were most directly impacted by controllable variables, while environmental variables had a relatively lower impact.

The importance to project success of controllable variables was also a conclusion of Tishler, Dvir and others from their multi-variate analysis of critical success factors in developmental defence projects (Tishler, Dvir et al. 1996). By definition, such projects are inherently risky and involve either the integration of existing and new products in a new way, for a new application, or the development of all-new products – and sometimes a combination of both.

Based on their analysis of 110 Israeli defence projects, the authors identified eight factors bearing heavily on the success of a development defence project. In descending order of importance these are: a sense of urgency - the more urgent the need, the greater the chance of success; the professional qualifications, sense of responsibility for project outcome and continuity of personnel appointments within the customer ‘team’; pre-project preparation, including proving technological feasibility and establishing the correct project structure; quality of the project development team, and of its leader; organisation culture within the project team, encouraging professional growth; design policy of the developing organisation - a clear policy on decision-making procedures and communications; design considerations in the early phases of the project – design to cost, reliability, ‘produceability’; and systematic use of schedule, budget and performance management tools.

Success and failure are also determined in part by the product innovation strategy selected by a firm, Cooper found in a separate study (Cooper 1984); his findings largely echo those of other studies cited in this paper, including his own. He studied the new product strategies of 122 firms in Canada, characterising these strategies on each of 66 strategy elements which in turn fitted into four categories: Nature of the products developed; Nature of markets sought; Nature of technology employed; Orientation and nature of the new product process.

Cooper identified five separate new product strategy types:

- Strategy A: The Technologically Driven Strategy (26.2 per cent of firms) – innovative, high-technology, high-risk new products which don’t ‘fit’ the developing company's existing product lines and have no relation to each other. Firms lack market orientation.

- Strategy B: The Balanced Strategy (15.6 per cent of firms) – similar high-technology product focus as Type A companies, but much stronger market orientation and product fit.
- Strategy C: The Technologically Deficient Strategy (15.6 per cent of firms) – total lack of technological sophistication, very low production and technological synergies, but strong market orientation
- Strategy D: The Low-Budget, Conservative Strategy (23.8 per cent of firms) – lowest R&D spending of all companies surveyed, products enjoy least differential advantage, but highest technological and production synergies of all firms surveyed
- Strategy E: The High Budget, Diverse Strategy (18.9 per cent of firms) – highest R&D spend (as a proportion of sales), but highly unfocused new product program – focus on radically new markets and new products; high risk, highly competitive sectors offering high rewards.

Perhaps unsurprisingly, the companies that performed best in this survey were those that adopted Strategy B: The Balanced Strategy – they had the highest success rate (72 per cent), the highest proportion of sales income derived from new products (47 per cent), and were equal-highest in terms of profitability. Strategy D was rated second, then A, C and E, in that order.

Cooper rates the Strategies thus: "B: Top performers; best on every performance gauge. D: Good success rate, low impact program. A: High impact; low success rates; poor profitability. C: Very poor results. E: Very poor results."

The strategies and orientations of firms were examined also by Paladino (Paladino 2007) who compared the performance of firms pursuing either a Market Orientation-based strategy or a Resource Orientation-based strategy. Resource Oriented firms can be likened to Defenders in the Slater & Mohr taxonomy, while Market Oriented firms can be likened to Prospectors.

Paladino suggests that Resource Orientation enhances firm performance by improving internal effectiveness and efficiency to achieve new product success, while the Market Oriented firm improves performance by enhancing customer value. This in turn suggests that managers seeking new product success should focus less on customer value and more on resource value, while those pursuing customer value should focus on market orientation.

This would seem to imply that Market versus Resource Orientation is an either/or proposition. But the research cited earlier suggests this is not the case and that successful innovators display signs of both types of orientation: they must be sensitive to market needs and also have efficient internal processes and a robust internal resources base. The fact remains, however, that most firms do have a dominant culture that tends towards one or other of these orientations, and Paladino suggests that Market Oriented firms may be better suited to service industries, in which customer-provider relationships are relatively more important than in capital equipment manufacturing industries, for example. By contrast, Resource Oriented firms would seem to be better suited to high-technology, high-quality manufacturing.

While she cautions that more research is necessary, Paladino's conclusions may have interesting implications for Australia's defence industry which derives the majority of its revenue from providing services rather than manufacturing new equipment. Many of Australia's prime contractors combine design and manufacture with service offerings, while smaller companies tend to be either specifically a service provider or a manufacturer.

Structural issues: the National Innovation System

At a higher level altogether Cornford (Cornford 2006), argues there are four main drivers of a country's innovative capacity: publicly-funded R&D, privately-funded R&D, availability of what he terms Highly Qualified Personnel (HQP) and access to risk capital. Based on research in Canada, Cornford argues the interaction between these factors results in a number of critical relationships: the ratio of investment in publicly funded R&D to that in developing HQP; the relationship of investment in privately funded R&D to that in developing HQP; the ratio of HQP to the total workforce; the ratio between investment in publicly and privately funded R&D; and the overall relationships between these factors.

To achieve optimal results, Cornford argues, the following key relationships must exist:

- Ratio of Privately funded R&D to publicly funded R&D must be greater than 3:1
- The ratio of HQP to the total workforce must exceed10:1,000
- The ratio of privately funded R&D to investment in developing HQP must exceed 3:2

When these relationships are in the right balance, he concludes, there are two important results: a product opportunity emerges for each $2 million of R&D spending; and for every four product opportunities, a venture investment occurs.

While these observations are based on research in Canada, the association between these relationships and commercialisation success suggests a predictive capability if they are overlaid on an existing commercialisation model. How far they can be applied specifically to defence-related R&D, and particularly to the Australian environment, remains to be established.

More research is required to identify other intrinsic factors that could add to the predictive capabilities of commercialisation models, both in themselves and when applied to commercialisation of defence-related R&D.

Discussion and future research

The general conclusion from the research cited here is that the success of commercialisation or new product development programs is determined by a number of factors: firstly, the careful selection of commercialisation or product innovation opportunities, via an appropriate screening process which takes into account technological, business and market synergies; secondly, the market orientation and knowledge of the innovator or entrepreneur undertaking the project; and thirdly, the proficiency with which he undertakes the development and launch process.

There is a divergence between the models described earlier in this paper and the research examined later on. Almost all of the models describe a process that's relatively rare within the defence industry: the development of a new piece of IP by a research organisation such as a university or publicly-funded research establishment, and its transfer and subsequent commercialisation by a start-up company.

Much more common is the process described and examined in much of the research cited above: the incremental development by existing companies of new products or services based on enhancements of existing ones. Some sources identify the variations in the processes required for new product development and incremental product development and much of the research sets out to identify inherent attributes of the firms involved which are determinants of new product or commercialisation success in different types of market.

It seems a reasonable hypothesis that this research could be applied to some of the commercialisation models discussed earlier. Where these models seek to set out a roadmap for a new venture based on a new piece of IP, the predictive value of the research examined here could help shape these new ventures according to the types of technology and market involved and the sorts of new product development strategies firms should follow.

However, in the Australian context and the commercialisation of defence-related IP by Australia's defence industry, the vast majority of effort is expended by existing companies, either developing new products from original IP or enhancing existing products. Therefore this research could also be applied usefully to existing commercialisation models in order to adapt them to this paradigm.

Many of the studies cited here focus on a process downstream from the original research, whether this was carried out in-house or by a research partner or provider. They do not link marketing efforts and essential customer knowledge with R&D, and they don't address explicitly the difficulties for innovators of taking a new product (or a new venture) across the commercialisation chasm described by Smith in the AIC's Commercialisation Progression Model – this is also frequently referred to as the 'Valley of Death'. In some cases established companies are able to fund new product developments internally, or through access to loans or other regular sources of finance; but many high-technology companies, especially SMEs, rely on external funding from venture capitalists, other investors or government grants to get them across the Valley of Death, even when undertaking an incremental innovation project.

Sources of finance naturally seek assurances of different types from and about the firms they lend to or invest in; the predictive value of this research may help in the identification of solid prospects and, indeed, may help companies make necessary changes to improve their chances of success and, therefore, their attractiveness to lenders and investors.

The issue of R&D needs to be addressed in more detail. Defence is a technology-driven sector and firms seeking to sell to defence forces or into the supply chains of major primes must either carry out their own R&D or develop a close relationship with an R&D organisation, a relationship informed by the firm's own knowledge of the customer and the marketplace.

Given the essentially high-technology nature of modern warfare and defence equipment it seems reasonable to postulate that models and processes developed to assist and guide the commercialisation of IP in the commercial ICT industry can be adapted to serve the high-technology elements of the defence industry. While fusion of different types of model may be problematic, it should be possible to develop a Predictive Model incorporating many of the features of the models described above as well as findings from the research cited in this literature review.

The model will be modified and refined based upon the results of the defence industry survey and case studies proposed as part of the author's research. The survey, in turn, will be shaped by examination of the models and research described above in order to establish whether they are considered important also by members of Australia's defence community.

The current draft of the survey questionnaire will be modified to address key issues identified in this literature review. Among other things, the questionnaire will address:

- Firms' R&D spending
- Firms' access to, and embrace of, IP generated externally
- Firms' access to commercialisation funding either internally or from external sources
- Firms' orientation – Market or Resource?
- Firms' product innovation strategies (A, B, C, D or E?)
- Firms' investment in their market knowledge and marketing skills
- Firms' investment in their technical and production skills
- Firms' powers of communications, both internally and externally
- Firms' perceptions of government policy, including defence industry policy and support for R&D and innovation more generally

The case studies will examine a range of failed and successful commercialisation projects and assess a number of key factors, including:

- Uniqueness of the product
- Quality of the product
- Price of the product

- Product match with user needs
- Company-product fit
- Nature of the market – size, level of competition
- Time to market
- Timing of market entry
- Marketing effort
- R&D efficiency
- Production efficiency
- Launch proficiency
- Size of the firm
- Personnel resources devoted to new project, including specialisations (technical, marketing, communications, sales, etc)
- Effects of government policy
- Access to development funding

It is hoped the Survey and Case Studies will be finished by the end of 2009, enabling this research to be completed by the end of 2010.

ENDS

REFERENCES:

Achilladelis, B., A. Robertson, et al. (1971). Project SAPPHO: A study of Success and Failure in Industrial Innovation. London, Centre for the Study of Industrial Innovation.

Andrew, J. and A. Sirkin (2007). Payback: Reaping the Rewards of Innovation. Boston, Harvard Business School Press.

Carnegie Mellon University (2002). "Innovation Exchange, a new Collaborative Model for Tech Transfer." Carnegie Mellon News **9**(8).

Cooper, R. G. (1980). "Project NewProd: Factors in New Product Success." European Journal of Marketing **14**(5/6): 277-292.

Cooper, R. G. (1984). "The Performance Impact of Product Innovation Strategies." European Journal of Marketing **18**(5): 5-53.

Cornford, A. (2006). Finding the Balance in Innovation and Commercialisation. Policy Research - Innovation. R. G. Lipsey. Ottawa, Atlantic Canada Opportunities Agency.

Ferguson, G. M. (2006). Commercialising Defence R&D - Why, and Why Not? Association of Old Crows Symposium 2006. Adelaide.

Gaul, D. J. (2005). Pathways to Technical Inovation: Submission to the House of Representatives Standing Committee on Science and Innovation. Canberra, CEA technologies Pty Limited.

Goldsmith, H. R. (1995). A Model for Technology Commercialization. Mid-Continent Regional Technology Transfer Centre Affilliate's Conference. NASA Johnson Space Centre, Houston.

Goldsmith, H. R. (2003). "Commercialization – the process of turning innovations into enterprises." American Venture Magazine.

Henard, D. H. and D. M. Szymanski (2001). "Why Some New products Are More Successful Than Others." Journal of Marketing Research **38**(3): 362-375.

Industry Canada (2006). People and Excellence: the Heart of Successful Commercialization - Volume II, Supporting Material. People and Excellence: The Heart of Successful Commercialization. Ottawa, Industry Canada.

Johne, A. and P. Snelson (1990). "Successful Product Innovation in UK and US Firms." European Journal of Marketing **24**(12): 7-21.

Kleinschmidt, E. J. and R. G. Cooper (1988). "The Performance Impact of an International Orientation on Product Innovation." European Journal of Marketing **22**(10).

Lux, D. and M. Rorke (1999). From Invention to Innovation, Office of Energy Efficiency and Renewable Energy, US Department of Energy.

Montoya-Weiss, M. M. and R. Calantone (1994). "Determinants of New Product Performance: A Review and Meta-Analysis." Journal of Product Innovation Management **11**: 397-417.

Paladino, A. (2007). "Investigating the Drivers of Innovation and new product Success: A Comparison of Strategic Orientations." The Journal of Product Innovation Management **24**: 534-553.

Peters, T. and R. waterman (1982). In Search of Excellence. New York, Harper & Rowe.

Rosa, J. and A. Rose (2007). Report on Interviews on the Commercialisation of Innovation. Ottawa, Science, innovation and Electronic Information Division, Statistics Canada**:** 10-14.

Rothwell, R. (1977). "The characteristics of successful innovators and technically progressive firms (with some comments on innovation research)." R&D Management **7**(3): 191-206.

Rothwell, R., C. Freeman, et al. (1974). "SAPPHO updated - project SAPPHO phase II." Research Policy **3**: 258-291.

Rothwell, R. and W. Zegfeld (1985). Reindustrialization and Technology. London, Longmans.

Slater, S. F. and J. J. Mohr (2006). "Successful Development and Commercialization of Technological Innovation: Insights Based on Strategy Type." Journal of Product Innovation Management **23**: 26-33.

Smith, G. (2002). Commercialisation Progression Model. Brisbane, Australian Institute for Commercialisation**:** 1.

Sohn, S. Y. and T. H. Moon (2003). "Structural equation model for predicting technology commercialization success index (TCSI)." Technological Forecasting and Social Change(70 (2003)): 885-899.

Sohn, S. Y. and T. H. Moon (2004). "Decision Tree based on data envelopment analysis for effective technology commercialization." Expert Systems With Applications(26 (2004)): 279-284.

Tishler, A., D. Dvir, et al. (1996). "Identifying Critical Success Factors in Defense Development Projects: A Multivariate Analysis." Technological Forecasting and Social Change (51 (1996)): 151-171.

Trenberth, R. J. (2004). Review of DSTO's External Engagement and Contribution to Australia's Wealth. Canberra, DSTO.

UKMoD (2007). Maximising Defence Capability Through R&D - A review of defence research and development, UK Ministry of Defence.

UniQuest. (2008). "Commercialising Your Research." Retrieved 17 March, 2008, from http://www.uniquest.com.au/index.php?sectionID=106.