ROYAL AUSTRALIAN AIR FORCE
AIR POWER DEVELOPMENT CENTRE

Working Paper
07

Towards Managing Uncertainty:
Coupling Experimentation with Rapid Prototyping

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The global security environment is more confusing, unpredictable and complex than ever. The number, scale, power and diversity of states and non state actors impacting global international relations is unparalleled in history. With an unprecedented number of participants in the global system, many with conflicting goals, predicting the international environment more than a short time into the future is becoming increasingly impractical and difficult. The steadily escalating complexity of contemporary human society is making uncertainty a fundamental characteristic. The path to tomorrow is now so non-linear and chaotic, with so many possible bifurcations, as to make accurate predictions impossible.[1]

Defence forces, and air forces in particular, are complex organisations that take a substantial time and resources to develop, equip and deploy. If the future is uncertain, there is a strong likelihood that a costly defence force may be devised and fielded, which is of marginal value in the strategic and operational circumstances that actually occur. An accepted methodology to manage an indeterminate future environment is to develop a high level of flexibility. This is not the flexibility engendered by tactical level standard operating procedures and common training, but rather dynamic flexibility at the strategic level.

The aim of such strategic level flexibility if applied to the RAAF would be to ensure that the air force is better able to offer Government practical and timely solutions to emerging international relations crises and problems. An air force needs to be able to react and field solutions faster than the challenges emerge to offer some prospect of deterrence, and to be ready for operations should this prove necessary. This is not easy to achieve, as air forces by their nature are technology based and capital-intensive, with long lead times to develop. However, if an air force is not sufficiently flexible, there is a real danger of it becoming a boutique organisation rarely suitable, or equipped, for the real conditions experienced. An air force inadequately flexible risks being at best irrelevant in a future conflict, and at worst being a wasteful expenditure of scarce defence resources.

This paper proposes a system of aerospace force experimentation tightly coupled with rapid prototyping as a coping strategy to manage uncertainty, at least partially, by developing flexibility as a major attribute. If the future is ultimately unknowable, then an air force has to have developed an inbuilt capacity to rapidly evolve and change in order to stay relevant and useful to the community it serves. This suggested strategy is deliberately and intentionally built around the shrewd use of technology. Air forces are obviously more than technology although without technology they are not Air forces. If technology lies at the heart of the suggested strategy, it is because technology lies at the heart of air forces.[2] In making an effective air force, an optimal blend of technology, people, intellect and knowledge is needed; no single factor is sufficient in and of itself.

There is no program or group in Defence at present that performs the strategy envisaged, although the Concept Technology Demonstrator (CTD) program, the emerging experimentation program and the Defence Science and Technology Organisation (DSTO) all have elements that could complement such a strategy. The CTD program aims to develop Australian technology to a level that makes this technology competitive for possible major project acquisition at some future time.[3] DSTO principally aims to provide scientific advice to the ADF although, as part of further developing organisational expertise and competence DSTO undertakes limited, specific research and development (R&D) work. The emerging experimentation program aims to support key decision makers in the development of key planning documents such as white papers, annual strategic reviews and the Defence Capability Planning Guidance.[4] None of these approaches are intended to address the issue of improving the strategic level flexibility of the ADF or the air force. The three approaches all have a definite and necessary mission and focus, but they do not address the issue of uncertainty through developing strategic flexibility by using rapid prototyping-based experimentation.

A CONTINUOUS INNOVATION STRATEGY

Almost all organisations are inherently flexible in that they possess the ability to change. However, flexibility has dimensions in terms of how far and how easily an organisation can change.[5] Relying on institutional flexibility as a technique to meet the challenges of an uncertain environment introduces a time, content or context element. An organisation needs to have created enough dynamic strategic flexibility to be able to develop quickly enough to meet any unforeseen circumstances. Warning times are decreasing, and thus the time available to adapt an extant force structure is lessening. There is an inherent disconnect between traditional acquisition methods that take several years to deliver when crises can emerge in a much shorter timeframes.

Conceptually, there are two broad types of flexibility. Type I (Static) flexibility is concerned with processes for dealing with foreseeable events and is well established in military and civil aviation. However, Type II (Dynamic) flexibility relates to the capacity to react to an unpredictable environment or technological changes and it is this type that needs to be developed and applied[6]. Further delineation as strategic flexibility is useful as this represents the 'capability which aids repositioning when conditions change[7].' Strategic flexibility relates to how an organisation positions itself with respect to future challenges and opportunities.[8] Dynamic, strategic flexibility is a characteristic necessary to make an Air Force less vulnerable and to take advantage of unforeseen change.[9]

The proposed strategy for creating sufficient strategic, dynamic flexibility involves developing and trialing cutting edge, novel, operational prototypes in a manner that allows the organisation to become innovative, creative and inherently adaptable. The strategy envisages investing in the development of many different new technology systems up to the point that they can be tested, capabilities assessed and acquisition data determined. Production is postponed because circumstances may change making the innovation more or less useful than originally believed. Stephen Rosen writes:

> Large scale procurement is deferred, in short to allow uncertainties to work themselves out. When long-term uncertainties become short-term requirements, decision makers can choose from an array of prototypes the system best suited to the needs of the day. A necessary component of this strategy, therefore, is a capacity for mobilising production from prototypes.[10]

The USAF and USN successfully used this approach in guided missile development in the 1950s when there were great strategic and technological uncertainties.

The application of this hedging approach can have broad cross- organisational impacts. The ripple-down effect throughout the organisation can generate opportunities, methods and alternatives for original and novel force employment and development. A critical part of the strategy is the development of prototypes suitable for testing as USN Admiral Cerbrowski, Director Force Transformation, notes:

> Experimental articles provide military personnel the opportunity to work directly with new physical prototypes while developing new concepts. The key leverage in the

> use of experimental articles is that they help people see the range of possibilities for performing operations in new ways that abstract discourses on innovative ideas cannot. This is crucial if the culture of change is to be widely adopted.[11]

Operators who can experiment with an operational prototype can more easily envisage the potential of the system than if the concept only remains intangible and theoretical. Operators can rapidly extrapolate from the experience gained in employing operational prototypes to devise innovative ways to use the new system or capability. The prototypes provide opportunities to develop and refine new concepts of operation to fully exploit the new capability, to evolve operational requirements as experience and understanding are gained, and to operate militarily useful quantities of prototype systems in realistic military demonstrations, and on that basis, make an assessment of the military utility of the proposed capability.[12] Through careful management, the development of operational prototypes can be used to nudge and push organisations to evolve in desired directions. The butterfly effect underpinning chaos theory can be harnessed to focus the latent energies of an organisation to a point where it can self-organise into new forms. In this manner, operational prototypes can act as change agents that 'pull' organisations into the future whilst, importantly, minimising the natural internal organisational resistance. Small high-leverage actions can be used to trigger major transforming effects and catalyse organisations, and their people, to want to evolve. A 'learning organisaton' can be created that considers continuous evolution a normal and desirable situation.[13] The impetus for change now comes from within organisations, rather than from impersonal external forces, as the staff are now a central part of the experiments with the operational prototypes they have helped developed. Air Forces are inherently complex, non-linear organisational systems and as such the small incremental change of experimenting with operational prototypes can be creatively managed to produce quantum organisational change.[14]

This strategy has important impacts on the time and cost of change. Experimenting with prototypes advances the overall process of introducing new technology into service a considerable distance. However, going only as far as an experimental model costs substantially less than introducing production standard equipment into unit service. These aspects are elaborated later when discussing technology readiness levels. This approach represents a compromise on optimisation between cost and warning time. Basing flexibility on a very short warning time would require a much larger, more diverse and quite costly service force structure. The proposed strategy attempts to reach a workable compromise between these two factors.

The continuous innovation concept uses experiments involving operational prototypes as catalysts for creating the recurrent organisational enhancement needed to handle an unpredictable future. An underlying tenet in this system of innovation should be that a fast 'pull through' into operational use should be feasible if the innovation, when trialed, is proven to be in tune to the real operational needs of the day. By the time an experiment is underway, the equipment developed may suddenly be very useful and could be considered for operational use. Inherently, this could not be for large-scale employment, however history indicates that in operations only a small force element may need to employ innovative, leading edge technology to allow the whole force to succeed.[15] Accordingly, the operational prototype experimentation concept process needs to focus on addressing short and medium term needs.

The existing capability development and acquisition system would remain focused on the longer-term needs, and especially those projects involving major platform acquisition that are complex and have high life cycle costs. Generally major platforms acquired under the existing capability development and acquisition system are multi-purpose. The acquisition time is long reflecting the complex nature of the procurement but the specific circumstances of the day when these platforms are fielded is most likely to be very different from when first envisaged.[16] Ameliorating the adverse impact of this inherent systemic paradox is a major aim of the suggested continuous innovation methodology.

The continuous innovation approach would build onto and around the force structure comprised of the small number of costly multi-purpose platforms. This strategy would create real opportunities to make the multi-purpose platform force structure more useful and employable in extant operational circumstances. These opportunities could include modifying the multi-purpose platforms, complementing them or creating adjunct possibilities as described later.

A PROCESS FRAMEWORK

Like all large organisations, Air Forces are bureaucracies requiring processes to turn ideas into reality; a mental framework for thinking about the problem of implementing continual innovation is needed. The requisite process can be envisaged as concept formulation, technology development, experimentation and lastly an acquisition or termination decision.

Concept Formulation

Historical evidence indicates that a necessary pre-condition for successful military innovation is the existence of a concrete problem offering real advantages to an organisation's effectiveness if solved.[17] It is essential to keep a near to medium term operational focus firmly anchored in the real world needs of the day with a firm and evident link to key strategic fundamentals. The focus on practical utility will ensure that resources are not expended on devising new means of achieving tasks inappropriate to strategic circumstances. Examples of a wrong focus could be Switzerland focusing on anti submarine warfare or Australia on defeating large scale mechanised land force attack.

A utilitarian emphasis though must not impede innovation and imagination. The functions military forces perform may be enduring through history, however the way of undertaking these functions can be completely new and novel. US Secretary of Defense Donald Rumsfield envisages 'transforming' the US armed forces. Innovation should therefore be thought of in terms of effects sought, not be prematurely stifled and straitjacketed into a platform centric methodology. An effects based approach is one of the key future force concepts noted in the ADF's Vision 2020 document.[18] Innovations must be assessed with clear and sensible measures of effectiveness reflecting the effect desired to be imposed on an adversary.[19]

The outcome of this work should be the formulation of a concept that describes the characteristics sought of the operational prototype from strategic, operational and tactical perspectives. This work will also provide a reference for determining 'fitness for purpose' of the equipment developed and trialed. This conceptual work needs to be closely informed by the new possibilities that current and emerging technology can provide. Conversely, technology can be developed down directions that are promising in terms of new force employment concepts. Technology and operational employment notions feed off each other, requiring cross fertilisation to achieve the best outcome.

Technology Development

The intention of the proposed strategy would be to focus on the small, fast to market equipment that is attuned to short timescales and provides the necessary catalyst for organisational innovation. The equipment developed would not be built to full mass production standards, but rather be of a build standard suitable for short-term experimentation purposes; the envisaged short in-service life would permit a correspondingly modest logistic support structure. However, the build standard would need to be sufficiently advanced to retain the option of being put into production in a timely manner if circumstances required. The equipment built would of those new and imaginative ideas and concepts not available elsewhere; this later type of equipment could be acquired for experimentation purposes through leasing,[20] hiring, loaning or collaboration.[21]

Inherent in this approach is the question of whether is it really practical for smaller air forces to build items for experimentation. Aviation has well defined standards and requirements for qualification and certification that can make modifying existing aircraft to accommodate new equipment a difficult, time consuming and expensive process. Moreover, integration of new equipment is becoming progressively more difficult as each new generation of aircraft become increasingly software dependent.

This is a sensible and valid argument. However, the type of prototype equipment envisaged in this concept is not complete manned aircraft as periodically occurs in the US. Australian ambitions would need to be considerably less and focus on lower cost, high payoff activities, possibly in some areas noted below. Inevitability this would mean a strong emphasis on the use of Commercial Off The Shelf (COTS) technology adapted for military purposes. This is now a common approach. The civilian technology base is developing considerably faster than the military one; using COTS leverages off this large-scale commercial investment. The US intelligence agencies, once a focal point for made to order military equipment, now increasingly uses COTS technology for a wide range of tasks. The COTS technology area is fertile ground; in October 2002 the US Defense Department requested COTS based anti-terrorist technology submissions and received some 12,000 proposals.[22]

The particular areas suitable for coupled experimentation and rapid prototyping can be determined using a mutual causality process where complex problems and systems are analysed using a framework of positive and negative feedback loops. While it can be made complex, mutual causality is a useful and easily understood methodology for providing 'systemic wisdom' that readily reveals the high-payoff areas to invest in.[23] Some broadly indicative areas where the concept of coupled experimentation and rapid prototyping may have utility include:

Off-Board Mission Systems. Force 2020 strongly emphasises developing a network enabled force with force elements receiving data and information from off-platform sources.[24] Manned aircraft elements of the force structure may be difficult to modify, but they can receive information generated by off-board systems and sensors. New and novel off-board systems and sensors could be developed that would provide enhanced situational awareness to manned aircraft, or perform off-board functions on command. The sensors and systems could be ground or sea based, or fitted to uninhabited or large aircraft. The whole area of network enabled warfare offers considerable potential for high operational payoff from focussed small investments. A robust experimentation program utilising operational prototypes could contribute significantly in this area.

Ground Support. The time an aircraft spends on the ground is time wasted. As the Israelis demonstrated in the Six Day War, quick combat aircraft rearming and turn round times can be a very significant force multiplier. New concepts and technology that greatly improves sortie generation rates whether for fast jets, maritime patrol or transport aircraft could prove very important for a small air force.

Uninhabited Aerial Vehicles (UAV). As recent air operations in the Balkans, Afghanistan, Yemen and Iraq reveal, UAVs will play important roles in many diverse areas in the future. The top end UAVs such as Global Hawk and the Boeing X-45 are complex air vehicles with correspondingly high development costs. However, much smaller scale simple vehicles, such as Aerosonde, offer low-cost transformational potential, especially when used 'en masse' in a swarm. Being uninhabited, many of the costly manned aircraft qualification and certification processes are unnecessary. Demonstrating UAV potential in many different roles in field experiments would be low cost while providing quite useful residual capabilities.

Operations Other Than War. While not a technology in itself, the area of non warlike operations remains a fertile area for original concepts, building operational prototypes and experimentation. Humanitarian, peacekeeping, disaster relief, and constabulary missions all could make good use of this approach. Enhancing air transport and surveillance/ reconnaissance operations could be particularly useful.

Chemical, Biological and Radiological (CBR) Warfare. While there is no great willingness to accept it, the likelihood of being involved in CBR warfare is steadily increasing. There may be specific CBR warfare domains where small investments in developing innovative operational prototypes may assist in defensive and counter proliferation tasks.

On Board Manned Aircraft. As alluded to, manned aircraft represent the most difficult and capital intensive area for developing operational prototypes. Any prototype equipment developed for a manned aircraft would need to be form, fit and function compatible to ameliorate integration issues. Examples could be new electronic components or items like the ALR 2002 Radar Warning Receiver. Equipment could also be carried in an external store although, aircraft carriage and integration aspects are still significant and would need careful thought. Regardless of this, in some circumstances, it may be cheaper to modify a manned aircraft to trial a concept than adopt another approach such as building an Uninhabited Combat Aerial Vehicle (UCAV).

Australian Technology. The proposed strategy offers an opportunity for 'pulling through' some Australian technology into use. There could be some important operational advantages in having selected niche items that are unique and that no one has developed technological, doctrinal or tactical counters for. Australia has a good commercial R&D base, although there are well recognised problems in transitioning to mass production. The quality of Australian researchers can be ascertained from the Inventiveness Coefficient that measures Patent Application per 10,000 people. Applying this measure, Australia is perhaps surprisingly in fifth place amongst

OECD nations, scoring 4.2 just behind the US in fourth place at 4.5.[25] USN Admiral Cerbrowski gives an indication of the potential of experimentation using Australian developed equipment:

> When one introduces an operational prototype, when you put something in the hands of people … that can indeed be very, very powerful. And there are several examples of doing that. We have one of those going on right now with the lease of a high-speed transport ship for experimentation with the Army, the Navy, the Coast Guard and the Special Operations Forces. You also have the Marine Corps experimenting with one out in the Pacific. And already, although these ships have been in the hands of the operators for only a matter of weeks, already you can tell that minds are racing and ideas are coming forward.[26]

The high speed ships referred to are Australian COTS products. Inherently, there is nothing preventing Australian companies and organisations from developing transformational technologies for experimentation by the Air Force.

Technology Readiness Levels. In any program seeking rapid prototyping there needs to be an understanding of the technology developmental steps. Using the US Technology Readiness Level (TRL) framework an appreciation of the maturity of the different types of technology can be gained. TRLs are a systematic metric/measurement system used initially by NASA[27] and adopted by several other organisations to address integrated technology planning.[28] The following matrix lists the various technology readiness levels and provides a description of each.[29]

Technology Readiness Level [30]	Description
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
3.5 Predict the functionality, performance, and cost.[31]	Us as input to a decision to pursue serious technology development.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively 'low fidelity' compared to the eventual system. Examples include integration of 'ad hoc' hardware in a laboratory.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in simulated environment. Examples include high fidelity laboratory integration of components.

6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond the breadboard tested for level 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from level 6, requiring the demonstration of an actual system prototype in an operational environment. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this level represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
8.5 Production/deployment[32]	
9. Actual system proven through successful mission operations.	Actual applicaton of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Table 1. Technology Readiness Levels

The goal would be to build equipment for experimentation to about TRL 6, as this is the point at which a representative model or prototype system would be available for testing in a relevant environment. Beyond TRL 6 the cost curve rises sharply as the equipment develops into a mass production item.[33] The demonstration undertaken might represent an actual system application, or be only indicative of the planned application but using the same technologies. At this level, several-to-many new technologies might be integrated into the demonstration.[34]

Experimentation

The penultimate step is the use of the prototypes developed in an experimentation program. Experimentation in the military context is the process of exploring innovative methods of operation, especially to assess their feasibility, evaluate their utility, or determine their limits. Force 2020 gives particular prominence to experimentation as a useful tool for organisational improvements needed to adapt the force to new challenges.[35] Enhancing a force's adaptability and innovation can be achieved through the careful and selective use of focussed experimentation.

Experimentation is how innovative ideas can be demonstrated and validated before possibly moving into operational service. A fundamental purpose of military experimentation is thus the acquisition of knowledge to guide decisions about an uncertain future. Experimentation is a means to an end; it is a tool - no more. Stefan Thomke of the Harvard Business School writes:

> Understanding … experimentation requires an appreciation of the process of innovation. Namely products and technology innovations don't drop from the sky; they are nurtured in laboratories and development organisations, passing through a *system* for experimentation. … A critical stage of the process occurs when a working artifact, or prototype, which can then be tested, discussed, shown to customers, and learned from.[36]

The value of a military experiment is that it provides the opportunity to observe military phenomena empirically—to learn by doing without the attendant costs of war. Military experimentation is a process of exploration and discovery. Measuring potential effects can be done by wargaming, analytical modeling, human-in-the-loop simulations, and field exercises using real equipment and/or surrogates. All of these methods have limitations but all contribute to more complete understanding.[37]

A combination of these methods making use of the strengths of each while offsetting their respective weaknesses is the best approach. The successful innovations in the inter-war period in German armour doctrine, close air support procedures and equipment, and Japanese and American carrier aviation all relied on a close relationship between wargame simulations and realistic exercises.[38] Stefan Thomke considers that in commercial industry, the combination of modern computer simulation and rapid prototyping techniques allows companies to gain knowledge quickly, and that knowledge can then feed more experiments at less expense then ever before.[39]

It is particularly important to experiment with the prototype equipment under realistic conditions. In actual practice, the forgotten and unimagined factors become very apparent where they were not during computer simulation. Proving that an innovation provides a distinct operational advantage cannot rely solely on computer simulation alone, as the stakes are too high. As US Deputy Secretary of Defense Paul Wolfowitz notes that:

> Over the last century, military field exercises and experiments that were oriented toward emerging challenges at the operational level of war have been important enablers of military innovation and transformation. Field exercises that incorporate experimentation at both the joint and the service levels provide an indispensable means for tackling emerging challenges. In the period between the wars, Marine Major Pete Ellis perceived that war in the Pacific was likely to come, and he proposed a landing concept that we now call amphibious warfare. The Marine Corps saw that the realisation of this doctrine would require special training and special equipment. Over time, and through repeated exercises, the Marines perceived the need for three different types of landing craft: one for the first troop assault; a second for the second larger troop landing; and a third to put tanks ashore. Taking Ellis's idea from the drawing board to practice beaches resulted in success in the sands of Iwo Jima, Okinawa and others.[40]

Acquisition/Termination

At the conclusion of the experimentation phase there are four potential outcomes: terminate, keep the equipment developed, keep as interim capability awaiting acquisition or move into acquisition.[41]

Termination. If the capability or system does not demonstrate military utility that is of contemporary relevance, the project is terminated. However, the information gained has expanded the overall technology and operational employment experimentation allowing an ability to grow this equipment should circumstances change. Fielding this equipment in the future would be considerably easier, and much faster. Overall responsiveness to emerging threats and circumstances would have been enhanced.

Retain In Service. The user's needs may be fully satisfied by fielding the residual capability that remains at the experiment's conclusion and thus there would be no need to acquire additional units. The equipment developed, and experiments assessing an innovation should be so structured, that the option to field the devise in a timely manner is retained.

Interim Capability. If affordable, fielding of the residual capability that remains at the completion of the demonstration could provide an interim and limited operational capability.

Acquisition. The user may recommend acquisition of the technology through any of the various acquisition methods. The transition of the technology from TRL 6 into a production and deployed item would be funded and project managed through the routine processes. With the technology at TRL 6 the project cost and schedule should be able to be estimated with reasonable accuracy.

RELATIONSHIP TO DSTO

A specific science and technology group provides scientific advice appropriate to military acquisitions and operations in many defence organisations. In the Australian Defence Organisation, DSTO provides this essential scientific advice; while this paper uses DSTO as an example, the same basic concepts could apply in any situation were the defence organisation has an integrated scientific research establishment.

In the proposed approach DSTO would be a crucial element as a source of technology advice, guidance and innovative ideas. Using it's current resources, DSTO sometimes builds equipment up to TRL 4 as part of the organisation's methodology of truly understanding specific technologies. Under the suggested system innovation approach, these good ideas could be taken the next step to prove and verify system performance in a realistic environment.

The extra funding would allow current DSTO work, that is presently unable to be bought on to a higher technology level, to have assessments made of it's operational utility. To achieve the desired results, the combination of DSTO and the RAAF would be essential. Moreover, the current CTD process coordinated by DSTO would provide a useful additional source of innovative thinking able to be developed further and trialed.

FUNDING

The sting in the tail is that resources would be required to make this approach work now and into the future. A long-term, permanent allocation from the overall air force budget would be needed. Money is available, therefore the issue is one of competing priorities. For smaller Services, resource questions are always difficult; the example below focuses on the RAAF although the basic considerations apply to other organisations, groups and Services as well.

The amount proposed for developing the technology trialed through experimentation is $30m annually or about 0.6 per cent of the RAAF budget.[42] With some careful planning, some separately funded DSTO and CTD work could be incorporated into the overall strategy. This would perhaps increase the total budget to about $40m or 0.8 per cent of the RAAF's budget.

This is a significant figure, although smaller in percentage terms by comparison to the R&D budget of other innovating organisations. The USAF's own S&T budget in FY2002 is about 1.7 per cent of the Service's total budget working towards a DoD mandated goal of some 3 per cent.[43] The US DoD overall S&T budget is around 4 per cent of the total DoD budget.[44] Even some commercial companies in Australasia spend somewhat more as a percentage of their total budget. Successful white goods manufacturer Fisher and Paykel Industries spends around 6 per cent of their total budget annually on R&D.[45]

It is no accident that some air forces or industries are more progressive than others; they invest in their future through R&D. The US National Research Council notes that the 4 per cent US DoD S&T budget provides 'great leverage as it has led in the past to the technical superiority of US Forces'.[46] Is 0.6 per cent of the RAAF overall budget too much to be better able to meet future challenges and opportunities? Without this spending will the RAAF have sufficient organisational flexibility to be as useful in the future security environment as it could be?

DSTO is resourced to about 2 per cent of the Australian Defence budget however this supports a wide array of activities including the running system and the acquisition organisation. DSTO resources can assist, but funding could not be diverted from the existing DSTO budget into the continuous innovation strategy envisaged without significant harm to DSTO.

The $30m amount could maintain a small office and fund the R&D work with the actual trials piggy backing off exercises and other planned activities. Regardless, $30m annually would be hard to find. Good ideas are in some respects easier to come by than the resources to make them into reality. Flexibility is not free. As Araujo and Spring sagely, if obviously, observe:

> The key to addressing strategic flexibility ... lies in the ability of the firm to identify, develop or acquire resources that can be deployed in alternative courses of action and in developing coordination processes that allow resources to be used in multiple courses of action.[47]

FURTHER PROBLEMS [48]

While flexibility is sought to handle uncertainty, there are some disadvantages. The need to choose a strategy cognizant of cost and time suggests that there would be some optimal level of flexibility. Too much flexibility may be harmful in that it may complicate analysis and confuse the decision-maker. The value of flexibility may follow the law of diminishing return where the marginal benefit of an additional option decreases as the number of choices increase.

There are diseconomies of scale in producing small numbers of different prototypes. Moreover, having a system relying on flexibility may make it seem less important to get it correct first time and thus more costly overall in the longer run. Increasing variety can also lead to complexity and confusion, and thus potentially raising overhead costs.

Emphasising flexibility can also cause decision-makers discomfort and anxiety. Decision-makers with an intolerance of uncertainty seek to make an early or pre-commitment to get rid of uncertainty, and hence also flexibility. Cautious decision-makers may prefer fewer decision choices and thus a system emphasising flexibility might be undesired. Hesitant or indecisive decision-makers may want less flexibility to avoid having to make decisions.

The close relationship between flexibility and uncertainty simply means that flexibility is a way of coping with uncertainty. Flexibility in itself does not reduce uncertainty. Giving a decision-maker more choices to optimise a response to emerging dilemmas may simply create more uncertainty in the mind of the decision-maker.

This is an important issue as the rationale for adopting dynamic strategic flexibility is to allow better preparation for handling crises in the complex modern world. If decision-makers find it hinders or confuses them, then it may not be a sensible strategy to adopt. Decision-makers may need decision support tools and specialised education to make the best use of a strategy emphasising the development of dynamic flexibility at the strategic level.

CONCLUSION

Air Forces in the future need to be more agile and flexible than they were during the long and stable Cold War. Strategic flexibility appears a most important attribute for the Air Forces in developing timely responses in a complex and uncertain future. There will not necessarily be as many years to change a force as there was previously.

A strategy for creating sufficient flexibility involves developing and trialing cutting edge, novel, operational prototypes in a manner that allows the organisation to become innovative, creative and inherently adaptable. The concept uses experiments involving operational prototypes as catalysts for creating the recurrent organisational enhancement needed to handle an unpredictable future. An underlying feature of this system is that the prototype can be quickly advanced into service if the innovation when trialed is attuned to the real operational needs of the day. The operational prototype experimentation concept process focuses on addressing short and medium term needs.

While this concept would improve flexibility, the financial implications would have to be carefully considered. An allocation of around 0.6 per cent of the RAAF budget is suggested; by comparison this is less than half the percentage the USAF allocates, only a seventh of the US DoD allocation, and a tenth of a well-known Australasian fridge maker. The resourcing decision would have to be made ultimately on a return on investment basis. Is the level of flexibility gained a good return for the investment? The USAF and a great many other successful companies and organisations invest in their future in this manner. Is it sensible for a small air force, like the RAAF, to do so? Is it sensible not to?

Regardless of the specific coping strategy adopted, the dilemma posed to military forces in general and Air Forces in particular, by the deepening uncertainty in the future international security environment requires careful thought. Military forces must be useful in the environment and circumstances found in the real world, not just in some abstract world of strategic theorists. A period of uncertainty will require adjustments to the way the development of military forces is undertaken. There needs to be some careful anticipatory thought and sensible actions lest an uncertain time deliver an unpleasant strategic surprise that we are unable to adequately manage.

ENDNOTES

[1] Dr. Linda P. Beckerman, *The Non-Linear Dynamics of War*, SAIC, 1999, http://www.belisarius.com/modern_business_strategy/beckerman/non_linear.htm, accessed 3 Jan 03.

[2] Some will have trouble with this revisionist view of placing technology at the heart of air power. However, without aircraft there could not be an air force; man cannot fly unaided by technology. It is possible to envisage land warfare without technology; it is absolutely impossible to envisage air warfare without technology. Air Forces are instead composed of a mixture of hard, tangible resources like technology, and soft perishable assets like people, skills and ideas. The goal of an Air Force is to have, at the right time, the correct combination of hard and soft air power means available to achieve the ends sought.

[3] The CTD program normally provides $2-3m annually for aerospace technology CTDs. [4] This process will allow broad and sometimes ill-defined ideas to be examined by experts in a logical process; the first experiment will analytically model and game force employment in different scenarios. Department of Defence, *Future Warfighting Concept*, Canberra, 2002.

[5] Slack, N., 'Flexibility as a Manufacturing Objective', *International Journal of Production Management*, Vol. 3, No. 3, 1983, pp. 4-13.

[6] Carlsson, B. 'Flexibility and the Theory of the Firm', in *International Journal of Industrial Organisation*, 7(2), 1989, pp. 179-203.

[7] Evans, John Stuart, *Flexibility in Policy Formation*, PhD Thesis, Aston University, 1982.

[8] Carlsson, 'Flexibility and the Theory of the Firm'. [9] Epplink, D Jan, 'Planning for Strategic Flexibility', in *Long Range Planning*, Vol. 11, 1978, pp. 9-15.

[10] Stephen Peter Rosen, *Winning the Next War: Innovation and the Modern Military*, Cornell University Press, Ithaca, New York, 1991, p. 245.

[11] Admiral Cebrowski, *Statement Of The Director Of Force Transformation Office Of The Secretary Of Defense Before The Senate Armed Services Committee United States Senate* 9 April 2002, http://www.senate.gov/~armed_services/statemnt/2002/April/Cebrowski.pdf , accessed 4 Jan 2003.

[12] *Advanced Concept Technology Demonstrations Introduction page*, Advanced Systems and Concepts Office, 7 May 2001, http://www.acq.osd.mil/actd/intro.htm, accessed 20 Jan 2003.

[13] Gareth Morgan, *Images of Organization; The Executive Edition*, Berrett-Koehler Publishers, San Francisco, 1998, pp. 82-6.

[14] *Ibid.*, pp. 230-33.

[15] Only 10-15 per cent of the German Wehrmacht in the 1940 Battle of France was well equipped and supplied and employing innovative doctrine and organisation. The remainder relied on horse drawn wagons and equipment reminiscent of World War I. But this was of no matter; the numerically small, technologically advanced mechanised units won the battles for the remainder to fill in behind.

[16] Inevitably it seems the multi-purpose platforms acquired years earlier do not have quite the right avionics, radios, sensors, weapons, electronic warfare or assorted other equipment for the actual circumstances arising.

[17] Williamson Murray, 'Innovation Past and Future', pp. 300-28 in Williamson Murray and Allan B. Millett, *Military Innovation in the Interwar Period*, Cambridge University Press, Cambridge Massachusetts, 1996. [18] *Force 2020*, Department of Defence, June 2002, p. 22.

[19] Murray, 'Innovation Past and Future'.

[20] For example the lease by the US Army, the US Navy and US Marine Corps of wave piercing catamaran, high-speed transport ships for experimentation. A.D.Baker III, 'Combat Fleets', p. 88 in *US Naval Institute Proceedings*, Dec 2002.

[21] The joint Global Hawk UAV maritime surveillance experimentation program involving Australia and the US is an example.

[22] June 1, 2002, *Raising The Ante*, Anne Laurent, http://www.govexec.com/features/0602/0602s3.htm, accessed 10 Jan 2003.

[23] Morgan, *Images of Organization; The Executive Edition,* pp. 236-42.

[24] Force 2020, pp. 19-20.

[25] *A Canadian Innovation Agenda For The Twenty-First Century,* Fifth Report of the Standing Committee on Industry, Science and Technology, Susan Whelan, M.P., Chair June 2001, http://www.parl.gc.ca/InfoComDoc/37/1/INST/Studies/Reports/indu04/13-ch2e.htm#Measuring%20Worldwide%20Innovation, accessed 12 Jan 2003.

[26] Arthur K. Cebrowski, Director, Force Transformation, *Special Briefing on Force Transformation*, Tuesday 27 November 2001 - 2:30 p.m. EST, http://www.defenselink.mil/news/Nov2001/t11272001_t1127ceb.html, accessed 5 Jan 2003.

[27] John C. Mankins, *Technology Readiness Levels*, A White Paper, 6 April 1995, Advanced Concepts Office, Office of Space Access and Technology, NASA, http://www.trecc.org/partners/TRL_paper.pdf, accessed 20 Jan 2003.

[28] For example in a 15 July 2001 memorandum, the US Deputy Under Secretary of Defense (Science and Technology) officially endorsed the use of TRLs in new major programs.http://www.sei.cmu.edu/publications/documents/02.reports/02sr027/02sr027.html#dod02, accessed 20 Jan 2003.

[29] DoD 5000.2-R; *Mandatory Procedures for Major Defense Acquisition Programs (MDAPS) and Major Automated Information System (MAIS)* Acquisition Programs, 10 June 2001, http://web.deskbook.osd.mil/reflib/MDOD/031DR/016/031DR016DOC.HTM, accessed 20 Jan 2003.

[30] John Mankins also suggested a measure of how much difficulty is expected to be encountered in the maturation of a particular technology is needed to complement the existing Technology Readiness Levels (TRLs) metric, http://www.hq.nasa.gov/office/codeq/trl/r&d3.pdf, accessed 20 Jan 2003.

[31] These are useful variations by DARPA PM Douglass Gage as noted in Caroline P. Graettinger, Suzanne Garcia, Jeannine Siviy, Robert J. Schenk (U.S. Army CECOM RDEC STCD), Peter J. Van Syckle (U.S. Army CECOM RDEC STCD), *Using the Technology Readiness Levels Scale to Support Technology Management in the DoD's ATD/STO Environments: A Findings and Recommendations Report Conducted for Army CECOM*, CMU/SEI-2002-SR-027, September 2002, http://www.sei.cmu.edu/publications/documents/02.reports/02sr027/02sr027.html#chap02, accessed 22 Jan 2003.

[32] *Ibid.*

[33] *Ibid.*

[34] Makins, Technology Readiness Levels.

[35] Force 2020, p. 25.

[36] Author's emphasis. Stefan Thomke, 'Enlightened Experimentation: The New Imperative for Innovation', in *Harvard Business Review*, Feb 2001, p. 68.

[37] Modelling and simulation while useful can do no more than be an approximate representation of reality; moreover, there are always hidden assumptions buried in the software code. However, while such simulations can provide the large numbers of cases necessary to generalise, they are not empirical evidence. Conversely field exercises are not repeatable in a rigorous sense and are usually costly; they are more credible than computer simulations but less so than empirical evidence derived from actual warfare.

[38] Murray, 'Innovation Past and Future', pp. 325-6. [39] Thomke, 'Enlightened Experimentation: The New Imperative for Innovation', p. 68.

[40] Deputy Secretary of Defense Paul Wolfowitz, *Prepared Statement for the Senate Armed Services Committee Hearing on Military Transformation*, 216 Hart Senate Office Building, Washington DC, Tuesday 9 April 2002, http://www.defenselink.mil/speeches/2002/s20020409-depsecdef2.html, accessed 6 Jan 2003.

[41] Based on a modified ATCD format. see http://www.acq.osd.mil/actd/intro.htm, accessed 6 Jan 2003.

[42] The percentage of the RAAF Budget varies with what the RAAF Budget is considered to actually be. In this case the percentage is based on the price of the Air Force Capabilities given in Table 1.2, *Defence Annual Report 2001-02*, Commonwealth of Australia, 2002, p. 35. [43] *FY 2002 USAF Budget Overview Jul 02*, MGEN Larry Northington Dep Asst Sec (Budget), http://www.globalsecurity.org/military/library/budget/fy2002/usaf/fy02budgetrollout.pdf, accessed 15 Jan 2003.

[44] This includes basic research, applied research and advanced technology development but not demonstration and validation, which the proposal for the RAAF includes. *Review of the Future of the US Aerospace Infrastructure and Aerospace Engineering Disciplines to Meet the Needs of the Air Force and the Department of Defense (2001),* National Academy Press, Washington 2001, http://www.nap.edu/books/0309076064/html/index.html, accessed 20 Jan 2003.

[45] Lewis, Geoff et al, *Australian and New Zealand Strategic Management: Concepts, Context and Cases*, Sydney, Prentice Hall, Australia, 2nd Edn, p. 706.

[46] Review of the Future of the US Aerospace Infrastructure and Aerospace Engineering Disciplines.

[47] Luis Araujo and Martin Spring, *Manufacturing Flexibility and Industrial Networks*, Paper prepared for the 18th IMP Conference, Groupe ESC Bourgogone, 2002.

www.escdijon.com/download/imp/pdf/128%20Araujo%20&%20Spring4.pdf, accessed 12 Jan 2003.

[48] This section draws heavily on Anne Ku, *Modelling Uncertainty in Electrical Capacity Planning,* PhD Thesis London Business School Feb 1995, pp. 315-16. www.analyticalq.com/thesis/ch.5.pdf, accessed 12 Jan 2003.