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MODELLING AIR OPERATIONS

By

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About the Author

Wing Commander Waters is a Supply Officer who joined the RAAF in January 1969. His more recent postings have included Bracknell UK, where he attended the RAF Advanced Staff Course in 1985, and RAAF Staff College, Fairbairn Canberra from 1986 to 1988, where he served as an instructor and the Director of Air Power Studies.

In January 1989 he was appointed Director of Studies as RAAFSC for the review of the RAAF's Command and Staff College. In June 1989 he was posted for six months to the newly formed Air Power Studies Centre where he contributed to the writing of the AAP 1000, Royal Australian Air Force Air Power Manual. From January 1990 he was the RAAF Visiting Fellow to the Strategic and Defence Studies Centre at the Australian National University. In May 1991 he was posted back to the Air Power Studies Centre, where he undertook a study of the air war in the Gulf, to be published in June 1992.

INTRODUCTION

A student of the combat history of air power can be sidetracked easily into examining specific air operations per se and becoming mesmerised by the thrill of flight, the glamour of aviators, and the destructive power which can be rained down from the skies. Furthermore, the pursuit of history, for the sake of history, can hold attraction for many. For others, it is a means of developing better concepts and strategies for the use of air power in the future. These concepts and strategies are complex and need to be simplified to ensure that they can be developed to their full potential. The rigour associated with analytical modelling is one such method of simplifying the detailed issues and achieving a better understanding of the strategies governing the use of air power.

The intent of this paper is to discuss the broader modelling issues relevant to air operations. In the first instance, the twin themes of combat history and combat analysis are seen as necessary precursors for establishing the need for modelling air operations. The value and limitations of modelling are discussed, and highlighted through a brief examination of the part played by modelling air operations in the 1991 Gulf War. Additionally, those elements of an air campaign which can be modelled are identified, and observations are made about the way ahead for modelling air operations.

COMBAT HISTORY

The importance of studying combat history is not the issue here, and to embark on an elaborate justification would detract from the main issue. Suffice it to say that to understand fully how air power may be used, one should know how it was used in the past and what changes it has undergone over the years. The principal role for military air power is to be prepared for use in combat; yet without first-hand experience in combat, how does one prepare? It is through systematic study of combat history, and the use of simulation where possible, that one prepares.

There are two aspects to the systematic study of history. First, there is the reconstruction of what actually happened, or as Dr Dennis E. Showalter[1] from the United States calls it, the study of evidence. Second, there is the application of the analytical dimension, whereby that evidence is interpreted. It is this study of combat history, performed through the disciplines of gathering substantiated evidence and conducting defensible interpretation, that has much to offer today's defence planners, who should look to use the historian's art and techniques to complement their professional knowledge and analytical expertise.

COMBAT ANALYSIS

To pick up on Dennis Showalter's point of interpretation, or in terms consistent with the thrust of this paper, analysis. Through combat analysis, one can determine the

[1] Showalter, Dr Dennis E., 'Two Different Worlds: The Military Historian and the US Air Force', *Air University Review*, date unknown.

effectiveness of doctrine, training, systems and equipment. One of the great problems in the past has been that the many variables which exist at any one point in time, and accurate descriptions of the circumstances extant during a particular combat, have proven difficult to gather during the heat of actual combat. Thus, caveats should be applied to specific combat analyses.

One prime example is an analysis of attrition rates during World War II, when the US 8th Air Force suffered a loss rate of some eight percent of its bombers during daylight raids over Europe in 1943. Yet, in October of that year, over Schweinfurt, 25 percent of the force was lost. The average loss rate may appear acceptable, thus precipitating a conclusion that tactics, techniques and procedures used in prosecuting daylight bombing raids were satisfactory. However, the high losses over Schweinfurt would indicate otherwise.

Another example occurred during the Korean War, when P/F-51 Mustangs suffered far higher attrition than did F-86 Sabres. On further analysis, one finds that most of the Sabre losses were to enemy aircraft, whereas Mustang losses were to ground fire. Mustangs were used for low-level ground attack – an inherently dangerous mission.

A third example stems from an analysis in a book by Professor Robert Ball,[2] indicating that most aircraft losses during World War II occurred from damage to engines; yet, during Korea and Vietnam, most fixed-wing aircraft losses were as a result of hits to the fuel system. After World War II, engines had been changed to gas turbines, and the fuel system occupied a considerably greater area. In all instances, the majority of aircraft lost went down in flames.

The point has been made, and it should not have to be laboured any further – caveats do need to be applied, and great care must be taken not to misinterpret the evidence. Moreover, generalisations should be expressed only in terms of the operational environment from which they are drawn.

This foregoing brief comment on combat history and analysis provides a start point from which one can examine the relevance of modelling to air operations. Modelling of air operations has been conducted for many years; however, the factors which have been modelled have tended to be limited to force size, numbers of casualties, and the measurable effects of firepower. These factors represent only the beginning and there are many others which are fundamentally as important.

MODELLING

Most modelling and simulation of military operations has been done at the tactical level of war, where there has been less inclination to model air power than to model land or sea power. Apart from a relatively few models per se, flight simulators are used, dummy weapons are carried, the separation of weapons from aircraft is simulated, air-to-air engagements are practised, and joint air/land and air/sea procedures are rehearsed. The latest simulation systems for the RAAF for example are

[2] Ball, Robert E., *The Fundamentals of Aircraft Combat Survivability Analysis and Design*, American Institute of Aeronautics and Astronautics, Inc, New York, 1985, pp 119-120.

electronic warfare and targeting systems incorporated into two operational flight trainers. The systems include threat jammers, surface-to-air and air-to-air missile detection and countermeasure systems, enemy radar warning systems, Harpoon, aerial mines and Forward Looking Infra-Red (FLIR) targeting systems.[3] The various tactics, techniques and procedures which are practised at squadron level in the RAAF involve only a handful of people in simulated combat. This is in contrast to the numbers of Army or Navy personnel involved in combat simulation.

If the modelling of air operations at the tactical level has been scant, what of modelling at the higher levels, from which force structure and force employment decisions will come? It is at these levels that the real dearth of simulation exists – a set of circumstances which does not apply to the Air Force alone.

Perhaps at this stage, two questions ought to be asked – first, what should a model do? In simple terms, a model should possess three fundamental characteristics: be an abstraction of something (an object); have a particular purpose; and provide a more cost-effective means of achieving its purpose than by using the object itself.[4]

The second question is a more complex one – what can modelling do for air operations? The beginning of the answer lies in a RAND model which was used as part of the Theatre Forces Programme for NATO. Research was led by Richard Hillestad from RAND, Santa Monica.[5] The RAND team reviewed the basic employment philosophy and contingency plans for the Allied Air Forces in Central Europe (AAFCE) to defeat a Warsaw Pact combined-arms, air-land offensive in the Central Region.

Several existing RAND models were modified to create the AAFCE Planning Exercise Model (APEX). APEX simulated air and ground operations in the Central Region over a 20-day period, and up to 90 variables were injected to reflect uncertainty, attrition, employment strategies, and so on.

Broadly speaking, the model showed that NATO's tactical air power was far more important to the overall campaign than was the case with the Warsaw Pact's. Results from the model showed the then-current AAFCE air campaign plan to be 'quite robust' but with certain elements such as Offensive Counter Air[6] being over-emphasised.

Analysis, based on the model, highlighted some interesting points. First, offensive counter air against critical Command and Control (C^2) nodes, third-generation aircraft, and sophisticated Surface-to-Air Missile (SAM) sites was effective, but broad runway attacks and attacks against airfield support services such as maintenance

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[3] The upgrade is discussed briefly in *Asia-Pacific Defence Reporter*, September, 1991, p 20.
[4] Thoms, Group Captain G.A., *Generation of Air Capabilities – Toward a Predictive Model*, Air Power Studies Centre, RAAF Fairbairn, Canberra, 1991, p 19.
[5] Findings of this research are summarised in *Project Air Force: Annual Report Fiscal Year 1989*, The RAND Corporation, Santa Monica, California, 1989, pp 12-14.
[6] Offensive Counter Air (OCA) involves attacks on enemy-occupied airfields; with aircraft, runways, airfields, and fuel and maintenance facilities being preferred targets.

facilities, were far less effective. Second, defensive counter air[7] operations were critical, and when enemy air operations could be predicted, the use of Combat Air Patrols (CAP)[8] and fighter sweeps[9] was most effective. Third, delaying and disrupting enemy ground forces had a significant impact on the battle, but air interdiction had to be sustained and prosecuted wholeheartedly to be effective. Fourth, the best time to attack enemy ground forces was as they 'moved-to-contact', because their composition made them higher value targets. For example, as forces move-to-contact, accompanying vehicles would be primarily combat ones, whereas, further from the battlefield, they would reflect a combination of combat and support vehicles.

Importantly, this and other models show that the sequence of air operations can be critical, depending on circumstances, and no one broad statement should ever be made on priority of force employment that could restrict the flexibility of employment options. That is, air power should not be applied heuristically on the basis of historical experience alone, but rather, through a continuing systemic analysis of the unfolding battlefield. Here, systemic analysis implies emphasis on the dynamics of force interaction and not on momentary force dispositions. Dynamics suggest that an enemy should not be engaged until he has expended a large proportion of his resources in deploying, and committed to an identifiable attack plan. Then, at the most appropriate moment, either just before or as advancing-to-contact, the enemy should be engaged to ensure maximum degradation of his capability and maximum delay of his attack plan. In this way, friendly forces would be more likely to seize and maintain the initiative on the battlefield.

While the foregoing comment centres on a tactical battlefield, that does not imply that a systemic analysis of the entire battlefield (strategic) should not be conducted. Indeed, selection of 'strategic' targets should support the composite air/land/sea strategy of the Joint Force Commander, and any attack strategy should be based on a systematic analysis of the dynamics of the enemy's strategic systems and their deployment.

LIMITATIONS OF MODELLING

Although modelling does offer the prospect of improved understanding of combat air operations, many of the models produced thus far have been flawed. For example, many models which incorporate air power aspects, started life as land power models, and the effect of air power has been virtually ignored. Air power inputs focused on their impact on the immediate tactical land force engagement. Invariably, joint models have concentrated on land operations, with air power simply being represented as in

[7] Defensive Counter Air (DCA) involves active and passive defence measures. Active measures include SAMs, AAA, and air defence fighters; passive measures include camouflage, dispersal, concealment, deception and hardening.
[8] Combat Air Patrol (CAP) in this case would involve fighter aircraft flying a 'racetrack' pattern at a certain altitude above an area of forces to be defended, such that the aircraft could be tasked immediately to identify and attack any intruding hostile aircraft.
[9] Fighter sweep essentially involves fighter aircraft being positioned above enemy airfields so that they can attack enemy aircraft as they become airborne. Fighter sweep is an element of OCA and necessitates enticing enemy aircraft into the air, under circumstances which favour friendly aircraft.

support. As an example, the much-touted joint model JANUS includes approximately 90 percent land and only 10 percent air simulation.

During the 1950s and 60s, the application of air power was mathematically modelled. However, the purpose of these models was to meet the individual needs of specific plans and programmes. Accordingly, development of the models was characterised by a lack of the integration and coordination needed to depict more fully the holistic nature of air power.

Another major limitation of modelling has been a tendency to ignore that anything is possible and to model only that which was believed to be feasible and readily quantifiable. For example, models which incorporate the High Speed Anti-Radiation Missile (HARM), tend to concentrate on the missile’s Probability of Kill (Pk), yet ignore the point that the tell-tale radar signature of an F-4G Wild Weasel with HARM would compel an enemy to switch off radar. This occurred in the Gulf War, and the F-4Gs, on many occasions, were successful even without firing missiles. Another side effect witnessed in the Gulf, which has never been modelled, was that the fear of detection and subsequent attack was sufficient to cause some Iraqi radars not to be switched on at all.

Combat prediction is difficult and the observation that predictive models did not forecast as many aspects of the Gulf War as anticipated has raised some questions as to the effectiveness and even relevance of modelling. Perhaps the question of effectiveness should not be levelled at modelling itself, but at the particular models in existence.

The problem of quantifying the effect on an enemy of psychological operations, attacks on national will, reduction in the morale of military forces, degradation of Command and Control (C^2), and disruption of operational planning makes the usefulness of modelling to the operational and strategic levels of war fairly tenuous. Because of this, modelling tends to have been restricted to the tactical and technological levels. Another limitation has been that while cause and effect relationships, in terms of tacts and technology have been modelled, those in terms of individual and group behaviour in combat have not. Group dynamics and individual performance in combat are part of the equation and need to be modelled and studied as well.

As an example, crew ratios for training and peacetime may bear little resemblance to that needed in war, especially initially, as the stress-fear-fatigue relationship comes into play. Stress in combat can be induced in two ways, through placing people in new surroundings and through exposing them to combat for the first time. Under these stresses, fear can rise and result in the onset of fatigue much sooner than would occur in peacetime and in training. Modelling has much to offer here.

Modelling has tended to concentrate on the offensive aspects of air power. Yet, there are pro-active defensive measures which are also suitable for modelling. For example, the use of passive defensive measures such as deception, dispersal, camouflage and concealment which leads to uncertainty in an enemy should be modelled so that the effects can be assessed.

For current models, the costs alone of running them have become almost prohibitively expensive in terms of setting up the database and familiarisation with the software. High levels of specialist expertise are needed for the limitations of the models to be understood and to ensure that the approximations used do not produce misleading results because of imprecision. As an example, the RAND Strategic Assessment System (RSAS) provides for about 30 days of combat data to be achieved in two hours, but involves some six months for one person to become proficient in the model and to prepare the data base.

Finally, subjective expert judgement does weight in so heavily, yet modelling has been used only for the objective, clearly quantifiable elements. Any model of the future should provide the wherewithal to quantify some of these expert judgements which to date have been too complex to describe algorithmically.

USE OF MODELLING DURING THE GULF WAR

While many models were used in the Gulf War, for quite specific purposes, two were of more general application. The first, taken by the USAF into theatre, was C^3ISIM.[10] It was designed to provide support at the military strategic planning level, but was able to be adapted for other uses. One use was in evaluating attrition.

A thirty-day assessment of air operations at the campaign level was undertaken, which included analysis at the specific mission (or task) level. The model used a detailed Air Tasking Order (ATO) as its input and wargamed the subsequent conduct of operations. A substantial workload was required initially to build the database, with this phase taking from August to October 1990. Then the threat had to be modelled because the wargame was designed around a Warsaw Pact threat and a NATO response. Delivery tactics, weapon types, time of take-off and time-on-targe represent the level of detail to which the model worked. Weapons effects were based on previously determined algorithms, but randomness was simulated using Monte Carlo techniques.

The main observation from the prototype model was that further analysis could reduce attrition by identifying ‘hot’ spots, improving route planning and Suppression of Enemy Air Defence (SEAD) targeting, and identifying the most vulnerable elements of Iraq’s Integrated Air Defence System (IADS). The model supported both the operational planning cell and the Electronic Combat (EC) cell. The threat, C^2 and EC were all inputs to operational planning, so there was considerable interrelation between the two cells, and the analytical model was able to support both.

Attrition analysis using C^3ISIM[11] was performed during Desert Shield but was not run during Desert Storm. As stated earlier, the threat data base was built by October, but as intelligence improved, the data base had to be changed, with new intelligence reports being input to the model. The problem of maintaining an accurate data base eventually led to termination of C^3ISIM as a planning tool because of the volume of

[10] The abbreviation stands for Command, Control, Communications and Intelligence Simulation.
[11] The author is indebted to Major F. T. Case of the USAF who explained the model itself, and its use in the Gulf.

input data, the manpower requirements, and the time required to update the data base which reduced its responsiveness.

Similarly, operations planning had to interact with the model, which also consumed computer running time. Importantly, the model was able to predict accurately the Allied aircraft losses and the Iraqi SAM losses which could be expected. The planners certainly benefited from such information in the weeks leading up to formulation of the final air campaign plan. Models such as C3ISIM must provide near real-time results to be useful tools for operations analysts and must instil in operational commanders confidence in the tools.

During Desert Shield, the model not only helped with the attack plan, but was used in determining the size of the force package needed and its constituent elements (known as a trade-off analysis), as well as providing an Air-to-Air Refuelling (AAR) analysis which could assess possible areas of congestion. Graphics and sequencing capabilities of the model enhanced is ability to undertake the AAR analysis. The trade-off analysis for example allowed the effect of moving F-4Gs from one area to another to be modelled.

During Desert Storm, the model could not keep pace with the Air Tasking Order (ATO), even though ATO production could take as long as 48 hours. However, the lethality of specific SAMs and the allocation of priorities to SAM targets could be assessed. As friendly air losses occurred, the model was used to determine the causes.

The importance of the use of C3ISIM in the Gulf was that a long-term, study-oriented model was taken into a near real-time operationally-oriented environment. It reinforced the notion that there is a place for operations analysis (which was well-established in World War II) and that the task of the future is to use computer modelling in near real-time to help the commander decide among possible courses of action. In terms of refinement of the model, the air-to-air aspect needs to be developed further, as does the effect of Anti-Aircraft Artillery (AAA). Aimed AAA was modelled but barrage AAA was not.

An important observation is that analysts and their models need to be exercised during actual operations in peacetime. In the case of the Gulf, interaction had to be developed – fortunately time was on the Allies' side. Trained analysts with appropriate tools, exercising with operations staff in any transition to war, have tremendous potential to help manage attrition and more broadly, assist the commander in his planning.

Analysts with operational backgrounds were critical to successful use of the model in the Gulf; a balance of highly-trained computer analysts and technicians, directed by other analysts with operational backgrounds, would seem to be the way ahead. There is a move within the USAF to select operators and train them in analytical techniques and then integrate them throughout the air staff and various commands.

The second model was not taken to the Gulf, but was used at the Defence Operational Analysis Establishment (DOAE) in the United Kingdom.[12]

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[12] The author is indebted to Mr Gavin Lidderdale of DOAE for his insight into DOAE modelling and analysis during the Gulf War.

DOAE formed an analysis cell on 11 August 1990 to track events during Operation Granby (the British deployment). The cell, which consisted of civilian scientists and military analysts from all three Services, was disbanded when the war ended. A model was used from the outset to convert forces to a broad combat strength measurement for comparative analyses. It was also used to gauge the length of time required for the Allies to gain air superiority and the best way for them to achieve it. Additionally, a study was undertaken of all conflicts in which Iraq had been engaged in the past. The final assessment was that the combat potential of the Iraqi Army was only 14-25 percent of that of the US and UK land forces deployed.

The importance of this type of historical analysis is that it provides an ability to economise military effort by determining an enemy's combat potential and tailoring a level of effort to meet that potential. As well as preventing an over-reaction, it has the effect of reducing the number of potential targets presented by friendly forces in a theatre of operations.

Movement and attrition rates of land forces were calculated, and once the war started, the model was run one day behind the war to test results, but wargamed ahead to determine the best terrain, tactics and scheme of manoeuvre. The model showed that Iraqi supply dumps and routes were not as critical as many believed. Iraqi strong points were the airfields, but rather than engage in a massive airfield closure campaign, the Allies' best option was to entice Iraqi aircraft into the air and destroy them there.

The model was also used to simulate the air/land environment and the following estimates were used for kills per sortie by tactical ground attack aircraft: A-10 – 1.0; F-16 – 0.5; F-15E – 1.0; AV-8B – 0.5; remainder – 0.3. Mission effectiveness could be affected through aircraft and weapon serviceabilities, weather and so on, and these factors were considered in arriving at the estimates above. Overall, the model estimated tactical kills per day as being 350 (700 sorties x 0.5 average). Unclassified sources showed some 4,280 tanks, 3,110 artillery pieces, and 2,870 Armoured Fighting Vehicles as being in the Kuwaiti Theatre of Operations (KTO),[13] so a short, high-intensity campaign[14] was required to interdict battlefield targets.

Small arms capability against aircraft, morale of troops under air attack, and degradation of tactical C^3I were difficult to quantify and became quite subjective. The secondary effects of dislocation and demoralisation are the keys to success in tactical operations, and attempts at quantifying these effects are rarely made by modellers.

During the war, there was considerable speculation about the need to degrade Iraqi forces by 50 percent. The decision to begin the ground offensive once enemy forces suffered 50 percent attrition also took into account which specific capabilities would be destroyed and which would be intact.

Initially, a direct frontal attack on Iraqi forces was modelled, which resulted in an Allied loss. All variations on the direct attack failed. An amphibious assault could

[13] *Jane's Defence Weekly,* 6 April 1991, p 529.

[14] 10,260 armoured targets divided by 350 per day equals 29 days approximately. Historically speaking, 29 days represents a short campaign.

only have been made on the southern side of Kuwait city as the remainder of the area was unsuitable for landing. Modelling estimated that under the best conditions 50 percent of Allied amphibious forces would be lost to mines and close-fighting, and even then once the assault had broken through, forces would be involved in urban fighting. The threat of using an amphibious assault was sustained, yet was probably discounted by high-level planners early in the deployment. In fact, a central frontal attack on Kuwait's border and an amphibious landing, supported by air elements which were in-place, became part of the deception plan in the KTO.

A shallow left hook was modelled and met with success; a long left hook was modelled and resulted in even greater success and minimal casualties; and finally, a mixed hook option was modelled. All options were modelled with vigorous Iraqi counter-attacks and Iraqi attacks with chemical weapons. Modelling showed that the effect of Chemical Warfare (CW) attacks would have slowed Allied operations, hence lengthening the war and consequently increasing Allied losses. However, modelling expectations were that protective measures would be effective against CW.

There were many other models which were run, with most showing that a war would take 10-14 days once the ground offensive was launched and result in over 20,000 Allied casualties. The failure of many models to factor-in the air element satisfactorily showed a lack of understanding of the effects of strategic air attack and a marked absence of lateral thinking on the part of many modellers.

In land force terms, an encirclement strategy is an inherently high risk one, but one with a very high potential for pay-off. Models showed that encirclement was the best option and that it had to be supported by a deception plan. They also showed that an amphibious assault would be too costly and would achieve little military effect.

Most models were based on the Central European theatre in terms of terrain, movement and attrition, and all had to be recalibrated for the Gulf theatre to be of any use. Considerable value can be derived from analysing all the assumptions in current models and wargames used during the Gulf War and modifying them for different theatres for future conflict. Suitable models can provide good decision aids to senior commanders, and distributed wargaming and joint/combined exercises will be necessary for future coalition warfare. However, within the models, weapon scoring methodology and areas of disagreement and uncertainty need to be developed and resolved.

Development of future concepts for the use of air power in an independent sense and as a pivotal element in manoeuvre warfare can be rigorously analysed as a result of wargaming and modelling. Future campaigns must be organised along joint lines, while recognising that there is a valuable contribution to be made by strategic air attack. The challenge for joint operations will be to realise that there may be segments of the overall campaign which are not joint. US President Bush articulated this point extremely well in April 1991 when he stated that joint operations involve using the right tool at the right time and not necessarily a bit of everything.

THE AIR CAMPAIGN

Before the way ahead for modelling can be discussed, there are two themes which need to be addressed – the notion of the extended battlefield and the objectives of an air campaign. The notion of the extended battlefield calls into question the generally-accepted clear differentiation between strategic and tactical air power.[15] The three air campaigns articulated in the RAAF's doctrinal publication, the AAP 1000,[16] are all strategic in nature, as they centre on a strategic aim. Counter air operations, including air defence, and air attack against an enemy's strategic base quite clearly focus on a strategic aim.

Not so obvious, but just as assuredly, air support for combat forces is oriented around a strategic aim. This support campaign should not be viewed simply as tactical application of air power on a remote battlefield with troops in contact. As witnessed in the Gulf, air power has much to offer against 'tactical' targets, well-before troops are in-contact. In other words, the battlefield extends from wherever fielded forces may be positioned back to the strategic base of a nation which sustains those forces.

Now, to the objectives of an air campaign. Nations possess five strategic elements which can be depicted as concentric rings, with the innermost ring representing the most critical. These elements, or rings, are: leadership, key production, infrastructure, population, and fielded military forces. Taken together, these elements form a nation's strategic centre of gravity and provide the strategic base and stability to fight a war. In countering a nation's ability to fight a war, concentration of effort should be directed against the inner rings, working out. The air campaign would be expected to minimise civilian casualties and collateral damage while minimising friendly losses. In so doing, the campaign would call for identification of an enemy's strategic weaknesses and concentration of friendly strengths against those weaknesses.[17]

Specifically, attacks against leadership should not be viewed purely in terms of the 'decision-making elite' concept proposed by Dr Ross Babbage.[18] Rather, they should be designed around command, control, communications and intelligence (C3I) centres. Areas of key production would include electricity and refined oil, and nuclear, biological and chemical capabilities. The elements of infrastructure which should be attacked include transportation, telecommunications, railroads and bridges. Erosion of national will to support the warring regime and the fielded forces represent the key elements of the population factor. Finally, in terms of fielded forces, attacks against strategic air defence and long-range offensive capabilities and any elite military forces (such as Iraq's Republican Guard) should be prosecuted.

[15] 'Strategic' is generally accepted as referring to air operations outside a single theatre or Area of Operations (AO), whereas 'tactical' refers to air operations within an AO. However, that is not the end of it, as the purpose or objective of a mission also has a direct bearing on whether a mission is regarded as strategic or tactical.

[16] The three air campaigns are identified as Control of the Air (involving counter-air operations), Air Bombardment (involving strategic strike and interdiction) and Air Support for Combat Forces, and are discussed in Air Power Studies Centre, *AAP 1000, Royal Australian Air Force Air Power Manual*, RAAF Base Fairbairn, Canberra, 1990, p 41.

[17] The author is indebted to Colonel John Warden III, USAF, for his succinct description of the five rings, given to the author during a visit to the Pentagon in August 1991.

[18] Babbage, Ross, *A Coast Too Long: Defending Australia Beyond the 1990s*, Allen & Unwin, Sydney, 1990, p 113.

Clausewitz argued that an enemy's field forces represented the prime centre of gravity, once a nation was at war.[19] While this may have been true once, when civil and military functions were concentrated in the one leader who would actually be in the field with the forces, it is not so today.[20] Today, air power allows a nation to reach over the fielded forces of another and behind them to attack the inner strategic rings of C3I and key production.

Attacks on population do not mean the wanton killing or bombing of civilians, but rather, the conduct of psychological warfare to reduce the support of that population for its government. The flexibility of air power allows this to be done through such things as leaflet dropping, vicinity bombing and so on.

The attacks on Iraqi oil were aimed at internal distribution and storage nodes, not at the production and export capabilities. Attacks on the electricity system were the result of very restrictive targeting guidelines. Specific pin-point delivery had to be used which could hit the switching facilities in the grids and transformer yards where civilians did not work and which could be rebuilt relatively easily after the war. Generator hulls and areas where people worked were largely left alone. Destruction of the electricity grid had a side effect of stopping fuel and water pumps; this side effect had not been considered during early planning.

Six telecommunications nodes only, represented the critical ones to be attacked, two of which were in Baghdad. Two weeks into the war, messengers had to be used to relay communications and Saddam himself had to move into Kuwait to run the battle of Khafji because his communications with the theatre had been damaged significantly. As to the charge of collateral damage from strategic air attacks, there was more accidental and collateral damage caused in Baghdad as a result of Iraqi SAMs and AAA being aimed too low than from Allied air attacks.

Air defence is the only way a nation can protect its strategic targets – its five rings – its centre of gravity. Thus, if a nation's air defence can be stopped or destroyed, the way would then be open for attacks against the strategic targets mentioned earlier. There was ample evidence of this in the Gulf.

Important and critical strategic nodes tend to be small in size. During World War II in the bombing of Germany, many such nodes were left untouched, yet surrounding buildings were reduced to rubble. In the Gulf, the specific nodes were attacked, without reducing surrounding buildings to rubble.

Ten percent of the bomb tonnages dropped in the Gulf involved precision weapons, yet accounted for approximately 80-90 percent of the critical damage achieved. The amount of weapons involved could have been moved by 450 C-141 sorties, which at logistics rates of effort witnessed in the Gulf, could have been completed in four days. The implication is that a major air campaign can be supplied quickly, because the

[19] von Clausewitz, Carl, *On War*, ed. and tr. Michael Howard and Peter Paret, Princeton University Press, Princeton, NJ, 1984, p 90.
[20] The year in which history reflects a change in thinking from Clausewitz's 'On War', published after his death in 1831, is 1883, when von der Goltz published his 'The Nation in Arms'. This is discussed lucidly in Martin van Creveld, *The Transformation of War*, Macmillan, New York, 1991, p 43.

quantity of Precision Guided Munitions (PGMs) needed to inflict the required levels of damage demand comparatively little air transport.

Attacks on an enemy's strategic centre, one capability at a time, provide that enemy with the opportunity to fix the first target while the second or third is being attacked, as seen in Korea and Vietnam. This form of 'series' attacks was argued against, for the air campaign in the Gulf. The Gulf War, through the use of stealth and precision, witnessed 'parallel' warfare, in which the whole breadth of strategic targets was attacked and the entire strategic base crippled in the first few days.[21]

When an air campaign is being planned,[22] the number of targets and aim points must drive the types and numbers of sorties needed. This number, *inter alia,* should be the determinant of force structure for a military force, and the use of offensive air power should be considered fundamental to any defence plan. Numbers of sorties required to cover all aim points is an output which can actually be measured and which could be 'factored in' to many existing models.

Eighteen months of the Combined Bomber Offensive in Germany could probably be done in 1991 in 18 days, using the concept of five strategic rings to help determine targets, and stealth and precision to attack them. In determining the most appropriate method of affecting strategic centres of gravity, planners would be well-advised to employ systemic thinking. For example, one must ask why Schweinfurt and Regensberg were attacked during World War II, when destruction of electricity grids would have achieved the required effect of closing the factories.

THE WAY AHEAD

Now, what of the future? What is the way ahead?

First, the modelling of air/land or air/sea operations is at the outermost ring of an air campaign's objective, and while attention should be paid there, it ought not to be focused there initially. There are five areas to a nation's strategic base and the battlefield extends from the very heart of the nation out to its fielded military forces. While most existing models cover the outer ring, little work has been undertaken on the four inner ones.

Elaborate, complex modelling centring on the threat-based planning of old is most certainly not the way ahead. A more generic-type abstract modelling is. Such models should be oriented to quick reaction analysis which can be tied to rapidly-changing circumstances such as budgets and strategic circumstances for example. Models should incorporate the underlying strategy of an air campaign, how it can be executed, and what the available options are. The overall objectives of an air campaign may be achieved through the roles of airfield attack, air support for land forces, deep

[21] The author is indebted to Group Captain A.G.B. Vallance, OBE, RAF for his explanation of series and parallel air operations, given to the author during his visit to RAF Bracknell in August 1991.

[22] For a comprehensive understanding of planning an air campaign, readers are referred to John A. Warden III, *The Air Campaign: Planning for Combat,* Pergamon-Brassey's International Defense Publishers Inc, Washington, 1989, especially pp 128-140.

interdiction and so on. Accordingly, the roles must be capable of being varied depending on the strategic and operational circumstances at the time.

New abstract approaches to high level models and simulations have made the costs of modelling much cheaper and the time taken to simulate, much shorter. Such approaches also provide the wherewithal to avoid the tendency to reduce the behaviour of complex systems to a small number of arbitrary measures of performance, such as efficiency or combat effectiveness ones. The most reliable measure of performance is the accumulative achievement of objectives over time. That is, the aim should be to achieve objectives, and thus the objectives themselves should be the measure, and the rate of achievement should be used to indicate degree of success.

Any model would need to assess the effect of new equipment, new capabilities, new training and new doctrine on the full breadth of air operations, as outlined in the RAAF's AAP 1000.[23] These operations encompass counter air, strategic strike, reconnaissance and electronic warfare, airlift, and combat support. Additionally, any effect on the ability to sustain the necessary levels of air effort would have to be considered.

While operations analysts can contribute immensely to a model, it would be crucial for aircraft operators and air operations planners to be involved to ensure that the model and subsequent changes remained responsive to the end-user. The RAAF recently produced a futures paper on analytical modelling which examines the generic generation of air capabilities and which remains responsive to the end-user. Any modelling of air capabilities must remain consistent with strategic guidance so as to provide a common set of automated tools to inform force development concepts, force employment and capability planning.[24]

Whatever model the RAAF arrives at in the future, it must be able to be updated automatically to reflect changes in doctrine, training and new capabilities. It may be necessary to develop a series of models to cover each sustainment function and each operational capability. This would have the effect of reducing the maintenance requirement of the model and the manpower needed to develop a full theatre model. With such a modular approach however, the RAAF would need to interface and update the models manually unless a standardised automated feature could be built in. Irrespective, the modular system would probably take longer to run, but would be cheaper and quicker to develop, easier to update and more likely to remain responsive to a wide range of changes.

The greatest problem for the future could be that the direction of modelling may be diverted because sufficient resources cannot be provided. The challenge will be to maintain direction and embrace changes at the outer edges of development or even to slow overall momentum, but to retain the essential direction. That direction should be to produce a predictive tool which provides an analytical method for assessing the impact of changes on the operational environment and use of resources due to the advent of new capabilities or the phasing out of old ones.

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[23] *AAP 1000, Royal Australian Air Force Air Power Manual*, pp 41-45.
[24] Thoms, *Generation of Air Capabilities – Toward a Predictive Model*, p 37.