Shmuel L. Gordon

Dimensions of Quality

A New Approach to Net Assessment of Airpower

The Jaffee Center for Strategic Studies

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Memorandum No. 64 May 2003

The Dr. I. B. Burnett Research Fund
for Quantitative Analysis of the Arab Israeli Conflict

Jaffee Center for Strategic Studies

TEL AVIV UNIVERSITY

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מימדים של איכות:
גישה חדשה להערכת עוצמה אווירית

English Editor: Judith Rosen
Graphic Design: Michal Semo
Production: Kedem Printing Ltd., Tel Aviv

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ISBN: 965-459-050-6

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Executive Summary

The following study presents and explores a new approach to evaluating the relative power of air forces. Most significantly, it proposes a model that allows many complex qualitative and quantitative factors to be processed and incorporated in an overall reading of the strengths of a set of rival air forces.

Until now, measurement in this field has focused on numbers of basic platforms, like aircraft, helicopters, and surface-to-air missile (SAM) systems. This work introduces a different methodology that encompasses several innovative modules. First, it emphasizes quality of systems, manpower, and other elements of power, rather than measuring quantities alone. Second, in accordance with the Revolution in Military Affairs (RMA), it counts and measures precision munitions, command and control systems, advanced intelligence systems, electronic warfare systems, infrastructure, manpower, synergy, doctrine, and planning, which are pivotal elements of modern military power. Third, each element is classified according to categories of quality. Fourth, it applies methodologies and technologies from decision making and economic disciplines to measuring the balance of airpower, and detailed data and assessments of professionals are integrated in a decision making computerized system.

The measurement of quality is not a mere intellectual exercise; rather, it is a systematic endeavor to enhance power assessments. This is especially critical when focusing on aerial balances of power. Air warfare is a technologically intensive medium, in which capabilities are determined in large measure by the *quality* of the assets at a force's disposal, rather than by their *quantities*. These assets include platforms, weapon systems, force-multiplying systems, infrastructure, and personnel. Hence, a comparative assessment of airpower must relate *both* to numbers of systems (aircraft, missiles, and so on), *and* to their qualities in terms of capabilities. In this context, the question of quality then becomes paramount: more accurate missiles hit their targets more reliably; better pilots are more likely to fulfill their objectives and return home alive; better intelligence gathering systems allow forces to locate and destroy more targets faster.

The present work proposes a model that allows for qualitative aspects of power to be quantified, compared, and integrated with quantitative elements, in order to create a more comprehensive picture of a force's strengths and capabilities. In practical terms, the applications of this model are in the field of net assessment, providing tools to assess operational requirements, doctrine, force structure, and resources allocation. In addition, this methodology can serve as a useful tool for intelligence experts to compare the strength and capabilities of air forces, and for assessments of inter-state airpower balances.

To implement the proposed model, the study applies it first to a virtual set of rival air forces. As a more illustrative and valuable demonstration, the model is then applied to a real-world conflict system, and measures the balance of power between the Israel Air Force (IAF) and the combined air forces of a hypothetical Arab war coalition intended to serve as a kind of "reasonable worst case peer-competitor." The application of the model highlights the superiority the IAF enjoys over the coalition as well as over the individual states that comprise it. Specifically, the model indicates that the IAF enjoys a considerable qualitative advantage in offensive capabilities vis-à-vis such a coalition, notwithstanding its arsenal's numerical inferiority. Its qualitative advantage in defensive power is likewise significant. These outcomes are later confirmed by extensive sensitivity analysis tests, which further validate the integrity of the model.

In the process of applying the model to the Middle East, the study sheds light on the operational-strategic realities prevailing in the region, and on related questions of doctrine and force building. The model demonstrates that the IAF's significant capabilities stem from two major factors. First, the IAF has a distinct advantage in combat systems, owing especially to the high quality of its advanced precision guided munitions and to its advanced aircraft.

The second factor contributing to IAF superiority stems from its advantages in support systems, personnel, and doctrine. The IAF has impressive intelligence gathering and support capabilities, which are tied together in an effective command, control, communications, computers, and intelligence (C^4I) array. It has also mastered the complex doctrinal concepts needed to integrate these various systems into a unified, synergetic *system of systems* – a comprehensive superstructure that ties forces in the air together with command and control systems, and with the means for gathering and disseminating information in real-time. Adding further to the IAF's strength is the quality of its personnel, who are both highly skilled and technically proficient due to focused training.

The assessment undertaken in this study also furnishes insights into the different procurement policies of the region's various states, which in turn invite certain conclusions regarding long-term changes in air doctrine. This is particularly poignant when comparing Israel, Egypt, and Syria, or comparing Turkey and Syria. Analysis of the forces at the disposal of Israel, Egypt, and Turkey strongly supports observations that these states have attempted to make a transition to western air doctrines. In contrast, examining the composition of Syria's air force reveals that it has not effected such a shift.

By quantifying the relative importance of different categories, the model clearly indicates that future efforts at modernization and force enhancement will likely be based largely on developments of precision munitions and target acquisition systems, rather than on the development of new platforms – a pattern that emulates developments in the United States Air Force and the Israel Air Force over the last decade. If so, and given the impressive abilities of its defense industries to develop and field cutting-edge systems, Israel seems assured of maintaining a dominant airpower in both defense and offense in the coming years.

Preface

Quality of systems and personnel is a widely-recognized component of military power, but comparisons of numbers and analyses of quantities dominate most of the "Balance of Power" studies that are published every year. One of the main reasons for the common methodology is the basic assumption that unlike "quantity," which is dependent on absolute sums that are easily measured, "quality" is a very difficult factor to define, analyze, and measure. There is no scientifically objective, generally accepted methodology for quantifying crucial quality factors in the context of determining balances of power. The purpose of this study is to present new methodologies and tools for measuring and quantifying quality, and to suggest a model for assessment that incorporates them.

The doctrinal revolution that has changed the armed forces of technologically advanced states calls for a new approach to power assessment. Yet the effort to build a comprehensive scheme to quantify all forms of military power is beyond the scope of a single study. Thus, the present work will concentrate on developing a model for assessing the relative power of rival air forces. Modern wars have demonstrated the primacy of airpower. From high-intensity (conventional) conflicts (HICs), such as the Gulf War, to certain low-intensity conflicts (LICs), like the 1982-2000 conflict in southern Lebanon, airpower has become a major factor in achieving not only military objectives, but also political goals. However, the need for accurate, detailed measurement of airpower has at times been obscured by assessment methodologies that focus on providing generalized assessments for determining overall balances of power.

The following work is based on the performance (quality) of a number of systems and other factors that play a role in the effectiveness and capabilities of air forces: weapon systems; command, control, communications, computers, and intelligence (C^4I) systems; platforms; means for electronic warfare and surveillance; and others. It will also address questions relating to the "human factor," among them, manpower capabilities, quality of training and doctrine, and motivation.

The goals of this study are to:

1. Propose a model as a tool for comparison and net assessment of balances of airpower among the forces of different states
2. Test the proposed model by applying it to a real-world conflict system, in an attempt to provide theoretical and practical insights for military and political leaders and policymakers
3. Describe how the model may be used by military commanders and policymakers to assess operational requirements, doctrine, force structure, and resources allocation.

I would like to thank those who helped me complete and polish this study. Special thanks must go to the former and current Heads of the Jaffee Center for Strategic Studies, Professor Zeev Maoz and Dr. Shai Feldman, who encouraged me to pursue this study, and for the Center's generous financial assistance. The comments from my colleagues at the Jaffee Center and from Dr. Uri Bar-Yosef were useful and constructive, as were those of many others I consulted, both in academia and the Israel Air Force. Daniel Levine, who made my study readable, and Beth Levi, who polished the style of writing, deserve thanks. Notwithstanding the kind assistance of these individuals, responsibility for the views and judgments expressed in this study is mine alone.

Introduction

This study proposes a new approach to evaluating the relative power of air forces in the Middle East. Until now, measurement in the field has focused on numbers of basic platforms, like aircraft, helicopters, and surface-to-air missile (SAM) systems. This work introduces a different methodology that encompasses several innovative modules. First, it emphasizes quality of systems, manpower, and other elements of power, rather than measuring quantities alone. Second, in accordance with the Revolution in Military Affairs (RMA), it counts and measures precision munitions, command and control systems, advanced intelligence systems, electronic warfare systems, infrastructure, manpower, synergy, doctrine, and planning, which are pivotal elements of modern military power. Third, each element is classified according to categories of quality. Fourth, it applies methodologies and technologies from decision making and economic disciplines to measuring the balance of airpower. Most significantly, this study presents a model that allows analysts to process and incorporate many complex qualitative and quantitative factors when seeking an overall reading of the strengths of rival air forces.

Measuring so many different elements introduces a separate challenge: how would it be possible to determine the influence of any individual element (for example, air-to-ground munitions) on the overall power of a given air force? Traditionally, experts in the field were charged with making these decisions, based on experience and intuition. The present study builds on this approach, combining both the subjective assessments of experts together with "hard" quantitative data on both quantities of systems and their quality.

According to the methodology of this study, the main elements of power were defined and classified, and then presented to experts who were asked to determine the weight that should be given to each. The average results of the experts' assessments were used as measures of the importance of those elements. After deciding on the importance of each element of airpower, the experts' assessments and the absolute numbers of each asset (e.g., thousands of missiles, hundreds of aircraft) were inserted into a computerized decision support system, which was designed to normalize the quantitative data together with the assigned importance of each element. In this manner, it was possible to produce answers to various questions about overall power, and the contribution of each element within it. The process was used to derive the offensive power and the defensive power of the rival air forces.

This methodology allows the analyst to "zoom in" on any particular aspect of the results. The analyst can thereby obtain a detailed view of the balance that exists in each of the various components that together make up the total capabilities of rival air forces. Hence also the flexibility of the system, as it enables analysts to change the quantities or importance assigned to each element, and to obtain immediate results.

It is important to emphasize that the purpose of this approach is to formulate net assessments, not to predict which force in a particular inter-state confrontation would emerge victorious in a given scenario. In order to explore the intricacies of a specific conflict scenario, one would have to take variables into account that go beyond each side's levels and quality of hardware and personnel. To gauge the likely outcome of a particular scenario effectively, one would need to make a number of a priori assumptions about the circumstances surrounding the conflict: is the conflict a surprise attack, where one side is caught unprepared? Are there external political-strategic conditions – such as superpower support or the lack thereof – that place limits on the use of specific weapons or tactics? Do meteorological conditions allow specific intelligence gathering or fighting systems to be used to their full potential? Such considerations require the analyst to make assumptions that would curtail the general applicability of the study, by tying it to specific real-world conditions that in actuality cannot be predicted with any degree of accuracy.

The Measurement of Quality

The quantification of quality is not a mere intellectual exercise; it is an instrument for measuring power, determining RDT&E (Research, Development, Testing, and Evaluation) policy, and comparing alternatives of force structure, procurement, training, operational doctrine, strategy, and resources allocation. Furthermore, finding a methodology to quantify quality provides a means for forming intelligence estimates of the power of potential rivals. In addition to determining overall estimates of capabilities, this kind of assessment allows the analyst to define the adversary's centers of gravity and locate points of weakness.

However, the process of quantifying the various qualitative elements of power poses several difficult challenges. Among these are: defining the variables themselves; determining their characteristics and the degree of their interactive influence; assessing the influence of advanced technologies on changes in power; and assessing the quality of manpower.

In particular, the latter two issues require some explanation. A crucial factor in measuring quality in the context of airpower is proficiency in advanced technologies. Indeed, so great is the importance of such proficiency that it must be considered one of the preeminent factors of modern warfare. Moreover, advances in aerospace technology and improvements in the quality of professional manpower complement each other. Therefore, the need to develop a manpower base that is technologically aware is especially vital. This is a difficult process, and as a result, the creation of technological manpower has often become a bottleneck in the qualitative enhancement of many air forces. Hence, it is important to refine methodologies for measuring manpower quality.

Measuring the quality of small numbers of units and weapon systems under predetermined environmental conditions is very different from measuring large forces in a dynamic environment. Airpower in particular is not measured by absolute indicators only, but by relative values as well. Analysis of command and control systems, decision making systems, and electronic and intelligence systems all add important elements to the net assessment of airpower. These qualitative measures are *power multipliers,* which make the quantification of the power of air forces more difficult. Also, state-of-the-art weapon systems require a *critical mass*; that is, a minimum number of systems are needed to accomplish a mission or significantly enhance the capabilities of an air force.

In a broader view, the term *critical mass* has another meaning, referring to the minimal size of the overall system of systems that is designed to harmonize the interactions of the different, mutually-enhancing systems, units, and doctrines. If one component forms a weak link in this integrative structure, the full capabilities of other systems will not come into play, throwing the air force out of balance and impairing its capabilities and effectiveness.

Moreover, the quality of a weapon system or its combat effectiveness is dynamic and relative. The quality of most systems declines as newer, more advanced systems become operational. Attrition due to training (loss of platforms and pilots, for example) is also a factor that can reduce existing power. As a result, part of the effort to procure new systems or to upgrade old ones may be intended solely to preserve one's relative edge in capabilities and power, in the face of procurement and upgrades by rival forces.

Factors Affecting the Balance of Airpower

The term “balance of power” refers to the power of potential adversaries within a given conflict system. Thus, comparative assessments should concentrate on relative power, as it is relevant to the states and conflicts in question, rather than on some abstract or exogenous measure of objective power.

In order to sharpen the methodologies and models of power assessment, some essential parameters of the analysis must be delineated. They include:

Threat and Response

Any international or regional conflict generates a variety of threats that involve different states in varying degrees of intensity and severity. A relative assessment of power should concentrate on the most severe threats first. Determining the severity of a given threat is not easy, given the vagaries of the international environment: each threat is embodied by a different set of conditions, and different capabilities come into play. A number of factors beyond tactical and operational concerns may also prove important, such as international coalitions and treaties, the violation of said coalitions and treaties, and internal conflicts, all of which weaken the capabilities of both sides dramatically. Thus, determining that State A’s air capabilities are greater than those of State B does not mean that State A’s force will necessarily emerge victorious in an actual combat scenario.

The Type and Intensity of Conflict

Types of war can range from theater-wide high-intensity conflicts (HICs) to low-intensity conflicts (LICs) such as counter-guerrilla and counter-terror warfare, and low-level border hostilities. A different possibility, threatening but nonetheless conceivable, is the use of weapons of mass destruction (WMD). Each type of conflict must be studied differently: a force that is highly successful in large-scale, high-intensity conflicts will not necessarily be effective against limited-scale guerilla fighting or cross-border infiltration.

Time and Space

An assessment of power should be framed in terms of time and physical space. Does the assessment relate to the present, or to the next ten to twenty years? Or, is it an historical case study, intended to provide lessons from previous conflicts? The advantage of looking back is the availability of broad and detailed data regarding a conflict whose outcome is known. On the other hand, the ability to provide appropriate and credible forecasts is essential for decision makers and long-term planners, despite possible gaps in the raw data. Similarly, specific characteristics of the region in question are also important because of geo-strategic, meteorological, political, and military considerations.

The Service (i.e., army, navy, or air force) to be Assessed

The broader the scope of a given study, the more difficult it is to produce a valid, reliable comparative assessment, considering the magnitude and diversity of the parameters involved. An assessment of the entire armed forces of a given state, while undoubtedly very useful, would entail a dauntingly complicated endeavor. The assessment of one single operational service arm (in this case, the air force) is easier, but the cost is curtailed comprehensiveness and usefulness to the overall decision making process. Indeed, there are critical linkages between combined forces from land, sea, and air that create both positive and negative effects on overall power. Conversely, by nature, each service has its own characteristics and needs that may function differently in other services. For instance, topography and terrain, which are exceedingly influential for ground forces, are less important for air forces. On the other hand (despite technological advances in sensors and guidance systems), meteorological conditions remain a factor in planning aerial operations, but exert less influence on ground forces.

Categories of Warfare (ground, air, or naval)

One might assume this to be easily defined, according to the parent arm of the service, i.e., the navy would deal with conflicts fought at sea, the air force with conflicts in the air, and the army with ground warfare. In practice, however, it is more complicated: there are certain overlaps in the operational responsibilities of a given state's various armed services, although these tend to vary from state to state. The US provides a good example: some aerial platforms, such as helicopters, are used by the US Army, Navy, and Air Force. Since there is an overlap of authority and responsibility between the different services, the categories of warfare are not necessarily limited by divisions between service arms.

Categories of Systems

A number of significant weapon systems – including information and space warfare systems – that were once the exclusive domain of the superpowers have since been acquired by many smaller states. This has the potential to wield momentous change in the balance of conventional warfare. In addition, the proliferation of WMD and surface-to-surface missile (SSM) systems has led to revolutionary and asymmetric types of non-conventional warfare, and to the creation of completely new scales for measurement and assessment. Faced with non-conventional threats, some states have attempted to overcome them by developing different defensive and offensive doctrines and systems.

Allocation of Resources

All elements of airpower, whether quantitative or qualitative, share a common constraint: dividing finite resources among the demands of budget and manpower. At the same time, overall budget size is not the only relevant variable; equally important is the balance that must be forged between allocations for different platforms, weapon systems, units, training, and infrastructure, in order to maximize a given air force's overall power and capabilities. Moreover, once acquired, budgets can be spent in any number of ways: should a given air force invest funds in procuring a new weapon system, or improve pilot training by adding flight hours? Such a decision represents a trade-off between improving the quantity or quality of systems, and improving the quantity or quality of the manpower tasked to operate those systems. Beyond this, there are additional decisions to be made. Suppose the air force in question decides to direct resources toward procuring new systems, should it acquire more aircraft, precision munitions, C^4I systems, or spare parts?

It should thus be clear that a close review of how resources are allocated can provide useful insights for assessing capabilities and power. However, obtaining sufficient and reliable data on the resource allocations of rival forces is a formidable challenge.

Intentions and Capabilities

In the context of this study, *intention* relates to roles, tasks, and doctrines, while *capability* refers to the degree to which those roles can be carried out, based on the existing order-of-battle. By these definitions, a weaker air force with a limited number of roles may be able to overpower a stronger air force that must divide its resources among a greater number of tasks. For example, the Israel Air Force (IAF), which plays a significant role in the country's national defense concept and in the governing Israel Defense Forces (IDF) doctrine, is committed to a broad list of roles and missions in wartime. In contrast, the Syrian Air Force's missions and roles are of limited scale. A direct comparison of capabilities alone would likely show the IAF to be considerably stronger than the Syrian Air Force. However, evaluating the ratio of roles to capabilities may reveal that the gap between the two air forces is less substantial. A smaller or weaker force may perform adequately when its missions are relatively simple, just as a stronger, more sophisticated force may fail if its capabilities cannot match the roles set out for it.

Configuration of Factors

Having defined in theoretical terms the factors that figure in the analysis of power of a given force, it is now possible to apply them to the actual scope of this study:

Threat and Response

The model offered in this study is designed to compare the relative power of air forces in the Middle East, with particular emphasis on Israel as it faces a coalition of Arab states. This coalition represents the most severe, if hypothetical, threat. In addition, other potential regional conflict dyads, such as Turkey and Syria, will be discussed.

Type of Conflict

The analysis focuses on potential high and medium-intensity conflicts.

Time and Space

The analysis concentrates on the Middle East, at the beginning of the twenty-first century.

Categories of Warfare

The model presented here concentrates on air-to-ground, air-to-air, and ground-to-air warfare. Variations in the command structure of different air forces present challenges for comparison: in Egypt, for example, unlike Israel, airborne platforms and ground-to-air defense systems do not operate under the same service arm. To overcome this problem, the following analysis encompasses all the elements involved in air warfare, regardless of their operational subordination.

Categories of Systems

The analysis encompasses conventional weapon systems only, excluding surface-to-surface missiles and weapons of mass destruction.

Allocation of Resources

While the subject of resource allocation is significant for the reasons outlined above, accurate and timely data is extremely difficult to acquire, since most states keep their national defense budgets secret. Therefore, although this analysis does not explore issues of resource allocation, they remain an important factor for further study.

Intentions and Capabilities

The model defines two general roles for air forces: an offensive role, and a defensive air superiority role, both of which will be defined below.

During the process of constructing the model, the system was run hundreds of times. At each intermediate stage, the results were studied and corrections and improvements were made. The most substantive shortcoming that emerged was the absence of sufficient and reliable quantitative data, mainly regarding precision guided munitions. This lapse prompted additional gathering of data. Upon achieving satisfactory results, implications were examined, insights formed, and conclusions drawn.

After some technical tests, the model and the decision support system were refined within the rubric of several projects:

- The model was implemented in two decision making games that were played out in the IDF's National Defense College.
- After further adaptation, the methodology was put into operation and has played a pivotal role in the decision making process of Israel's Ministry of Defense regarding possible future force development and procurement.
- The model was tested by constructing two "virtual" air forces and evaluating their relative power (see Chapter 2).
- The model's reliability, validity, and accuracy were then verified through sensitivity analysis (see Chapter 4). The verification process examined four types of variables to be used in the model: (a) the impact of changes in the weight of each element (e.g., inaccuracies in experts' assessments); (b) the effects of changes in one expert's view; (c) the influence of changes in the quantitative data (numbers of aircraft, missiles, etc.); and (d) the ramification of changes in the expert assessments of the qualitative elements (synergy, preservation of power, and so on).

These sets of tests proved invaluable in providing experience for further use of the model. They also provided the opportunity to identify and resolve problems as they arose.

The study is organized as follows:

- **Chapter 1** reviews past theoretical approaches to power assessment, with an emphasis on attempts at the quantification of quality.
- **Chapter 2** presents the method by which the new model was built, and demonstrates its use by comparing two "virtual" air forces.
- **Chapter 3** applies the model to a detailed exploration of the existing balance of power between Israel and a coalition of Arab air forces.
- **Chapter 4** aims to verify the results of the model, using sensitivity analysis to measure the effect of errors in raw data or assessments on the overall results obtained.
- **Chapter 5** applies the model to other potential conflict dyads in the Middle East.
- **Chapter 6** provides interim conclusions, and proposes avenues for future research.

Chapter 1

Past Approaches to Power Assessment

The attempt to devise models that allow the comparison of different military forces is not new. Initial theories were developed during the First World War, and grew in sophistication both during and following the Second World War. Models vary both in terms of approach and in terms of the ultimate goal that they are designed to serve. Attempting to "rationalize" a defense budget by means of analyzing cost-effectiveness, or intending to determine force levels for the purpose of a disarmament agreement, will necessarily differ from attempts to measure the effectiveness of two forces on the eve of an imminent confrontation.

This chapter presents a review of the relevant literature and focuses on the development of force assessment models, methodologies, and concepts. The discussion that follows is tailored to the overall goals of this study: hence an emphasis on models that deal with conventional conflicts and balance of power formulations, especially as these relate to airpower. In addition, it will examine the development of methodologies for measuring the overall *capabilities* of forces (especially air forces) and ways of comparing the operational capabilities of different forces.

Each section of the chapter reviews specific dimensions within the development of comparative force assessment. The first presents an historical overview of early attempts during the two world wars and their analytical descendants. The chapter then proceeds to discuss assessment literature in the context of the Cold War, arms control analysis, and the effects of the Revolution in Military Affairs (RMA). Finally, the discussion will explore two issues that are intimately related to the present model: the quantification of power, and the development of capabilities-based assessment.

Initial Attempts at Power Assessment

Efforts at developing a comparative assessment of military power began in the early twentieth century. The first researcher to attempt such a methodology was Lanchester, who proposed a model that emphasized quantity over quality, arguing simply that in order to compensate for a twice-larger rival force, one should enhance the quality of one's own force by two squared (Weiss 1983, 79-82). Lanchester's work appeared in 1913-14 in a series of articles that were published in book form in 1916.

While Lanchester's formula was a notable beginning, its simplistic nature presented a number of deficiencies. First, it made no provision for situational conditions, assuming rather that every given friendly unit would be within range of every enemy unit, and that kill probability did not depend on range. Second, it did not account for movement, retreat, or advance, when in fact, engagements that continue until one side is wiped out are rare; retreat usually begins much earlier. Finally, Lanchester assumed that the composition of units on each side would be identical, whereas in an actual engagement each side would likely field different combinations of artillery, infantry, armor, tactical airpower, and so on.

Moreover, the prescriptive nature of Lanchester's formula is essentially exogenous in its approach; it does not calculate the balance of power as a function of the variables that are part of the battle. By Lanchestrian logic, a force that is sufficiently large should always overcome a force that is sufficiently small – clearly, not an assertion supported by history in any but the most extreme examples. While superiority in numbers increases the *likelihood* of victory, it does not provide a guarantee.

Various methodologies of systems analysis and operations research were developed during the Second World War in order to help resolve certain tactical and technological problems, in turn opening the door for different forms of quantitative analysis (Majone 1985). The initial attempts emerged out of Britain's Royal Air Force (RAF), with the methodologies developed there later adopted by other nations as well. Jones (1978) documented the activities of the first Operations Research Group and its contribution to some prominent RAF operations. The success of these new methodologies created a strong belief that most of the obstacles to quantifying military power could be overcome.

One methodology that gained influence after the Second World War reflected an empirical approach, made possible by the massive quantity of accurate data gathered on all aspects of air warfare, including numbers of sorties; bombs dropped and results obtained; and the performance of individual platforms and weapons. In addition, data was amassed on strategic decisions made by politicians and generals, and the strategic consequences of air operations. This huge body of data enabled MacIsaac (1945) and his team at the US Army Air Force (what would later become the US Air Force – USAF) to produce highly detailed studies about the Allied strategic air campaign against Germany and Japan. MacIsaac's work had considerable influence on USAF operational doctrine and strategy, especially on the choice of enemy national and military assets as prominent targets. However, while MacIsaac's work answered some questions about the effectiveness and efficiency of strategic bombing campaigns, it did not produce a model that would allow qualitative and quantitative factors to be measured together.

A research effort similar to MacIsaac's was carried out by a team led by Eliot Cohen more than forty-five years later, in the wake of the Gulf War air campaign (Cohen 1993). This more recent effort, while satisfying the need for raw data and broad analyses of processes, successes, and failures, did not undertake a quantified analysis along the lines proposed in this study. Indeed, despite the author's recognition of the revolution in air warfare caused by new weapon systems, C^4I systems, and electronic warfare systems, quantified analysis remained very thin (Cohen 1993, Vol. IV, 252).

During the 1960s, the US Department of Defense (DOD) made efforts to develop and adopt methods to quantify the economics of defense, and to apply cost-effectiveness calculations to weapon systems and military units. This type of approach can play an especially dominant role in the formulation of annual defense budgets. Former US Secretary of Defense Robert McNamara was a pioneer in this direction, though his success in the field was only partial. His tenure saw a general enhancement of both theory and practice in evaluating and overseeing economic factors and considerations in the activities of the DOD and related bureaucracies. On the other hand, his team tried but was unable to produce assessments of power that served the requirements of the armed forces. Consequently, McNamara inadvertently set back the cause of quantitative assessments of quality by some years.

Some explanation for this lack of success may have been the inability to marry economic concepts of cost-benefit to the other side of the equation: the effectiveness, efficiency, and strength of the force in formation. Enthoven and Smith (1969) illustrated these shortcomings in their analyses of the B-70 and TFX (F-111) projects, demonstrating insufficient attention to effectiveness considerations, technological limitations, and operational requirements. Hitch and McKean (1969), themselves "McNamara Kids," argued that in practical problem-solving, the analyst must look for "proximate" criteria and data that serve to reflect what is happening to military strength. Davis (1994) claimed that defense planning during the McNamara era did not focus sufficiently on operations planning and capabilities.

Another point should be made in reference to annual budgets. The US Air Force spends only about 24% of its entire procurement and development budget on main platforms, specifically, new aircraft. The years 1985-1996 saw a decline of 28% in the number of US aircraft and 73% in aircraft purchases (Tirpak 1996, 23, Table 4). Clearly, the USAF deliberately gave priority to advanced weapon and electronic systems rather than large numbers of new aircraft. This represents a conceptual shift to which the analytical community has yet to adjust. Furthermore, the DOD now devotes a considerable share of its budget to creating the "technological infrastructure," in order to advance the military potential of a wide range of future technologies. Overall, however, there is insufficient detail regarding allocations of resources to allow for detailed and insightful analysis of how this factor influences building armed forces.

Following the Vietnam War and the 1973 Arab-Israeli War, new considerations dominated the process of defense planning in modern military establishments, mainly due to the introduction of precision guided munitions. Despite previous failures, analysts all over the developed world renewed their efforts to design models to quantify military power. Dupuy (1979) published an experiment that sought to explain the outcomes of wars based on a quantified model that measured the power of the participant armies or forces. His model was sensitive to a number of qualitative elements (among them, an element he called "national fighting effectiveness"). Dupuy's experiment did not, however, win much support. It was criticized because of a number of miscalculations and illogical equations, and its lack of utility as an effective tool for the assessment of existing forces and for planning future force structures. Nevertheless, this pioneering research broke new ground with its claim that judgments and assessments of expert professionals could be quantified.

The Cold War Influence

The superpower competition of the Cold War spawned a new kind of research that emphasized balance of power assessments, based on economy, population, territory, and nuclear forces as the main sources of national power (Cline 1975). Cline's work sought to ease the formidable task of describing various elements of international power, and drafted a set of formulae to correlate these factors. However, Cline was under no illusions regarding the limited utility of his model, acknowledging that his system was "not a magic measuring rod, for the variables are not absolutely quantifiable. It is simply a shorthand notation or index system to replace words and judgments, once these have been defined" (p. 11).

During the Reagan Administration, strategic planning emphasized the possibility of a global conflict with the Soviets that might potentially escalate to nuclear war. Significantly, the RAND Corporation's work reflected the differing fighting quality of armies highlighted by Dupuy, and the special non-Lanchestrian nature of operational-level breakthroughs due to forward defenses with poor force-to-space ratios (Davis 1994, 24-29).

Some additional steps were taken in Europe, when Lutz (1986) detailed the difficulties of measuring military power. His research highlighted a number of significant issues related to the quantification of important qualitative elements. It addressed the complexity of the subject in general; the definition of quality in terms of battlefield capability; the difficulty associated with the collection and assessment of quantitative data; the use of scenario analysis to simplify complex issues; and the comparison of defense expenditures. His research, however, concentrated primarily on nuclear forces. Perhaps for this reason, it lacked many parameters required to analyze conventional conflicts effectively.

Among the most visible products of the Cold War-inspired balance of power school of analysis are annual publications dedicated to monitoring the balance of power in specific regions or within specific conflict systems. Produced by institutes such as the International Institute for Strategic Studies and the Jaffee Center for Strategic Studies, periodicals such as *Military Technology* and other “Balance of Power” studies use numbers of main platforms in order to analyze the strengths and weaknesses of nations, and the combined strength of potential coalitions. During recent years, details about modern systems and force multipliers have been introduced into these studies, but no numbers, operational data, or implications have been printed or discussed (IISS 2001; Feldman and Shapir 2001; SIPRI 2002).

Arms Control Analysis

Closely resembling the formulation of Cold War era balance of power assessments are efforts to quantify the armed forces of states that seek to enter into arms control agreements. Most arms control negotiations in the twentieth century sought to reduce or restrict forces; to do so effectively, it was necessary to find ways to quantify and compare the power of military systems that were organized along inherently different lines, and which therefore resisted direct comparison.

The first successful attempt to negotiate an arms control agreement was completed in 1921 at the International Conference on Naval Limitation in Washington. From the viewpoint of power assessment, the Washington Conference is interesting because it focused on overall numbers of capital ships only, thus ignoring the qualitative factors of aircraft carriers and submarines, which had proved their capabilities in the First World War.

The next significant effort to limit conventional forces occurred more than fifty years later, with the 1973 Commission on Security and Cooperation in Europe (CSCE), and the Mutual and Balanced Force Reductions (MBFR). The objective of these talks was to produce a measurement of the balance of power as a baseline for further discussions. The MBFR talks began with NATO's proposal to decrease numbers of troops, regardless of qualitative considerations such as numbers of elite units, armor units, or infantry. McCausland (1996) noted that among the difficulties encountered in these talks, the most significant focused on reaching agreement on quantities. Indeed, this obstacle has continued to hamper efforts, both academic and governmental, toward building a database acceptable to professionals and policymakers.

In the post-Cold War and post-Gulf War environment, both governments and analysts have begun to deal with regional arms control (Feldman and Levite 1994). Such analyses remain in a nascent state, as a number of significant elements have not been adapted to the new capabilities of manpower and weapon systems. Moreover, most analyses continue to concentrate on non-conventional weapons and on quantities, rather than on capabilities of main platforms and their deployment. Important issues such as modern conventional weapon systems and power multipliers remain insufficiently defined, limiting the accuracy of these assessments.

Proof of this assertion may be found in the Conventional Armed Forces in Europe (CFE) Treaty. The CFE accord was signed in 1990 between the members of NATO and the Warsaw Treaty Organization (WTO), and limited five categories of weapons: tanks, aircraft, artillery, attack helicopters, and armored combat vehicles (ACVs). Here too, no quality classifications were made within each category – the focus was on numbers of units, and not on their capabilities. High-quality US-made multi-role aircraft were compared to older, less capable Russian ones, with no distinction made between them (Crawford 1995, 7).

More recently, Cordesman (1999) authored a balance of power analysis written from the point of view of arms control. His analysis, which focused on the Middle East, revolved around three primary issues, namely:

1. A detailed survey of each state's available resources and weapons imports
2. An examination of different ways to count force, with possible ways to reconcile force quantity with force quality
3. The premise that different scenarios have a strong influence on the overall balance of power

By counting high-quality platforms separately, and by making calculations of economic and manpower resources, this study significantly advanced the discourse on both arms control and force assessment. Nonetheless, its success in measuring the military balances of the armies, air forces, and navies of all Middle East states in a variety of different scenarios was limited by the failure to include all aspects of high-quality precision munitions in the calculations.

The Revolution in Military Affairs

The technological revolution in the capabilities of armed forces in general, and air forces in particular, was first demonstrated in the Lebanon War. However, the tight curtain of security drawn by the Israel Defense Forces around the war prevented full recognition of this change. Only with the Gulf War did a full understanding of the RMA significance emerge, and thus more recent literature encompasses methodologies and approaches to measuring the new elements of airpower.

Leading examples are studies by RAND Corporation analysts. Davis (1994) recommended that defense planning shift from concerns about force structure to concerns about configuration, diversity, new operational concepts exploiting technology, and information dominance where achievable (p. 40). Davis also called for a shift in the kind of analysis that should occur: rather than planning for projected needs or threats, government institutions should identify a broad range of important operational objectives and then emphasize “capabilities-based planning.” As Davis noted,

> Such planning is much better suited for encouraging diversity and adaptation than “requirements-based” or “threat-based” planning, where attention focuses on meeting estimated needs for a few precisely defined threat scenarios. (p. 5)

According to these and other studies, measuring capabilities is essential for an effective build-up of military power.

Quantifying Military Power

Quantifying military power involves a number of different disciplines. Strauch (1983) noted several different fields of study required to quantify military force effectively.[1]

[1] Strauch lists these various disciplines as follows: operations research, game theory, mathematical methods, computer simulation and modeling, probability theory and statistical inference, econometrics, decision theory, using experts to “score” weapon systems’ effectiveness, net assessment, systems analysis, and “Decision Makers Pragmatic Process.” For a concise summary of various efforts at scientific analysis, see Stockfisch (1987).

However, despite worldwide recognition of the significance of modern weapon and electronic systems, the commonly-accepted practice of comparing forces based on counting overall numbers of main platforms (aircraft, tanks, and so on) – without looking at their relative capabilities – persists largely unchecked. For example, a 1994 study examining the use of long range bombers presented the inventory of aircraft and tanks in various countries around the world, and used these numbers as the main criterion to measure military capabilities (Buchan 1994, 397-99). No mention was made of the relative capabilities of these arsenals.

Over recent decades, computerized simulations and mathematical models have become prominent tools for the assessment of military capabilities. Since it is impossible to create one simulation for every possible level of engagement and to input the enormous amount of technical and operational data for every weapon system in existence, a number of partial models and simulations have been constructed. A concerted effort is underway to use a collection of partial simulations as "building blocks" for a comprehensive simulation of campaign-level engagements. Significantly, this "collective elements" approach is analogous to Aspin's "bottom-up review" methodology (Aspin 1993).

However, this approach does not lack for critics. Buchan (1994) noted ironically that:

> Just sorting through the "alphabet soup" of models of various sorts can be a considerable challenge, and selecting the appropriate model for specific applications can be an art in itself since they differ dramatically in scope and level of detail. . . . There is a great danger of missing the forest for the trees and risking really misleading policymakers. (pp. 404-07)

Nor is Buchan alone in his criticism. The "aggregation" approach has raised objections from others in the analytical community. Hillestad and Juncosa (1993), in their aptly-titled *Cutting Some Trees to See the Forest*, expressed their doubts as well, noting that the building blocks of different models are not sufficiently mature for the pragmatic assessment of military capabilities:

> Although we do not suggest that the Lanchester square law is a realistic depiction of actual conflict, the fact that, even for this linear system of equations, consistent aggregation and disaggregation cannot be done without severe restrictions…[implies] that *ad hoc* approaches to varying resolution may not lead to consistent models. . . . The frequent absence of any empirical data on how forces or weapons might fare in battle has often

> forced analysts to build models in high detail in hopes that engineering test data can be extrapolated to combat outcome. Frequently, however, this approach amounts to compounding assumptions upon assumptions regarding interactions in conflict, assumptions that are completely subjective. (p. 19)

Recent publications continue to praise modern and future military technologies and doctrines, while ignoring useful data and quantified analysis (Keany and Cohen 1996). From the methodological point of view, however, some studies have made important progress. Cordesman, writing in 1996 about the Arab-Israeli military balance, dealt with quantities, qualities, and budgeting, explaining difficulties of definitions, fine assessment, analysis, and scenarios. A study published by Brower in 1997 formulated an analysis of the balance of airpower in the Middle East, defining in detail some of the significant elements of airpower and comparing some of the capabilities of the Middle Eastern nations. While including a number of important factors, the results indicated the need for some fine-tuning: Brower found that the power of the Israel Air Force had increased *51 times* since 1973, and that its capability to destroy hard targets was 7.5 times greater than all the Arab air forces put together (Brower 1997, 11, 19). Such conclusions, when compared to those that will be presented in the forthcoming chapters, seem greatly exaggerated. They may have resulted from a lack of accurate data, or they may be related to inaccuracies in methodology and errors in equations.

Analysis of Capabilities

The general trend in assessments has now moved in favor of the analysis of capabilities. As Frostic and Bowie (1994) noted, the “campaign-oriented style of analysis has become a central feature of [US] defense planning” (p. 351). The authors described in some detail a typical military campaign of the sort RAND has used extensively in assessing capabilities, and concluded: “Most of the discussion could have applied to warfare for many years past” (p. 383). However, only two pages of their study comment on the implications of deep fire against enemy forces. There is no significant comment on the revolutionary influence of modern systems on considerations such as mobilization and logistics.

One of the authors, an experienced fighter pilot, has argued elsewhere that the use of precision weapons in large numbers has added a new dimension to air warfare. The ability to see enemy dispositions and movements throughout the battle area enabled Allied airpower in the Gulf War to realign whenever the Iraqis relocated.

Surveillance sensors, combined with systems that could operate around the clock, denied the Iraqis any potential sanctuary. The capabilities that produced such dramatic effects were weapon systems such as the JSTARS and LANTIRN targeting and navigation systems, global positioning technology, and advanced platforms like the F15-E (Frostic 1994, 61-67). Thus, the present research intends to confront the challenge of providing quantitative analysis in light of these new systems and their capabilities.

The aforementioned lapse in capability analysis is not uncommon, even in studies that have appeared since the 1991 Gulf War. Papers by Bowie (1995a and 1995b) and Harshberger and Shaver (1994) shared similar flaws. Bowie's analysis was limited by its rather conservative emphasis on platforms, and the concurrent lack of attention it gave to weapon, avionic, and C^4I systems. Indeed, the study contained data only on aircraft, helicopters, surface-to-air missiles, and economic issues, and hence its restricted focus. Furthermore, the limited alternatives it presented for airpower modernization, which dwelled on the number of modern aircraft (i.e., platforms) the force in question must procure, represented the conservative, outdated premise that a state's annual expenditure on airpower should be devoted primarily to the procurement of new aircraft. Harshberger and Shaver focused the bulk of their analysis on aircraft, ignoring other factors such as C^4I systems, which tie independent platforms and weapons together into an overall system with synergistic effects. These systems also need modernization, in order to guarantee air superiority and air-to-ground capabilities.

Significantly, however, there are some analyses that meet the challenges presented by the impact of modern technologies on air warfare and airpower capabilities. Senior analysts at RAND formulated a framework for the evaluation of airpower regarding relative capabilities (Bowie et al. 1993). In it, the authors factored the effects of modern weapons, airborne and ground-based C^4I systems, surveillance elements, and other force multipliers into their analysis. While this methodology included a set of simulations and models whose validity remain unproven, the work was a considerable step forward towards advanced assessment and planning of airpower capabilities.

The model proposed in this study follows my article in *The Middle East Military Balance 1999-2000* (Gordon 2000), in which I proposed a methodology that would differentiate between qualitative elements and quantitative ones, and listed sets of key elements of force assessment and their relationships. I also suggested directions for future research; this study builds on and broadens the tentative conclusions of that article.

Chapter 2

The Model

A fundamental assumption of this research is that military power in general, and airpower in particular, should be measured mainly by operational, quantifiable capabilities. However, it must be emphasized that capabilities are dependent on a number of factors, including quality of means and manpower and their respective quantities. Before proceeding, therefore, it is necessary to define the various qualitative and quantitative elements of airpower, such as aircraft, weapons, manpower, and so on. This chapter delineates these elements and then outlines the methodology and procedures that were used to develop the model.

The chapter is divided into the following sections:

- *Determining the Elements of Airpower*

Which elements are to be considered when trying to determine airpower? What systems are needed, and what roles do they play? How are differences between offensive and defensive combat to be expressed?

- *Quantifying Expert Assessments*

The list of elements of airpower was presented to independent experts, who were asked to evaluate the elements and propose suggestions. Given the prominence of expert assessments in the overall functioning of the model, compiling a set of factors acceptable to the experts was a crucial step.

- *Phases of Constructing the Model*

Once the various factors affecting airpower were selected, it was necessary to construct a working model that would reflect the complex interactions between these factors. This raised certain questions, such as, what was the relationship that existed between manpower and platforms, or between platforms and munitions? Given the relationships, how was the relative importance of each element to be assessed as a part of the overall whole?

- *Demonstrating the Model in Use*

Against this background, the model will then be demonstrated by means of comparing two “virtual” air forces. This will give the reader a sense of how the model works, before proceeding to a full-fledged comparison of real-life air forces.

The chapter will conclude with a brief discussion of the limitations of the model, and the ramifications for future aspects of research.

Determining the Elements of Airpower

The first phase of building the model involved creating a list of the various elements that affect airpower and assessing the relative importance (or *weight*) of each. The outcome of this process was an index of weighted elements. The following section describes the creation of the index: drafting a master list of elements, and developing a process to determine the weight that should be assigned to each.

1. Initial Phase

The process of building the model began with defining the study’s objective in the context of the current geopolitical environment. Next was the need to define the primary operational roles assigned to each air force considered in this model, and the capabilities required to carry out those roles.

During this phase, it was decided that the optimal procedure for compiling a useful index was by creating categories of criteria. For example, offensive and defensive platforms, aircraft, missiles, and the like were grouped together in the category of systems, while numbers and types of bases, repair facilities, and so forth were gathered into the category of infrastructure. Each category was then divided into sub-categories, for example: the systems category was divided into platforms, weapon systems, support systems, and so on. In some cases, the sub-categories themselves were broken down further: weapon systems were thus divided into air-to-air missiles, air-to-ground missiles, and so forth. Once an initial list of elements was drafted, it was discussed thoroughly with professionals in the relevant fields. Their feedback was used to refine the list and to formulate a more detailed index.

2. Selection of the Elements

At the outset, a group of military experts was chosen to take part in the selection and classification of the elements of aerial power, and to calculate the weight to be assigned to each.

The critical role of the experts and their independent judgment was essential to constructing the model. Therefore, a heterogeneous panel of 21 experts was assembled, although not all participated in the entire process. Members of the panel, none of whom were in active military service, included professionals from four related but distinct fields. The experts were:

- Members of aircrews and commanders of air force units
- Operations researchers and systems analysts
- Intelligence officers
- High-ranking officers of the ground forces

The experts were asked to rank the elements according to their overall influence on airpower. In this way it was possible to eliminate low-scoring elements that did not play a significant role in the total quotient of airpower. The result of this process was a ranked list of elements, which enabled the attempt to build a credible and practicable model for quantified assessment. Before this list can be presented, however, a brief review of the factors that determine the capabilities of air forces follows.

3. Factors that Determine Capabilities in the Air

Aircraft and Helicopters

Comparative analyses are frequently based on quantity and types of aircraft and helicopters. Such comparisons have traditionally emphasized maximum speed, payload, flight ceiling, and similar measurements. More important nowadays are maneuverability, acceleration, stealth, ease and cost of maintenance (maintainability), and adaptability in the face of new weapon systems.

Avionics

The operational capability of any aircraft also depends significantly on the performance of advanced avionics, which enable target detection and acquisition, including radar for air-to-air and air-to-ground missions; fire-control systems to exploit the advantages of precision guided munitions; navigation and communications systems; and electronic warfare (EW) systems, which enhance survivability in a hostile environment. These systems can dramatically affect an aircraft's performance, even for variants of the same airframe. There is a world of difference between the F-15A, a single mission, air-to-air aircraft, which lacks most of the systems needed for air-to-surface missions, and the F-15E, with its advanced systems for multi-role deployment.

Munitions

Here the emphasis is on the capacity of the platform – whether a fixed-wing aircraft, helicopter, or surface-to-air missile battery– to employ advanced munitions. A platform lacking precision munitions is like a toothless tiger. For example, an F-117A Stealth Fighter may succeed in penetrating enemy air defenses undetected, but without laser guided munitions, it will not be able to acquire and destroy its intended target.

Sensors, Intelligence Gathering, and Target Acquisition

Additional bottlenecks in improving aerial warfare capability often concern abilities needed to gather information, to detect targets, and to assess the results of operations. These abilities are related to sensors, intelligence gathering systems, and target acquisition systems. Integrating airborne warning and control systems (AWACS), joint surveillance target attack radar systems (JSTARS), satellites, and more traditional means of intelligence gathering is crucial to the quality of airpower. Consequently, modern air forces devote considerable resources to the development and procurement of intelligence systems.

Airborne Support Systems

There are additional airborne support systems that are essential to overall capabilities. These include satellites, unmanned airborne vehicles (UAVs), air-refueling planes, and airborne electronic warfare systems. All of these are intended either to augment the capabilities of aircraft and attack helicopters, or to replace them.

C^{4}I Systems

Battle management (command in real-time) requires sophisticated command, control, communications, computers, and intelligence processing systems (C^{4}I). Since the speed of decision making processes in air warfare is very high, the quality of C^{4}I systems is a dominant element in determining operational effectiveness.

Quality of Manpower

For any force that places high standards on planning, execution, and maintenance, manpower quality is a key element in tapping the full potential of the technologies, weapons, and C^{4}I systems. Beyond a certain baseline quantitative threshold, the *quality* of the manpower takes clear priority over *quantity*. For example, after a necessary number of pilots have been trained, a manpower budget might be better used to provide more advanced training to a smaller number of pilots.

R&D and Industrial Infrastructure

Most of the systems with which small and medium-size air forces are equipped – particularly main systems – are developed abroad. Advanced R&D and industrial infrastructures are required to adapt them to local requirements and conditions, and to develop and produce specialized systems and components. For example, Israel's industry has developed high-quality products such as avionics systems, originally intended for the Lavi fighter. Though the Lavi itself was scrapped by the Israeli government in the late 1980s, the technologies developed for it are now used to enhance existing aircraft and munitions. Israeli defense contractors have the ability to execute sophisticated projects such as upgrading the Phantom jet and the CH-53 helicopter. Unique developments, such as the Arrow anti-ballistic missile (ATBM) system and the Python 4 air-to-air missile, are indicative of the level of Israeli defense industries. Brower (1997) has asserted that the Israeli electronics industry, most notably its pool of military-aware software developers, engineers, and scientists, has had the single greatest impact on the military balance in the Middle East over the last decade.

Advanced Technology

Advanced technology is also essential for various logistical, maintenance, and organizational systems that support planning and operational levels. To enhance the qualitative edges conferred by advanced technology, air forces must maintain external industries that engage in development and production, to ensure that their development programs remain linked to the systems' designated needs and uses.

4. Operational Roles

The comparison of rival air forces cannot be properly undertaken without discussing the operational roles assigned to each one. This includes consideration of each one's particular force doctrine, and the overall national defense concept within which it operates. An air force tasked with a large number of complex and demanding missions in wartime may find itself hard-pressed to fulfill those tasks, even if it is, from an overall viewpoint, superior to its rivals. In contrast, a relatively rudimentary force that is able to devote all of its resources to a single mission may find that it is able to compete against a larger, better developed force that needs to divide its time and attention among a number of different missions.

The model developed in this study has defined two major roles: offensive air superiority on the battlefield (i.e., the capability to destroy surface targets and airborne and surface-based threats), and defensive air superiority. In this context, it should be recalled that, unlike land-based forces, an air force is unable to conquer and hold territory. It is used to seek out targets for annihilation. To do so effectively, it must have several different capabilities. These are noted below, within the rubric of the offensive and defensive operational roles that this model examines:

a. Offensive Superiority over the Battlefield

Offensive superiority over the battlefield is aimed at achieving control of the battlefield and obtaining freedom of action and movement for air and ground forces. Within this framework, an air force's missions include, but are not limited to:

- Defeating, destroying, or neutralizing enemy ground forces
- Eliminating weapons of mass destruction, including the missiles intended to deliver them
- Destroying centers of gravity and points of weakness, such as strategic targets, C^4I systems, and other essential ground targets
- Achieving superiority over opposing aircraft and SAM arrays

To achieve these ends, an air force must be able to destroy a large number of different targets in a short time, inflicting heavy losses on enemy forces while maintaining a low attrition rate. This in turn demands the ability to shape an autonomous capability – that is, capability independent of other functions, such as intelligence gathering – to destroy arrays of ground forces, air defenses, SSM systems, and strategic infrastructures deep inside enemy territory. Accomplishing these tasks requires achieving air superiority over enemy territory as well as one's own.

Achieving freedom of action requires a far-reaching qualitative advantage in manpower, operational planning, real-time command of operations, and exploitation of advanced technologies. The successful combination and implementation of these tools, and the resulting immense destructive potential of modern airpower, was powerfully displayed in the Lebanon War and in the Gulf War.

b. Defensive Air Superiority

The other basic role of any air force is defensive air superiority – defense of the homeland and its armed forces. This role can be performed by using different systems or combinations of systems, namely:

- Interceptors, assisted by early warning and C^4I systems
- SAM systems, assisted by early warning and C^4I systems
- Combinations of interceptors and SAM systems

Since the Vietnam War and the Israeli-Egyptian War of Attrition, opinions have been divided over which represents a more effective form of air defense: SAM systems or aircraft. While the advent of new technologies, notably stealth technology, has added a new wrinkle to this debate, there is in fact no real contest. The optimal air defense consists of integrating many different systems into an overall "system of systems," which combines interceptors, SAM systems, and many additional support systems.

The discussion of operational roles and air doctrine also embraces a more nebulous group of factors that affect airpower. Unlike the factors listed earlier in this chapter, however, these are of a more conceptual and organizational nature. For example, to what extent has a given force's commanders internalized doctrinal concepts that enable maximizing the resources at their disposal? This set of factors can be divided into three main groups: system of systems, preservation of power, and operational culture.

System of Systems

Large combined campaigns involve the integration of a range of systems and units into a cohesive force to execute different missions. Moreover, air forces themselves consist of a broad range of systems and units. Their tasks are complex and difficult to accomplish, not least because they encounter defenses in the form of large, highly potent arsenals. To accomplish its missions swiftly and with the lowest number of losses, an air force must integrate various systems and units within a comprehensive *system of systems*. This integration has two advantages: first, it produces a synergistic effect. That is, by combining a number of systems and units, the "whole" becomes greater than the sum of its constituent parts, enabling better results to be achieved with a smaller force. Second, such systems provide backup: if one system or formation does not function as expected, other systems and formations that have been integrated into the operation can fill the gap. The more difficult the situation – for example, the more unfavorable the force ratios, or the greater the intensity of threats – the more synergistic capability is necessary to ensure the favorable outcome of air operations.

Preservation of Power

Airpower should be organized and operated on the premise that preservation of airpower during and after a war is crucial. The scarcity and vulnerability of major weapon systems, and the vital need for a strong air force throughout any conflict and its aftermath, demand tenacious adherence to this tenet. At the tactical level, this encompasses far-ranging efforts in order to ensure the survivability of main platforms, C^4I arrays, infrastructure, and other elements.

Attrition of airpower is caused primarily by the intensity of operations that a force must undertake. Therefore, the nature of the threats faced by a force and the importance of its missions help battle planners determine whether the risk associated with a specific mission is justified. Among the other factors that affect preservation of power are the relative quality of manpower and weapon systems at the disposal of enemy forces, real-time planning and command, decision making processes, and weather conditions. The IAF in the Lebanon War, the western coalition in the Gulf War, and the NATO alliance in the Kosovo conflict were air forces that preserved their power and hence were victorious. Since deterrence has become an important role for armed forces, and since air forces have become a major player in combat doctrine, a strong level of airpower must also be maintained in order to preserve deterrence capabilities throughout the fighting and after. This requires preservation of power both at the strategic and tactical levels.

Operational Culture

Operational culture is the set of values and norms that guide the behavior of a core group of military forces. For example, a culture can foster taking initiative to gain an offensive advantage. An offensive approach seeks to shape the campaign and to create preferential conditions so that an air force can employ its full potential while ensuring high survivability**.** Loss of initiative is liable to result in a loss of air superiority, and will thus reduce an air force's effectiveness. At the same time, any cultural propensity must coordinate with external factors, such as environmental conditions, the realities of a given situation, the guidelines given by the political and senior military leadership, and the enemy's specific weaknesses.

Quantifying the Experts' Assessments

The experts weighed the various elements of airpower mentioned above, and their weight assignments were then incorporated into the model, as represented in Tables 1a and 1b.

Table 1. Elements of Airpower

Table 1a. List of Elements and their Importance

(On a scale of 0-10; 0 = least important, 10 = most important)

Elements of Airpower		Weight
Operational Capabilities and Roles		9.7
	Offensive superiority over the battlefield	9.5
	Defensive air superiority	7.7
Systems		9.7
i.	***Combat Systems***	9.25
	Aircraft	9.6
	Helicopters	8.2
	Air-to-air munitions	9.5
	Air-to-ground munitions	9.5
	Surface-to-air systems	6.8
	Additional platforms (UAVs, satellites)	7.0
ii.	***Airborne Support Systems***	9.0
	Intelligence systems	9.2
	Electronic warfare	8.5
	Technological infrastructure	8.7
	Physical infrastructure and logistics	8.3
Manpower		9.3
	Aircrews	9.7
	Support manpower	8.5
Infrastructure		8.3
	Air bases	8.6
	Logistics	8.4
	C^4I	9.0
System of Systems		9.5
	Synergy	9.3
	Rate of operations	9.4
	Preservation of power	9.2
	Operational culture	9.6

Table 1. Elements of Airpower
Table 1b. Tabulated Results

Degree of Importance	Number of Elements	%
9 and above	17	60.7
8 – 8.99	8	28.6
Less than 8	3	10.7
Total	**28**	**100**

A cursory review of Tables 1a and 1b reveals that most of the elements presented to the experts were rated quite highly, a result that seemed to confirm the validity of the preliminary phases of the process. With regard to air defense, a close examination of the results reflected a marked disagreement among the different experts. Respondents with an air force background rated this capability more highly than did those without such a background. As a result, this role received a surprisingly low rating.

Some of the results noted above reflect priorities and doctrines of western-oriented forces such as the IAF and the USAF. Such doctrines, which emphasize offensive approaches, tend to downplay the importance of surface-to-air defensive systems. It seems reasonable to assume that Russian and Syrian analysts would rate them differently.

In addition, the balance between aircraft and attack helicopters on the one hand, and platforms such as remote piloted vehicles (RPVs) and satellites on the other hand, has shifted in favor of the latter. However, it is to be expected that not all scholars and professionals would immediately recognize or confirm this phenomenon.

Phases of Constructing the Model

The list of weighted factors that affect airpower created a basis for determining how to analyze airpower in a general sense. However, these factors then had to be incorporated into a comprehensive model that would group them together in related categories. The categorization fulfilled two goals. First, it provided a way to express the functional interactions of different elements, as will be shown below. Second, and no less important, it gave the model a modular structure. This allowed specific comparisons of each element to be made between different forces, as will be demonstrated in the following chapter.

1. Creating the "Parameters Tree"

The elements defined in consultation with experts were divided into *categories* (systems, manpower, infrastructure, system of systems), each of which was then divided into several *sub-categories*, which in turn were themselves divided: each sub-category was divided into *groups*, which were then divided into *types*, and were further differentiated by both quality and performance as *parameters*. This yielded an overall "tree" of parameters, as represented in part in Figure 1.

2. Incorporating the Experts' Answers into the "Tree"

The parameters tree was distributed to the experts, who were asked to rate the relative importance of each element, by giving it a percentage of the weight of each given category, sub-category, group, or type. Since each individual element is expressed as a percentage of the weight of the entire class, the sum of the weight of the elements within each breakdown will be 100. Thus, giving one element in a class a high score necessitates reducing the importance of related parameters in the same class. For example, if combat systems (an element in the systems category) are assigned 60% of the total weight of the systems category, then support systems (the other element in the same category) must score 40%. Figure 1 illustrates a partial sample of the model and the experts' weightings.

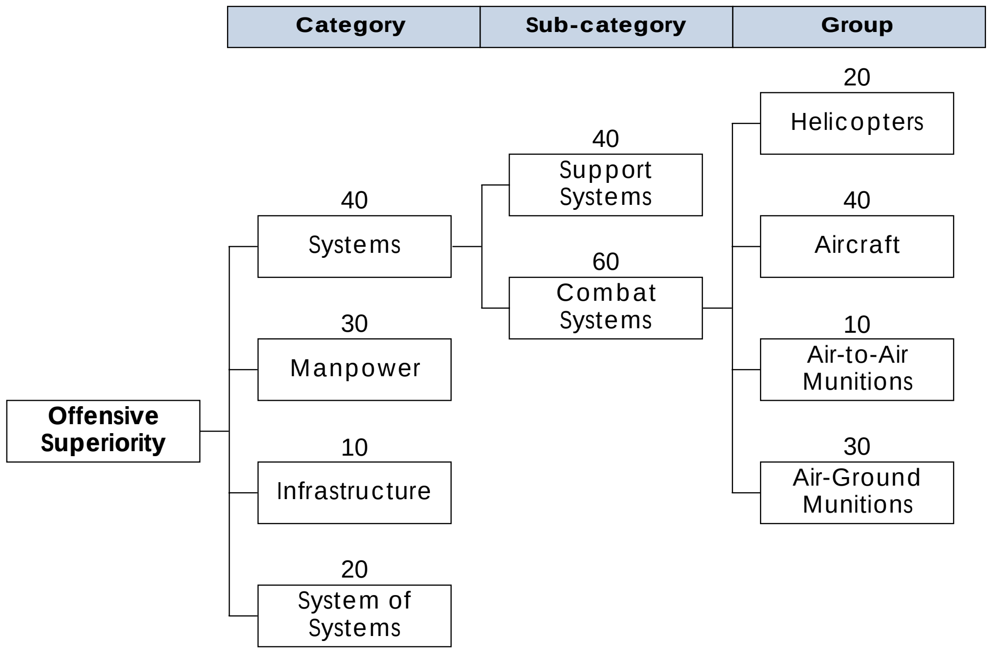


Fig. 1. Sample "Parameters Tree" with Weightings Added

3. Computing the Weight of Each Element

In order to calculate the weight of each element, one must consider its weight against the other elements in the same classification, as well as the relative weights of the other sub-categories and of the overall category itself, as follows:

> Overall weight of element = (its weight in relation to other elements in the same classification) x (the weight of the sub-category) x (the weight of the category)

For example: the overall weight of aircraft (an element in the systems category and the combat systems sub-category) is 0.096, indicating that, as a single factor, it has an overall influence of 9.6% on the total offensive superiority rating of the air force in question. Using the formula presented above, this figure is derived by multiplying the weight of the aircraft element (0.4) by the weight of the weapons sub-category (0.6). The product (0.24) is then multiplied by 0.4, the relative weight of systems, as follows:

$$0.096 = (0.4) \times (0.6) \times (0.4)$$

The results thus indicate that aircraft represent 9.6% of the total power of an air force. Since the determination of the combined weight is an essential component of the model, this process was repeated with every category, sub-category, group, type, and parameter. The results were then reexamined exhaustively, until they represented as accurately as possible the evaluation of the experts. The end product of this phase was a list representing the importance of each element of aerial power.

4. Collection of Data

At this stage, the required quantitative data – numbers of platforms, manpower data, and numbers of airfields – were gathered, verified, and added to the model. In some cases (relating primarily to qualitative parameters), there was no way to obtain quantitative data. For example, one of the factors that the model sought to measure was synergy – the ability of an air force or coalition of air forces to combine disparate systems, personnel, and assets into an effective, unified whole. In these cases, the professionals were asked to rate each air force on the basis of their experience and judgment. The results of these assessments were also carefully reviewed.

The quantitative data on platforms and batteries was drawn primarily from the Jaffee Center for Strategic Studies database. Regarding advanced weapon systems, data was obtained from the SIPRI Arms Transfer Project, updated to early 2001. The calculated outcomes of the professionals' assessments for the qualitative parameters were also added. The product of this phase was a set of tables that consisted of the quantitative data that was required for the study. Appendix 6 comprises the raw database on PGMs.

5. The Decision Support System

For the purpose of evaluating the data, a computerized decision support system used by government and military organizations was chosen. The system was originally designed for analysts and researchers in many fields, enabling individuals and groups to perform a structured analysis of defined elements, evaluate alternatives, and analyze and record the conclusions. The system also features the ability to combine personal knowledge and accumulated experience within a formal analytical process: the user can integrate raw data with personal or group judgment to enhance the decision making process.

The present system is based on the creation of sets of elements of power for the two different airpower roles that the model sought to measure. The offensive superiority power model may be found in Figure 2, while the defensive power model is presented in Appendix 2. When examining both Figure 2 and Appendix 2, readers will note that a number of different weapon systems are divided into *classes*. This was done to facilitate the distinction between higher and lower quality weapons and systems – class one indicates the highest level of quality within a given type of system, class two the one below, and so forth. A list of these systems, and the classifications they were given for the purposes of this model, may be found in Appendix 3.

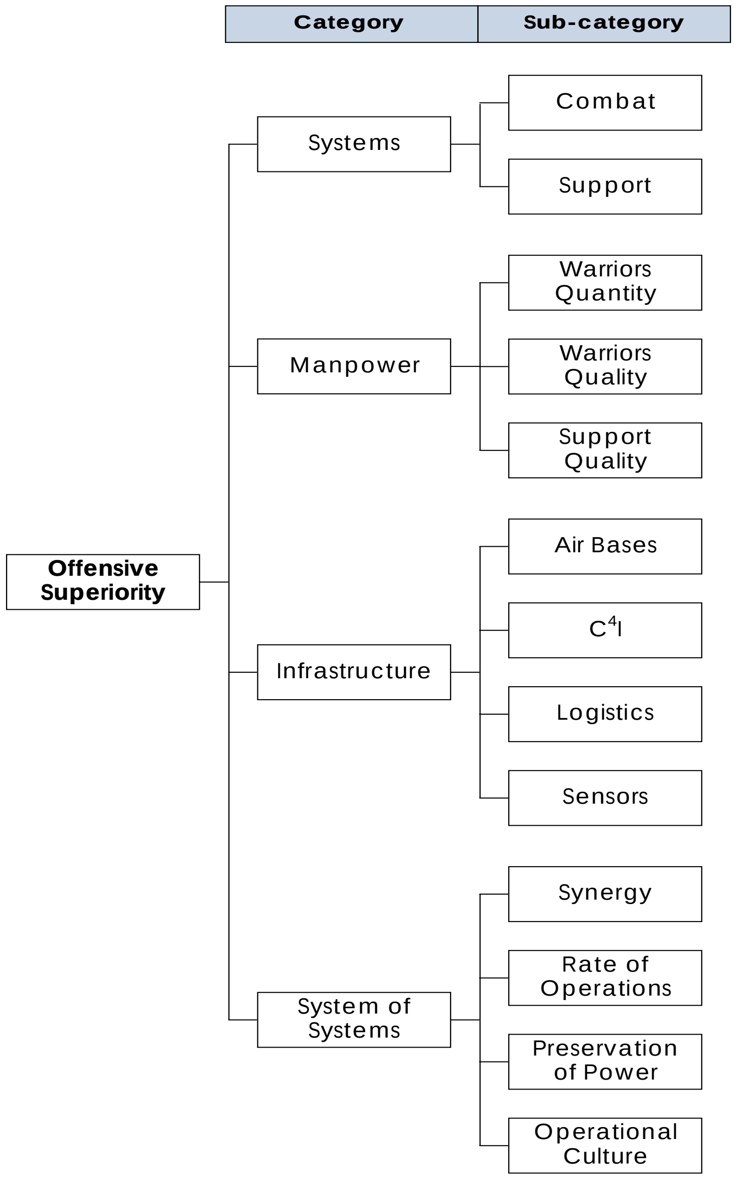


Fig. 2. Offensive Superiority Model

Fig. 2a. Categories of Offensive Superiority Capability

(Note: Categories of defensive air superiority are presented in Appendix 2)

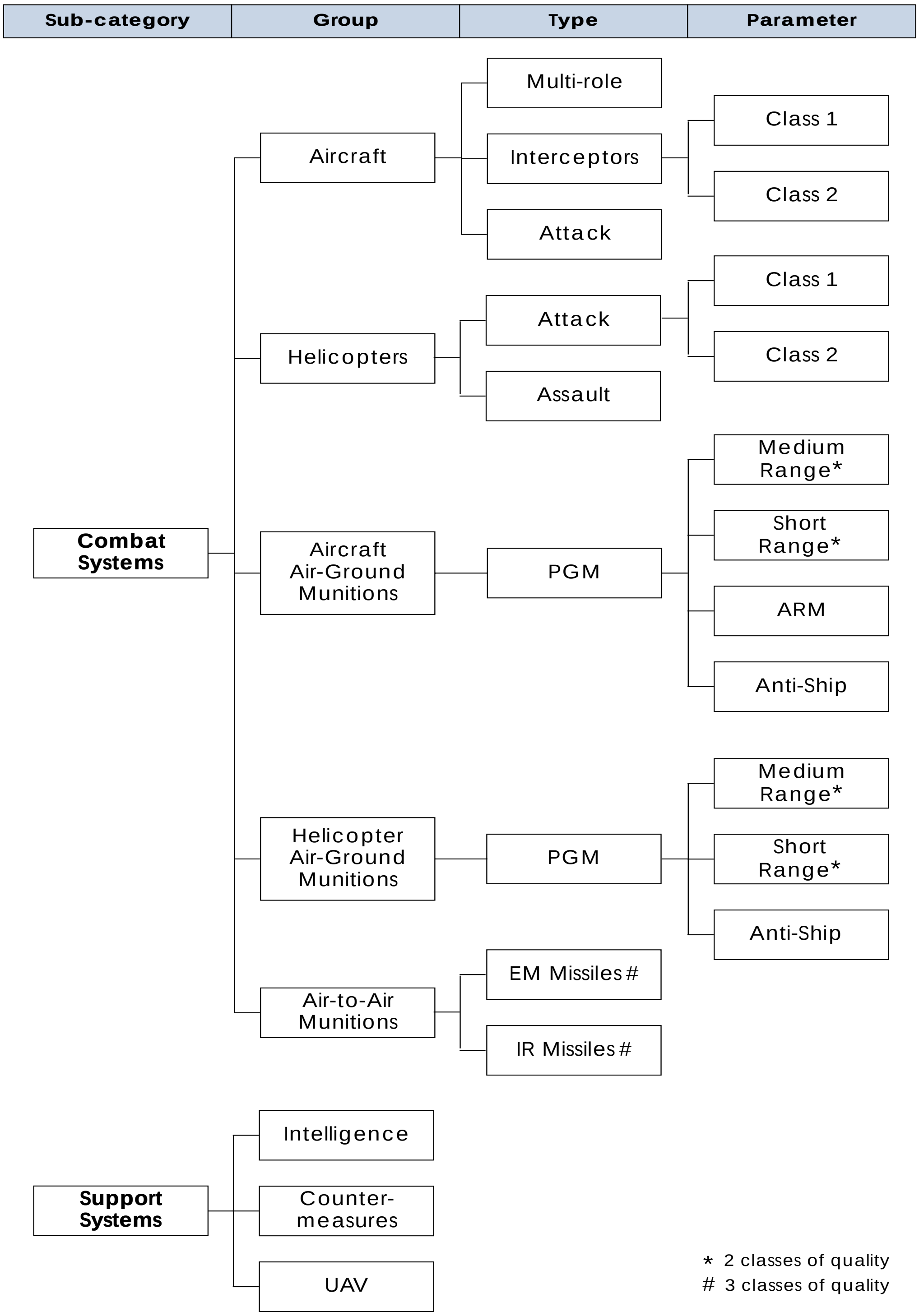


Fig. 2. Offensive Superiority Model

Fig. 2b. Offensive Superiority: Systems

Demonstrating the Model in Use

In order to provide a practical explanation of how the model and the decision support system work, an analysis based on two imaginary air forces (Air Force A and Air Force B) will be presented. This will demonstrate the model's functioning in action, before proceeding to more in-depth analyses of regional forces in the Middle East. Table 2 presents the number of aircraft held by both Air Force A and Air Force B, according to their quality and the weight assigned to each type of aircraft (interceptors, multi-role, etc).

Note that in employing the model, the experts' assessments of the weight have been assigned to each component in the form of a coefficient of power (which appears in the column below as "weight"). These are used to measure the total power of a given system. In this fashion, comparable systems of different qualities can be compared and reconciled. A detailed explanatory legend appears below Table 2.

Table 2. Relative Power (in Aircraft) of Two "Virtual" Air Forces

1	2	3	4	5	6	7
Aircraft Type	**Quantity**		**Weight**	**Measured Power**		**Ratio of Power A:B**
	Air Force A	*Air Force B*		*(Col. 2)x(Col. 4)* *Air Force A*	*(Col.3)x(Col.4)* *Air Force B*	
Multi-role	270	100	0.55	148.5	55	2.7
Attack	100	360	0.20	20	72	0.28
Interceptors						
Class 1	80	40	0.20	16	8	2
Class 2	50	500	0.05	2.5	25	0.1
Total	**500**	**1000**	**1**	**187**	**160**	**1.17:1**

- Column 1 presents the various types of aircraft, according to their offensive operations quality.
- Columns 2 and 3 present the number of each type of aircraft in Air Forces A and B, respectively.
- Column 4 indicates the coefficient of weight, reflecting the quality rating assigned to each type of aircraft.
- Columns 5 and 6 present the *power* of each air force for each type of aircraft, by multiplying numbers of aircraft in columns 2 and 3 by the coefficient found in column 4.

- Column 7 presents the power of Air Force A *relative* to the power of Air Force B in each category.
- The overall relative power of the aircraft possessed by Air Force A as compared with that of Air Force B can be found at the bottom of Column 7.

As shown by the last line in Table 2, Air Force B has twice as many aircraft as Air Force A, but the *structure* of the two air forces is very different: Air Force A has a distinct advantage in terms of the *quality* of the aircraft at its disposal. Over half of the aircraft of Air Force A are of high quality, whereas only one tenth of the aircraft of Air Force B are of high quality. The resulting ratio of relative power (as it appears on the bottom-right of Table 2) is that Air Force A is stronger than Air Force B by a factor of 1.17, despite the fact that it has half as many aircraft.

This figure is an example of a measurement taken for *one* element alone. When the model computes the relative power of all the elements, it normalizes the quantities of different categories in order to prevent situations where categories with high numbers of individual units, like short range missiles, would overshadow categories like platforms, which typically have smaller numbers of units.

Limitations of the Model

As with any methodology of military power assessment, the model used here has its drawbacks. First, it does not use scenarios, which are important aids and are used frequently by military establishments in evaluating military capabilities. Second, the model provides an evaluation of aerial power in the abstract, and does not relate to other factors that influence the results of air campaigns, such as meteorological, geo-strategic, and political factors. Third, the model requires access to an extensive, detailed, and accurate database, which is not always available. Fourth, the model needs to be updated every few years, to keep abreast of new procurements of systems, improvements in technology, manpower, and doctrine, changes in regional force structures, and other circumstances. The progressive obsolescence of what were once cutting-edge technologies must be an assumed fact of life when assessing airpower: advanced weapon systems will inevitably be relegated to second-line status (and their weight coefficients duly adjusted) as new weapon systems are developed and procured. Finally, the model is heavily dependent on the use of expert analysts and their accumulated talent and experience, and is thus highly sensitive to their proficiency and experience.

Chapter 3

The Balance of Airpower in the Arab-Israeli Conflict

Against the background of the model's construction and its demonstration of relative airpower assessment, we can now put the model to work. This chapter attempts a systematic comparison of the various air forces in the Middle East: the analysis presented here will focus on a possible confrontation between the IAF and a broad coalition of Arab air forces, including those of Syria, Egypt, and Jordan, and an Iraqi expeditionary force comprising 20% of its air force. The IAF-coalition evaluation allows the model to be shown to its full advantage in comparing relative powers and capabilities.

One qualification to the comparative analysis that follows: the likelihood that this Arab coalition would materialize under present conditions is low. Given the current regional power balance, the various tensions and conflicting interests among the Arab nations would seem to prevent them from forming an effective coalition against Israel. Nonetheless, the political environment in the Middle East is dynamic and very difficult to predict. Few, for example, would have anticipated that Syria would join the United States in a war against another Arab power, as in the Gulf War. The use of this coalition, therefore, should not be attributed to the tendency of military analysts to court disaster by focusing on worst case possibilities.

Therefore, precisely because one cannot entirely dismiss such a potential coalition, its value lies in serving as a kind of "reasonable worst case scenario" in terms of the threats facing the IAF. The assumption is that Syria, at present, would join any coalition against Israel that had a reasonable chance of success. Egypt and Jordan, notwithstanding their peace treaties with Israel, could still consider Israel a potential threat to their national interests in certain situations. Iraq has already demonstrated several times both a capability and a willingness to send substantial expeditionary forces to the Syrian front, despite tensions that have existed between them. Finally, a coalition consisting of the combined air forces of Syria, Egypt, Jordan, and 20% of the Iraqi Air Force would indeed represent a severe threat both to the IAF and the Israel Defense Forces as a whole. Thus, even if the odds of such a threat materializing are low, its extreme severity nevertheless prompts attention.

It is the very longevity and prominence of the Middle East conflict that makes the implementation of this model so potentially significant for analysts from other regions. Over the last fifty-five years, the confrontations in the Middle East have featured western-developed combat systems, wielded by Israel, and Soviet-developed systems, wielded by the Arab states. As such, the Arab-Israeli wars have served as both a testing base and an operational evaluation battlefield for new weapon systems, technologies, doctrines, and strategies. This holds true both for the nations in the region and for the superpowers that supplied them. For the US and the former USSR alike, the wars in the Middle East were a unique opportunity to see their weapon systems and combat doctrines in action against the systems of their adversary. As a result, the analysis of this conflict stands as a model for analyses of other potential conflicts in the world.

This chapter is divided into several sections. The first section uses the model to conduct an overall assessment of the balance of aerial power in the region. The next two sections present a detailed, element-by-element assessment, divided according to operational roles: offensive power over the battlefield will be examined first, followed by defensive power. The following part of this chapter will provide a summary analysis of the balance of aerial power, as emerges from the element-by-element assessment.

Quantities of weapon systems such as aircraft, helicopters, and SAM systems appear in Appendix 4. An additional detailed list of precision weapons is located in Appendix 6, courtesy of the Stockholm International Peace Research Institute (SIPRI), which collected this data and permitted its use. With that, some gaps remain in accuracy and in details; it is hoped that these may be rectified in future publications.

The various weapon systems in the possession of each state in the region have been grouped by quality, in the context of both defensive and offensive roles. These groupings may be found in Appendix 3. The main difference between considering offensive roles and defensive ones is the presence of air-to-surface munitions in offensive roles, while defensive roles include surface-to-air systems. Another difference is the manner in which aircraft are classified with regard to the different roles. For instance, the F-16 C / D is considered a multi-role aircraft in the offensive role and a Class 1 Interceptor in the defensive role.

Applying the Model: Overall Assessments

By allowing the incorporation of qualitative factors, the model has a clear advantage over a military balance analysis that relies solely on a quantitative comparison of weapon platforms and units. Intuitively, it is often clear that one air force is superior to another despite its smaller size. The model presented here allows us a scientific methodology for verifying or discrediting such intuitive assessments.

This kind of comparative deduction can be demonstrated through the following two illustrations. Table 3 provides a comparison of the overall numbers of offensive assets held by the Israel Air Force with that of a coalition of the Syrian, Egyptian, and Jordanian Air Forces plus an expeditionary force comprising 20% of the Iraqi Air Force. Such a coalition would potentially represent a formidable challenge to the IAF.

Table 3. Quantities of Offensive Power Systems

Element	Israel	Coalition	Egypt	Syria	Jordan	Iraq (20%)
Systems						
Platforms*	**878**	**1736**	**711**	**776**	**146**	**103**
Aircraft (Total)	**503**	**1113**	**489**	**490**	**91**	**43**
Multi-role	270	211	195	0	16	0
Interceptors						
Class 1	73	41	18	20	0	3
Class 2	0	465	150	295	0	20
Attack Aircraft	160	396	126	175	75	20
Helicopters (Total)	**232**	**516**	**143**	**260**	**53**	**60**
Attack	107	243	101	90	22	30
Class 1	42	36	36	0	0	0
Class 2	65	207	65	90	22	30
Assault	125	273	42	170	31	30

(Continued on page 56)

**Total includes aircraft, helicopters, and airborne support systems*

Element	Israel	Coalition	Egypt	Syria	Jordan	Iraq (20%)
Air-Ground Munitions – Fixed-Wing Aircraft						
Medium Range						
Class 1	300	0	0	0	0	0
Class 2	0	0	0	0	0	0
Short range						
Class 1	300	0	0	0	0	0
Class 2	1160	894	824	0	0	70
ARM	1100	150	60	0	0	90
Anti-ship	0	197	90	0	0	107
Air-Ground Munitions – Helicopters						
Medium Range						
Class 1	300	0	0	0	0	0
Class 2	775	1427	1419	0	0	8
Short Range						
Class 1	200	0	0	0	0	0
Class 2	4248	22595	13595	5400	2060	1540
Anti-Ship	0	69	62	0	0	7
Air-to-Air Munitions						
EM Missiles						
Class 1	114	0	0	0	0	0
Class 2	320	649	553	0	96	0
Class 3	376	1870	190	1346	204	130
IR Missiles						
Class 1	400	0	0	0	0	0
Class 2	1700	6187	5747	0	440	0
Class 3						
Airborne Support Systems#						
Total	**143**	**107**	**79**	**26**	**2**	**0**
Intelligence Systems	34	48	32	14	2	0
Countermeasures	9	4	2	2	0	0
UAVs	100	55	45	10	0	0
Warriors	1229	2429	995	1086	204	144
Air Bases	11	58	29	21	6	2

 # Refers to aircraft

The raw numbers of fixed-wing aircraft and helicopters shown in Table 3 reveal the coalition's considerable numerical advantage over Israel: 2:1 in numbers of fixed-wing aircraft, and 2.2:1 in helicopters. However, this does not represent the true balance of forces among these rivals. Most military observers would argue the opposite proposition: that the IAF enjoys air superiority. This claim can be justified if a more detailed evaluation that compares the quantity *and* quality of different types of aircraft is undertaken, as is shown in Figure 3.

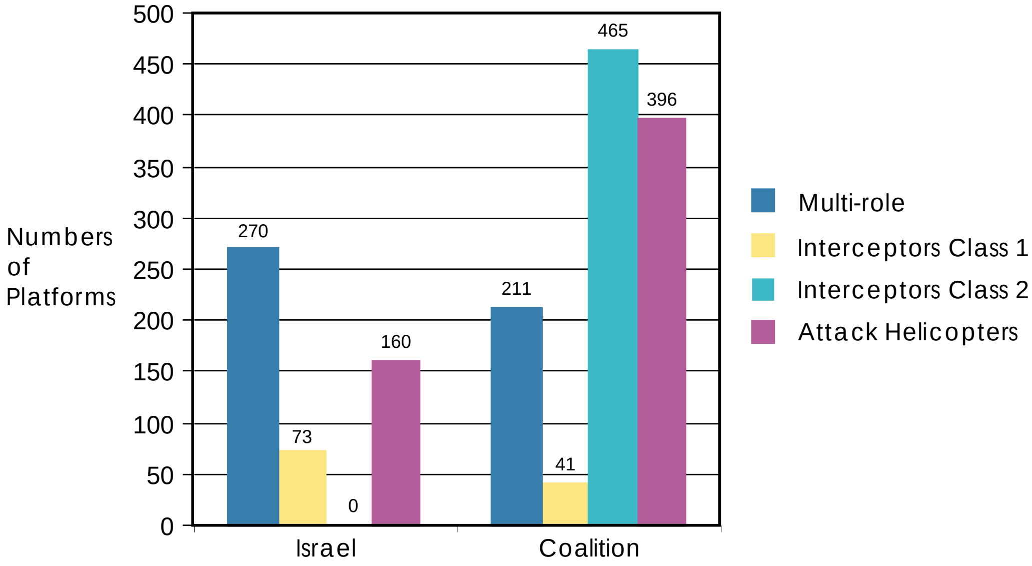


Fig. 3. Comparison of Platforms

This figure delivers a complex message: the IAF enjoys an advantage in high-quality aircraft, but the coalition has a decisive advantage in medium-quality aircraft. From here, it is difficult to reach a clear conclusion as to the balance of the two airpowers. If other weapon systems – helicopters, missiles, and UAVs – are added, the resulting portrait would be even more complicated and confusing.

In contrast, the model developed for this study enables combining all of these elements – fixed and rotary-wing aircraft, missiles, and so on – into a single classification, called "combat systems." This in turn allows the quantification and comparison of the entire offensive fighting capability of a set of rival air forces. Figure 4 shows this comparison in a general form, though more detailed depictions are also possible.

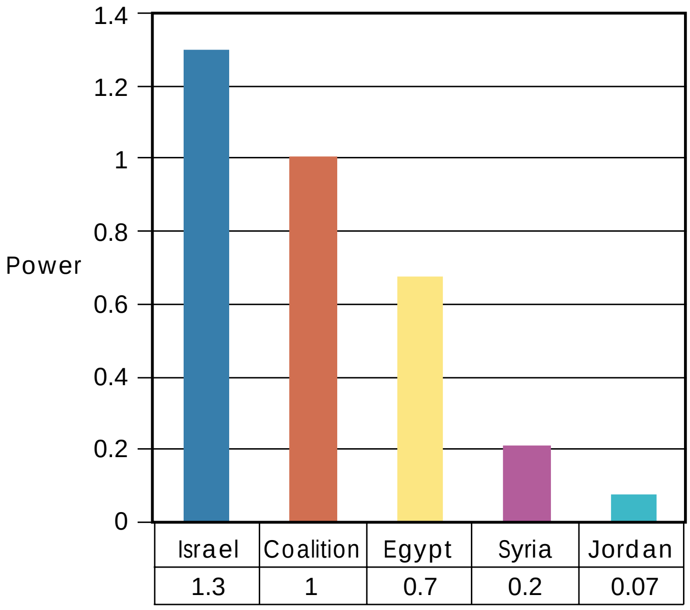


Fig. 4. Offensive Power: Combat Systems

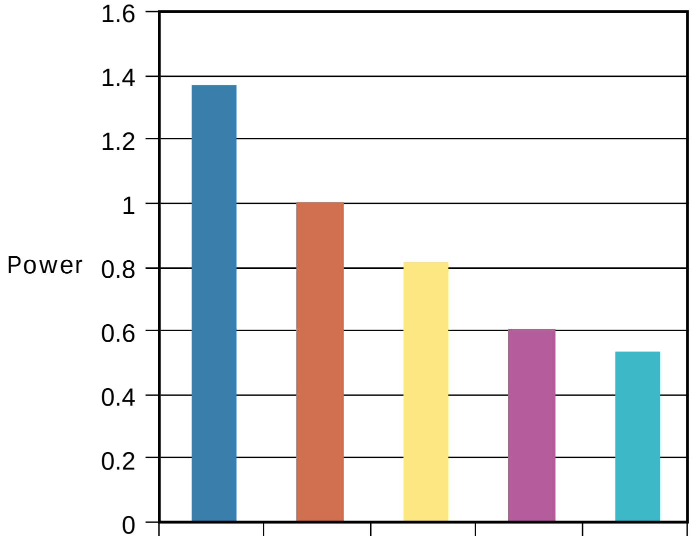
Figure 4 clearly demonstrates the superiority of the Israeli air force in combat systems. It offers an integrated evaluation of the quantities and the qualities of each state's combat systems, and presents them in an easy-to-understand format. It is also possible to derive detailed conclusions about the relative power of each group and type of combat system from the data contained in each set of force ratios.

This brief illustration demonstrates clearly the model's potential for providing new insights from existing data.

Applying the Model: Offensive Power

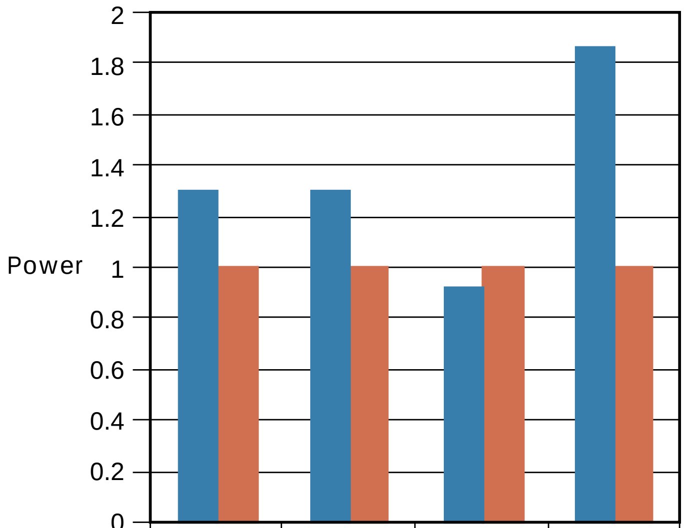
The first detailed application of the model concentrates on the offensive superiority over the battlefield mission. Figure 5 illustrates the relative offensive power of the IAF and the air forces of the Arab coalition.

Figure 5 demonstrates the substantial advantage of the IAF in offensive roles. This advantage is all the more impressive because quantitatively, the IAF suffers a 1:2 disadvantage in numbers of aircraft, attack helicopters, and airborne support systems, such as intelligence gathering and countermeasure systems. The ratio is even higher (1:2.7) for precision guided munitions. The IAF is also at a 1:2 disadvantage in aircrews, and a 1:5.3 disadvantage in the number of airbases.



Israel	Coalition	Egypt	Syria	Jordan
1.37	1	0.8	0.6	0.5

Fig. 5. Offensive Power



	Systems	Manpower	Infrastructure	System of Systems
Israel	1.3	1.3	0.9	1.9
Coalition	1	1	1	1

Fig. 6. Offensive Power: Main Categories

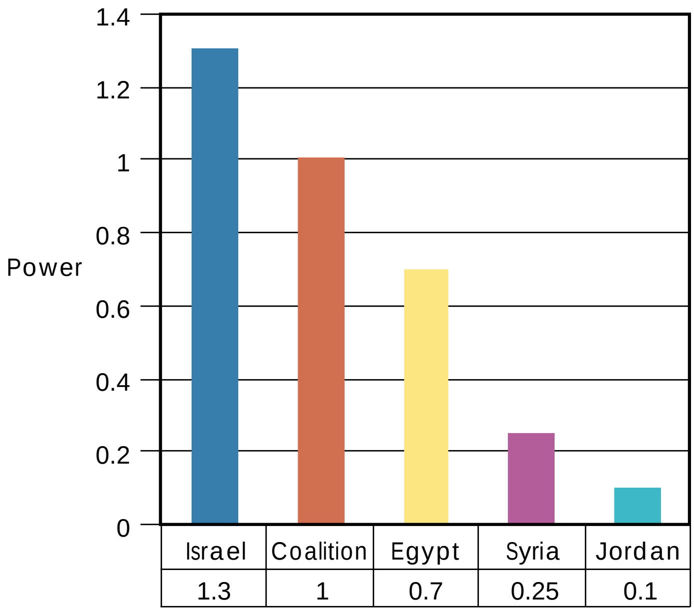


Fig. 7. Offensive Power: Systems

Despite its quantitative inferiority, the IAF appears to enjoy a distinct superiority in terms of overall offensive power. This superiority is derived from its sophisticated C^4I systems, its advanced system of systems, its professional, highly motivated personnel, and its superior weapon systems. This is illustrated in Figure 6, which breaks down the main categories of elements: systems (platforms, weapon systems, and others); manpower; infrastructure; and system of systems (which represents synergy, rate of operations, preservation of power, and operational culture).

To explain the interaction of these various elements and their effect on the overall balance of power, each of these categories is analyzed individually below.

Systems

Figure 7 compares the relative power of the systems at the disposal of the IAF, the coalition, and the Egyptian, Syrian, and Jordanian Air Forces.

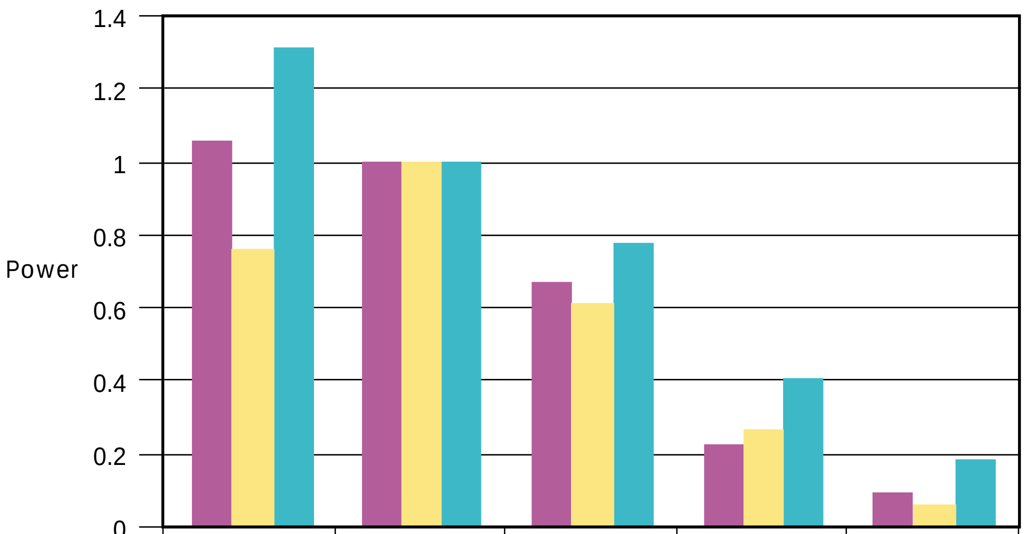
The rivals differ in the capabilities of their systems to the extent that the *qualitative* edge of the IAF overwhelms the *quantitative* advantage of the coalition. The IAF procures advanced systems and weapons, both from domestic suppliers and from the US. Furthermore, Israeli military industries are among the most advanced in the world in certain areas, evidenced by their production of the Arrow Anti-Tactical Ballistic Missile System, the Silver Arrow Long Range Unmanned Airborne Vehicle, and PGMs for attack helicopters and aircraft. The IAF qualitative advantage is most salient in multi-role aircraft, first-line interceptors, air-to-air missiles, and air-to-ground guided munitions.

The Egyptian Air Force, the fulcrum of any potential Arab coalition, is completing a long process of transformation to Western systems and technologies. With US assistance, it has procured various modern systems, such as aircraft, attack helicopters, air-to-air and air-to-ground guided munitions, SAM systems, C^4I systems, early warning systems, and electronic warfare systems.

The modernization of any air force is often limited by economic constraints, reflected clearly in the Syrian Air Force. The Iraqi Air Force (not depicted) is even less enviable, with UN sanctions effectively blocking any effort at modernization.

Platforms

The modular structure of the model enables the analyst to "zoom" into details and examine individual sub-categories. We will now consider the various sub-categories that compose the systems category, beginning with platforms. Figure 8 displays the balance of power in aircraft, helicopters, and airborne support systems such as intelligence gathering platforms and UAVs.



	Israel	Coalition	Egypt	Syria	Jordan
Aircraft	1.05	1	0.67	0.22	0.09
Helicopters	0.75	1	0.6	0.26	0.06
Airborne Support	1.3	1	0.78	0.4	0.18

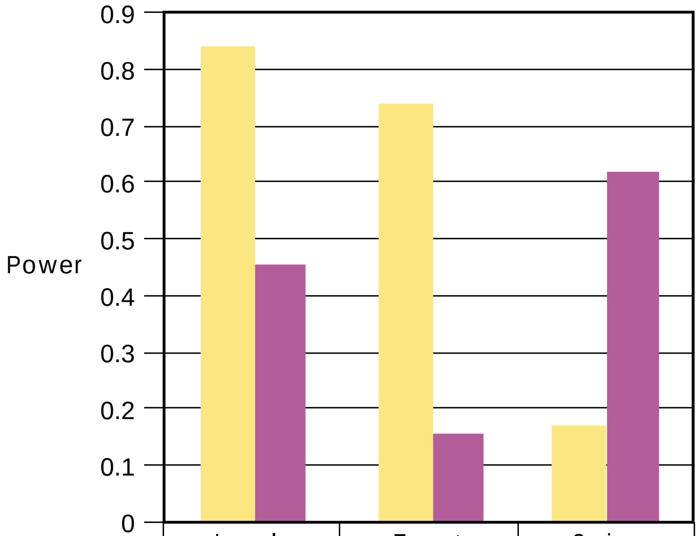
Fig. 8. Offensive Power: Main Platforms

Figure 8 demonstrates that the IAF's superiority over the coalition in systems is *not* derived from an advantage in aircraft and helicopters. On the contrary, its moderate superiority in fixed-wing aircraft is countered by a significant disadvantage in helicopters. Indeed, the only group in this sub-category where the IAF has a clear advantage is airborne support platforms.

To refine this picture even further, Figure 9 demonstrates one example of the level of detail the present model can provide. It displays the breakdown of the various types of helicopters in the possession of the Egyptian, Syrian, and Israeli air forces. From this breakdown, it is apparent that the Egyptian Air Force limits its emphasis on assault helicopters. Syria, in contrast, has favored the procurement of assault helicopters.

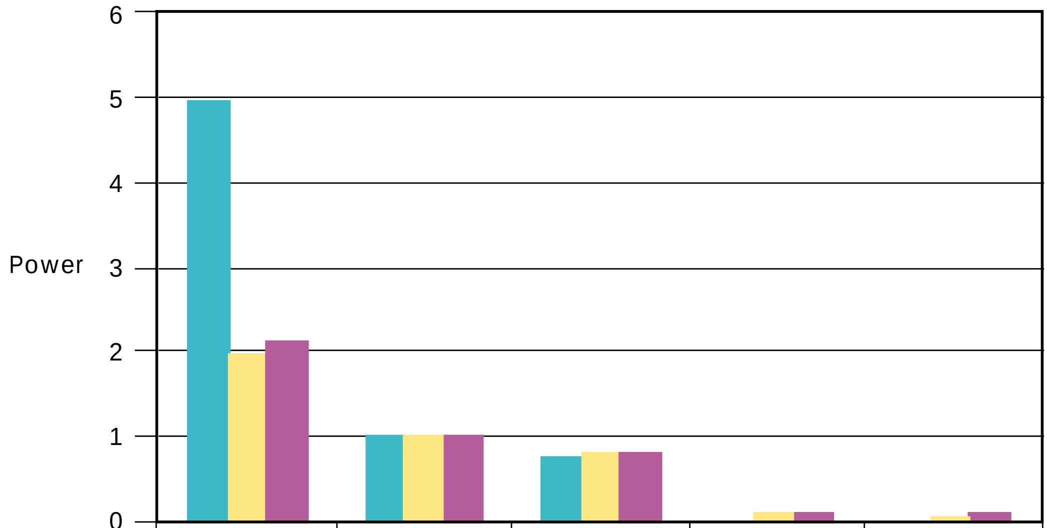
Precision Munitions

Despite the fact that the IAF's edge in platforms is marginal, the model indicates that the IAF has a distinct offensive advantage over the coalition in systems. The explanation for this lies in the factoring of other groups within systems, particularly the balance of precision munitions. The numerical data in Appendix 6 presents a mixed picture: the IAF has a clear quantitative advantage in air-to-surface munitions



	Israel	Egypt	Syria
Attack	0.84	0.73	0.17
Assault	0.45	0.15	0.62

Fig. 9. Offensive Power: Helicopters



	Israel	Coalition	Egypt	Syria	Jordan
Air-Surface Munitions for Aircraft	4.95	1	0.74	0	0
Air-Surface Munitions for Helicopters	1.97	1	0.82	0.09	0.03
Air-to-Air	2.1	1	0.8	0.1	0.1

Fig. 10. Offensive Power: Precision Munitions

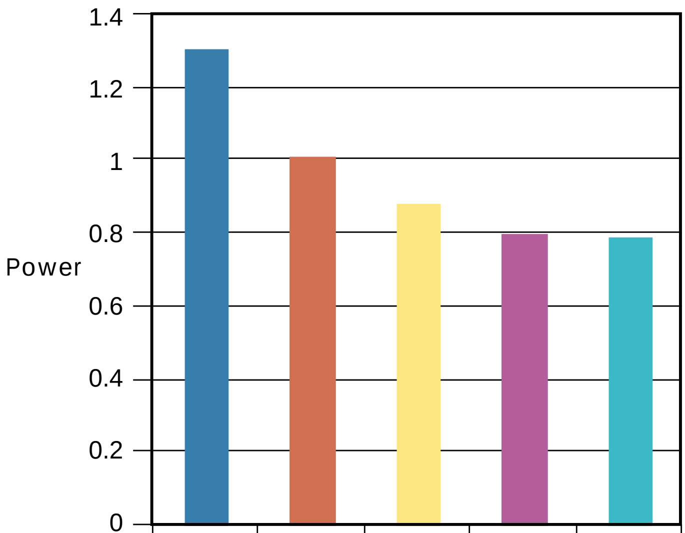
for aircraft, and an apparent disadvantage in both air-to-surface munitions for helicopters and air-to-air munitions overall. However, when viewed through the results of the model, the IAF's overall superiority in PGMs is considerable. Figure 10 displays the balance of power of the IAF, the coalition, the Egyptian Air Force, the Syrian Air Force, and the Jordanian Air Force in munitions.

This figure illustrates the dominance of the IAF in "smart" weapons, providing the main factor for its advantage in systems. In emphasizing PGMs, the IAF's approach resembles that of other "postmodern" air forces, since in recent decades, PGMs have nearly replaced platforms as the main factor of aerial power. The degree to which a given air force has succeeded in recognizing and responding to this shift, and in developing new policies of RDT&E and procurement, have come to determine its ability to modernize effectively.

Generally speaking, the IAF is inferior in numbers, but it has acquired high-quality weapon systems, many of them developed and manufactured domestically. The Popeye medium range air-to-surface missile, the Python 4 all-aspect infrared air-to-air missile, new variants of helicopter-borne medium range missiles, the Arrow anti-SSM missile, the Green Pine radar system, and the Barak ship-defense missile system, are all among the most advanced systems of their kind. Developing state-of-the-art weapon systems requires allocation of significant resources, not only monetary, but also scarce human resources, including engineers, researchers, and highly skilled technicians, and other assets such as laboratories and materials. Israeli R&D capabilities ensure a technological advantage for the near future. However, funding for R&D is exceedingly limited, and this insufficiency may impede Israel's ability to develop next-generation weapons in the future.

Manpower

Quality is the decisive component within manpower. With that, it should be noted that quality, as it is understood here, is not a "black box," limited to its abstract meaning. Most elements of quality are measured by *quantitative* parameters, chief among which are results that can be achieved from training and doctrine. Better pilots launch their munitions more accurately and destroy more targets in a sortie. They react more quickly to new threats, and have higher rates of survival, allowing them to return to base and participate in additional missions. Similarly, better technicians execute their responsibilities more quickly and reliably.



Israel	Coalition	Egypt	Syria	Jordan
1.3	1	0.9	0.8	0.8

Fig. 11. Offensive Power: Manpower

Figure 11 compares the personnel of the IAF, the coalition, and the Egyptian, Syrian, and Jordanian Air Forces, and illustrates the significant advantage the IAF holds in manpower over its rivals.

Complementing the importance of quality, manpower quantity is also a critical factor. For example, larger numbers of aircrews are crucial if a force must sustain an ongoing high-intensity conflict. Moreover, the *ratio* of aircrew to aircraft is important, because aircraft fatigue is slower than the fatigue experienced by aircrews. Thus, a higher ratio of crews to aircraft translates into a capability to fly more missions. The coalition's 1.7:1 advantage over the IAF in this realm is therefore significant. In contrast, the *total* number of personnel in the various air forces is of little significance. An air force is an organization that relies on the professionalism and motivation of its technical manpower – technicians, logistics and C^4I specialists, and others. Large numbers of low-quality, lesser-trained personnel offer little benefit in this regard.

The synergistic effect that results from integrating modern technologies and high-quality manpower greatly enhances the IAF's advantage in manpower in the overall balance of airpower. From this perspective, the IAF's advantage may very well be even greater than the model indicates, because experts often tend to underestimate the quality of their own force.

Infrastructure

Most evaluations of balances of airpower ignore infrastructure as a significant category of elements, due to insufficient data and because traditional assessment approaches emphasize platforms. Analysts tend to ignore the saying, first attributed to Napoleon, according to which armed forces "march on their stomachs." Yet soldiers need to be fed before they can fight; planes need to be fueled, armed, maintained – all of which means that they depend on sophisticated logistical arrays in order to function effectively. This requires a comprehensive infrastructure, consisting of bases, C^4I centers, communications networks, fuel depots, and logistical centers. In addition to accelerating the rate of operations, the importance of infrastructure increases in the following circumstances:

- as prolonged conflicts or operations progress
- as the intensity of fighting grows
- as an air force struggles to survive under concentrated attack

Figure 12 illustrates the relative strengths of the infrastructures available to the IAF, the coalition, and the Egyptian, Syrian, and Jordanian Air Forces.

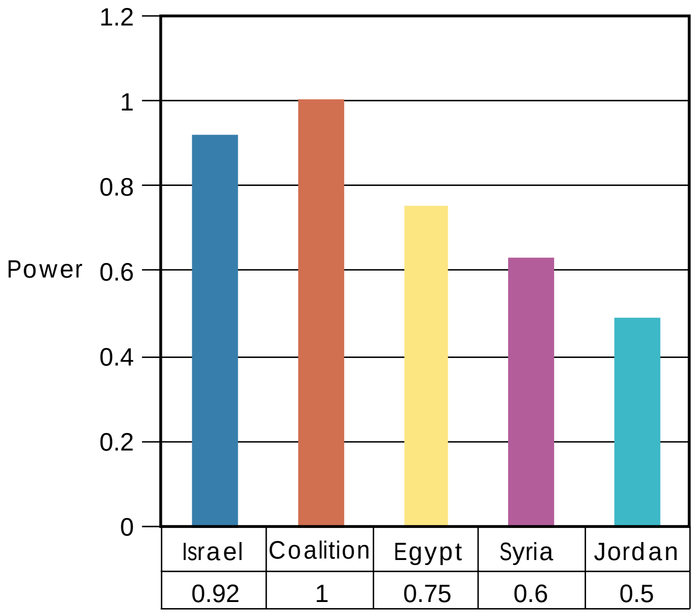


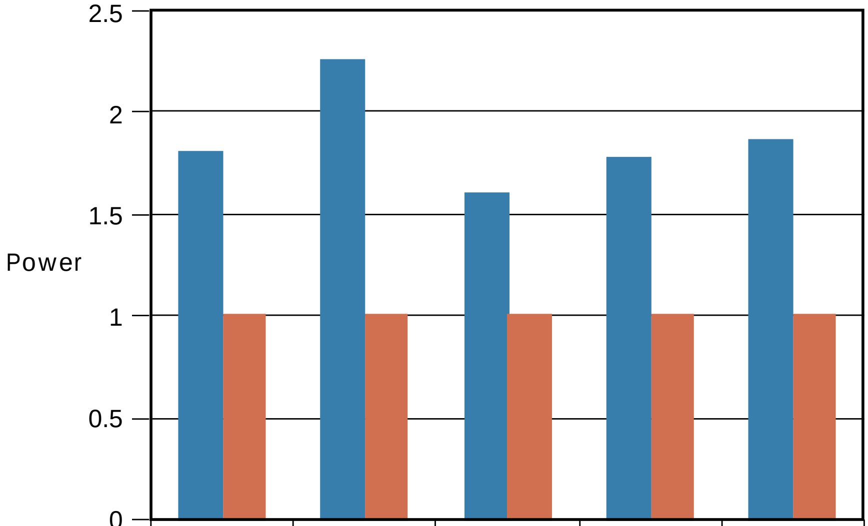
Fig. 12. Offensive Power: Infrastructure

The model's results indicate that despite its modern infrastructure, the IAF suffers certain inferiorities compared with the coalition, chiefly due to Israel's small size. Coalition air forces have more assets and more fighting men and women, and are better dispersed.

System of Systems

This category of elements is composed almost entirely of qualitative factors, including synergy, force multipliers, rate of effective operations, and preservation of power. These elements depend heavily on the quality of manpower – particularly commanders, fighting personnel, operational planners, and developers of C^4I systems.

The term "system" has two contexts: technological and organizational. System of systems is thus a complex concept, consisting of the integrative combination of platforms (aircraft, helicopters, UAVs, satellites, SAM systems), weapon systems, and C^4I systems and centers (which integrate operational organizations, doctrines, concepts of operations, processes of planning, command in real-time, debriefing, and battle management). The challenge of transforming a variety of distinct technological and organizational systems into a workable, effective, and integrated array is the role of a properly functioning system of systems. Figure 13 illustrates the relative strengths of the systems of systems of the IAF and the coalition.



	System of Systems	Synergy	Rate of Operations	Preservation of Power	Operational Culture
Israel	1.9	2.25	1.6	1.8	1.8
Coalition	1	1	1	1	1

Fig. 13. Offensive Power: System of Systems

Only a few air forces have demonstrated the ability to forge a successful, modern system of systems, and they do not include the Arab states, which have essentially neglected this aspect of force building. Indeed, it is in this area that the IAF enjoys its most formidable advantage, which enables it to exploit relatively limited resources to the fullest, and to maintain a high rate of offensive operations while simultaneously enjoying a high degree of force preservation. All the Arab air forces have only modest capabilities in this critical dimension.

Furthermore, the ability of the individual Arab states to build an effective system of systems is only part of the issue, as it ignores a larger question: their ability to work together in an orchestrated fashion. Four separate national forces fighting together would require a cohesive superstructure that ensures the compatibility of diversified doctrines and tactics, and interoperability in equipment and communications. Since this structure does not presently exist, the coalition would face a problem of coordination among the various forces. This includes aircraft, SAM systems, C^4I systems, and the problem of electromagnetic interference among them.

Applying the Model: Defensive Air Superiority

The discussion has thus far focused on offensive air superiority over the battlefield. Switching the focus to defensive air superiority reveals some differences in the weight of certain elements, evolving generally from the fact that the operational roles themselves are different. Defending one's national airspace involves weapon systems (such as SAM batteries) that are not used in offensive missions. Moreover, even weapon systems that have dual uses (such as multi-role fighters) will be employed in different quantities and exploit different capabilities. This section is designed to present and explain the most significant differences between the elements within the two kinds of operational roles.

Figure 14 compares the defensive capabilities of the IAF, the coalition, and the Egyptian, Syrian, and Jordanian Air Forces.

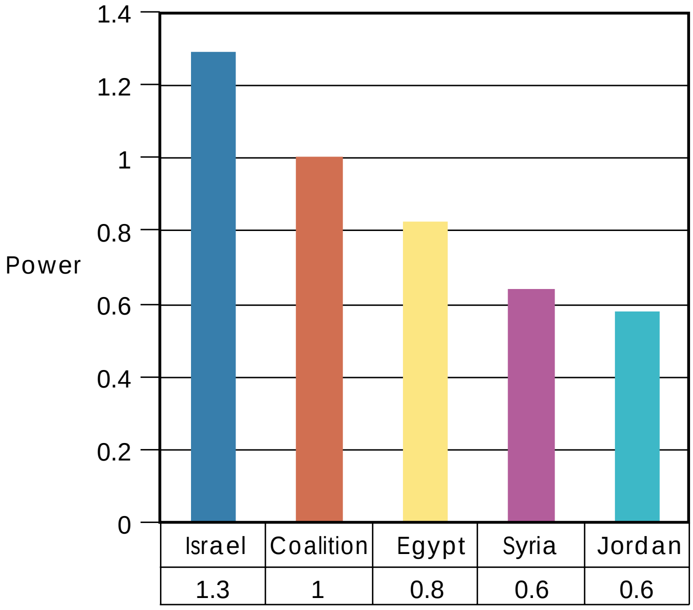
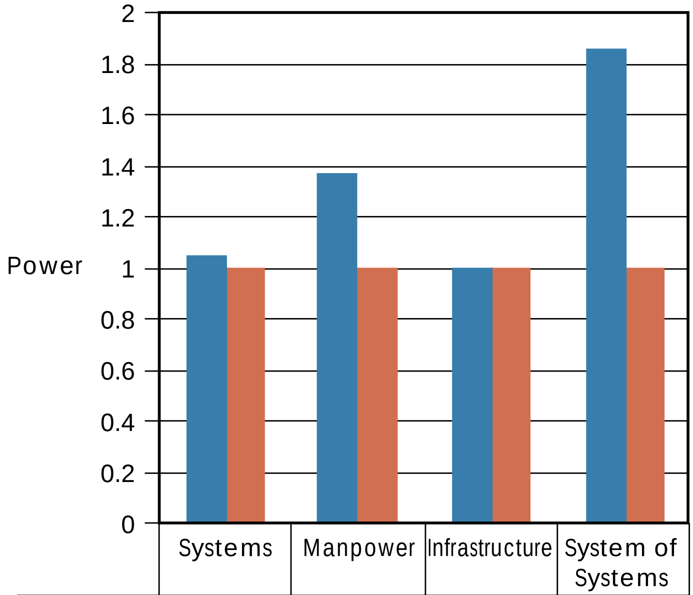


Fig. 14. Defensive Power

The overall assessment of the IAF's remarkable defensive superiority roughly equals the assessment of its offensive advantage. This may be probed and analyzed by focusing on more detailed data, beginning with Figure 15.

Figure 15 illustrates a breakdown of the main categories of defensive power, and serves as an introduction to a more detailed discussion of them. A significant



	Systems	Manpower	Infrastructure	System of Systems
Israel	1.04	1.37	1	1.85
Coalition	1	1	1	1

Fig. 15. Defensive Power: Main Categories

dimension to the discussion is the contrast of the categories as they figure in offensive and defensive operational roles. The main change that should be mentioned from the outset is that the IAF's advantage charted in the systems category in the analysis of its offensive power does not exist in the defensive context. This is the result, as noted above, of the different natures of the offensive and the defensive roles, which stress different capabilities and systems. These differences will now be elaborated upon on a category-by-category basis.

Systems

The requirements for achieving defensive air superiority dictate the use of specialized systems that do not play a function in the offensive role, such as surface-to-air missile batteries. Other systems, such as aircraft or attack helicopters, are designed to function in both offensive and defensive missions. However, in defensive missions, they will use different kinds of ordnance and be deployed in different configurations. Figure 16 presents the balance of defensive power of Israel, the coalition, Egypt, and Syria in the systems category.

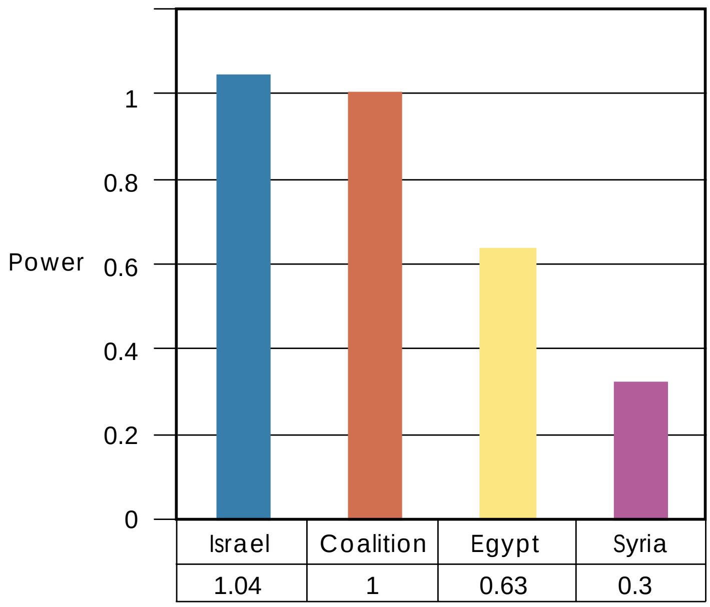


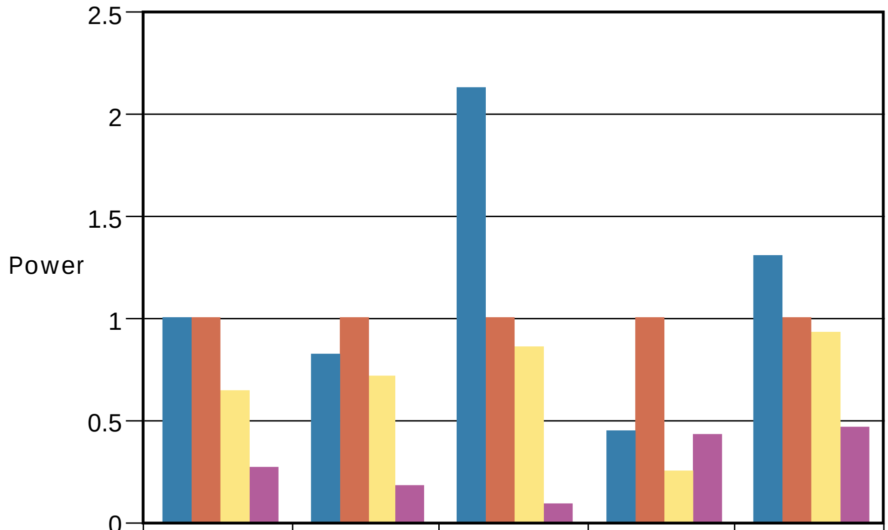
Fig 16. Defensive Power: Systems

Figure 17 focuses on the various groups in the systems category that combine to achieve defensive superiority, and presents the relative power in each for Israel, the coalition, Egypt, and Syria.

The most interesting phenomenon is the equality between the IAF and the coalition in interceptors. Despite the IAF's emphasis on superior aircraft, such as the improved versions of the F-15 and the F-16, the coalition succeeds in maintaining parity in this important element of airpower. This is due primarily to the efforts of the Egyptian Air Force to acquire US-made systems and upgrade the platforms in its arsenal, and to the number of interceptors in the Syrian Air Force. Significantly, however, the Syrian Air Force has an aging arsenal and poor maintenance. Therefore, its real power decreases significantly every year.

Attack helicopters play a unique role in defensive air superiority, functioning as a crucial defensive system against enemy attack helicopters. Hence, as the offensive role of attack helicopters has grown, the defensive role accorded to them has grown as well. Given that the same helicopters fulfill both defensive and offensive roles, the IAF inferiority in the offensive role regarding helicopters presupposes a parallel inferiority in the defensive role.

The IAF does, however, enjoy a salient advantage in air-to-air munitions. This is partly due to the fact that Israeli defense contractors have traditionally focused on



	Interceptors	Attack Helicopters	Air-to-Air Munitions	SAM Systems	Airborne Support Systems
Israel	1	0.8	2.1	0.5	1.3
Coalition	1	1	1	1	1
Egypt	0.6	0.7	0.9	0.3	0.9
Syria	0.3	0.2	0.1	0.4	0.5

Fig. 17. Defensive Power: Main Systems Elements

developing munitions and avionics systems for existing platforms, rather than developing the platforms themselves. That tradition has become the decisive reason for the dominance of the IAF in air-to-air munitions. The Rafael-produced Python 4 infrared air-to-air missile, and the mounted helmet sight that enhances its performance, are strong examples of innovations that contribute to the IAF's predominance in this arena.

On the rival side, the coalition's major asset in air defense is its dominance in SAM systems. The IAF has focused on acquiring high-quality (and expensive) systems such as the Patriot and the Arrow systems. Despite the impressive capabilities of these systems, however, they do not overcome the outstanding quantitative superiority of the coalition's combined SAM systems. Furthermore, the IAF's modest edge in airborne support systems cannot compensate for the coalition's overall quantitative advantage.

Infrastructure, Manpower, and System of Systems

Generally speaking, infrastructure has the same importance for offensive and defensive roles. Nevertheless, in the defensive role, another component of infrastructure is added for arrays of SAM systems, sensors, and command posts. When considering the power balance of infrastructure for defensive roles, the force ratios are: coalition 1.0, IAF 1.2, Egypt 1.2, and Syria 1.0.

Various minor changes in manpower and system of systems do not significantly affect these categories. The comparison of defensive air superiority power and offensive air superiority power highlights the similarity between the two roles in the Middle Eastern context, because some platforms and most of the manpower, infrastructure, and system of systems are used for both the offensive and defensive roles.

Israel vs. the Coalition: Summary and Assessments

Since 1993, with the improvement of relations between Israel and the Arab world, many have questioned whether a multi-state Arab war coalition should still be a factor in assessment, and if so, which states are to be counted as possible members. Such observers are in effect asking how *likely* this scenario appears to be in light of political developments in the region. How probable is it that Iraq, Syria, and Egypt would all join forces to attack Israel? Would Jordan join such a coalition? While a number of cogent arguments could be made to support the idea that such coalitions are unlikely given prevailing regional and political realities, the actual probability of the coalition's materializing is beyond the scope of the present framework, which concentrates on operational capabilities. Therefore, the thrust of the present study is determining what the balance of such a coalition would be, rather than the political factors that render its formation more or less likely.

The IAF and the Coalition

Quantitatively, Israel is at a significant disadvantage in total numbers of aircraft, helicopters, and munitions. This numerical disadvantage is even greater for SAM systems, although the translation of this disadvantage into battlefield capabilities is difficult. Given the circumscribed mobility of SAM systems, their influence is limited to those specific zones that lie within their operational ranges.

However, Israel possesses high-quality, advanced munitions, some of its own development and manufacture. The ability and experience to translate these advanced munitions into operational capabilities against both armored and airborne targets, and to achieve high rates of destruction while preserving its own power, are prominent factors in the IAF's defensive and offensive superiority.

Application of the model highlights and explains the components that collectively make up the IAF's superiority – offensive and defensive – over a coalition of potential opponents, and illustrates its limitations. It provides a similarly nuanced evaluation of the air forces that together form the Arab coalition. However, here a stipulation is in order. As noted above, this study seeks to measure power based solely on qualitative assessments and quantitative data, without regard to any specific conflict scenario. This methodology is not designed to translate abstract capabilities into battlefield successes. The fact that the IAF has certain operational superiorities does not, in and of itself, mean that the sum total of its capabilities would be sufficient for carrying out *all* of the missions that would be required of it in "real life." Thus, it should also be clear that despite its defensive air superiority, the IAF would be unable to prevent sporadic penetration by aircraft, helicopters, and gliders into its airspace. In addition, its missile defenses are based on the Arrow Missile Defense System, which has only recently achieved initial operational capability (IOC). On the other hand, the IAF has developed and deploys a formidable defensive system of systems that would challenge any serious attempt to threaten the State of Israel and its armed forces from the air.

The IAF's *offensive superiority* can be exploited to destroy enemy ground forces, SSMs, national command systems, and other important elements of an enemy force. Furthermore, over the last few years, the IAF's prominence in IDF offensive doctrine has become more pronounced. The two most recent air wars fought in the Middle East (the war in Lebanon and the Gulf War) have served as models for the formation of IAF doctrine, training, R&D, and procurement. Consequently, more resources have been devoted to enhancing its offensive power.

The coalition air forces have not been able to meet the requirements of modern offensive warfare. In order to play an effective role, a combined multi-national air force would need to construct a joint efficient system of systems, capable of reacting in near real-time as situations unfolded. Not having done so, the coalition's air forces would likely be unable to integrate effectively in a joint military campaign. In addition, their shortage of cutting-edge standoff air-to-ground munitions, along with the IAF's defensive superiority, would combine to dwarf the ability of the coalition air forces to orchestrate jointly complex offensive operations. Were such a coalition *not* to include all of the partners named in this analysis (Egypt, Syria, Jordan, and an Iraqi expeditionary force), the IAF would enjoy an even greater advantage.

The results of this study demonstrate that the IAF has also achieved *defensive air superiority*. Its ability both to defend the country's skies and provide cover for IDF ground units is high, though the depth of the contingency zones and the number of SAM systems and aircraft employed by the coalition could prevent the IAF from acquiring air supremacy at any given place and time. The result is that holes in Israel's air defense could form, which would enable some successful coalition strikes against strategic targets.

The analysis demonstrates in detail that the sophistication of the IAF's system of systems surpasses that of the coalition. In addition to each Arab state's individual weaknesses, a coalition would be plagued by the problem of coordinating a variety of non-interlocking systems, with each state fielding different platforms, SAM systems, and C^4I systems. These difficulties would likely reduce the total effectiveness of the coalition. With that, the coalition's main advantage, its quantitative preponderance, should not be entirely discounted. The large number of attack helicopters at the disposal of the coalition could coalesce into a critical mass with sufficient destructive capability to delay and contain attacks by the IDF in certain arenas.

The IAF at present commands a potent deterrent image. However, this would be much curtailed if the coalition partners had only limited political goals, or if a number of extra-regional military or political factors were to change (for example, were Israel to lose American support, or were Iran to join the coalition). The gravity of such possibilities, however, should not be overstated: even in the face of a failure of Israeli strategic deterrence, the IAF would likely retain sufficient operational-level deterrence to limit both the objectives of the ground war and the scale of SSM attacks.

There is a risk inherent in the IAF's preponderant role in overall IDF power and doctrine, in contrast to the secondary importance that the coalition states accord to their air forces. While the IAF is a highly advanced and capable force, its many responsibilities within Israel's national security and military doctrine mean that in wartime the IAF would have to divide its forces among a large number of complex and demanding tasks. Notwithstanding the premise advanced in this study that quality should take a prominent place in capabilities assessment, quantity *does* count when operational demands grow in number and / or complexity. In contrast, the more rudimentary coalition forces would be able to focus their limited resources on fewer objectives. If intelligently employed in an orchestrated fashion, these forces could gain a number of operational achievements, despite their overall inferiority.

A pivotal principle of IDF doctrine is to transfer the site of battle to enemy territory and achieve a decisive, swift, operational-level victory in an intensive campaign. In the absence of a swift victory, a main threat to the IAF is the attrition that it would sustain in the wake of continuous operations. In the 1973 War, the IAF incurred heavy losses in the first days of the fighting and needed an American airlift to maintain wartime operations. Six years earlier, at the outset of the 1967 War, the IAF also suffered high rates of attrition in the battle for air superiority. In future wars, the IAF will not be able to sustain attrition rates of such magnitude, due to its shift toward smaller numbers of platforms and advanced munitions. For example, were the coalition to adopt a sustained strategy of attrition, or attempt a series of strategic strikes using their surface-to-surface missile systems, the IAF's strengths could be compromised, notwithstanding whatever tactical achievements it might gain. It would thus either have to reduce the intensity of its engagements, or develop the means, doctrine, and tactics needed to reduce its attrition rate significantly, while sustaining both operational deterrence *and* intensive, high-tempo campaigns.

Operational conditions that might limit the use of airpower, or international pressure to suspend or curb use of airpower, severely threaten the IAF. Any mutual neutralization of air forces would alter the overall balance of forces in favor of the coalition and disproportionately cripple Israel. A partial answer to that weakness is the strategic agreement with the United States for the pre-positioning of essential war materiel – including major weapon systems – in Israel, and the presumed assurance of a US emergency airlift, were one to be needed.

For the Arab coalition, the Gulf War provided valuable, practical lessons which are validated by this study. Most crucially, the importance of various advanced systems (such as precision munitions, electronic warfare, and the relatively new field of information warfare), was forcefully brought home. Another potent lesson, which is not analyzed in this study, was the impact that SSMs had on both Israeli morale and on the legitimacy of their use. Such systems represent both a basis for strategic deterrence and a partial Arab tactical response to Israel's air superiority. In the coming decade, technological and operational match-ups between SSM systems and anti-tactical ballistic missile (ATBM) systems will become a prevalent element in the Middle East balance of forces.

Egypt

The Egyptian Air Force has attempted one of the most far-reaching modernization efforts of any Arab air force in the Middle East, weathering the burdensome transition from Russian systems and doctrines to Western ones. Budgetary shortfalls have indeed slowed the pace of this shift, and the Egyptian Air Force still retains relatively outdated Russian systems, such as SA-2 SAM systems and MiG-21 fighters. These, however, will be retired in the next few years. Moreover, the Egyptian Air Force's increasing confidence is reflected in its acquisition of aircraft for deep-penetration strikes into enemy territory. Previously, the importance of this potential mission was downplayed, but today it probably represents a more substantial role.

Overall, Egypt's thrust is toward an enhancement of the air force's traditional roles both in defensive air superiority and offensive superiority over the battlefield. Today's Egyptian Air Force fields cutting-edge French and American-made systems, such as the Mirage 2000 and the F-16C / D, equipped with modern air-to-air and air-to-surface munitions. Defensive capabilities are supported by newer systems, providing noticeably-enhanced C^4I and EW capabilities. These air defense systems would present a considerable challenge to attacking aircraft.

Egypt's offensive superiority over the battlefield and deep-penetration capability is multiplied by air-to-ground precision munitions (albeit not of the most advanced types), UAV systems for surveillance and target acquisition, and the deployment of attack helicopters. As a result, the Egyptian Air Force already constitutes a substantially improved force.

Offensive air superiority: In a trend that will likely intensify in the years ahead, Egypt's air force has acquired a moderate offensive capability. This constitutes a change in the balance of power between Egypt and its neighbors. However, these qualitative improvements are somewhat offset by limited modernization and the mediocre quality of its manpower. The Egyptian Air Force still needs to train tens of thousands of operational, technical, and maintenance personnel, as well as aircrews and commanders who can fully exploit the potential of the modern systems it has acquired. Moreover, critical organizational changes have yet to be implemented. However, each successive year narrows the gap between the sophistication of the equipment in Egyptian arsenals and the skills of the manpower that must operate it. Joint exercises with the US Air Force have helped to improve the Egyptian Air Force's operational prowess, and to acquaint its pilots and commanders with cutting-edge doctrines and tactics.

Defensive air superiority: In keeping with Soviet doctrine, Egypt divides responsibility for achieving defensive air superiority between its air force, which deploys aircraft, and the Air Defense Forces, which deploy SAM systems. Surface units are also equipped with short range SAM and anti-air artillery (AAA) systems. A key shift in Egyptian air doctrine has been a new emphasis on interceptors in the defense of the country's airspace and its ground forces. The War of Attrition saw aircraft increasingly replaced by SAM systems, which a few years later scored significant successes in the 1973 Arab-Israeli War. On the other hand, more recent conflicts, such as the war in Lebanon and the Gulf War, have demonstrated that interceptors may play a dominant defensive role. That doctrinal change is clearly manifested in joint Egyptian-American air exercises.

In the event of a conflict between Egypt and Israel, the struggle for defensive air superiority would likely take place over the Sinai Peninsula. Here, the Egyptian Air Force could prevent the IAF from achieving air superiority for a short time or, alternatively, force the IAF to commit a considerable portion of its forces to that mission at the expense of other essential tasks. Similarly, in the defensive role, Egyptian SAM systems have also taken great strides with the acquisition of a substantial number of Improved Hawk SAM systems and western-manufactured early warning systems.

The infrastructure at the disposal of the Egyptian Air Force affords it the promise of being able to absorb an attack and cope with the rigors of a lengthy war at the same time. However, in this scenario, the vast expanses of the Egyptian heartland (the populated area of the Nile Delta) are a drawback, since air defense must be spread thinly across large areas. To compensate, Egypt is building a broad technological military infrastructure, covering the entire spectrum from the assembly of main combat systems – such as tanks, helicopters, SSMs, and self-propelled guns – to encouraging an electronics industry. This infrastructure will boost Egypt's ability to support the technological and logistics needs of its air force.

The most formidable challenge involved in refurbishing the Egyptian Air Force is integrating the various systems, units, and organizations into a coherent system of systems. In this realm, the Egyptian Air Force has so far demonstrated only limited progress, and successive years of improvements are needed to enhance its capabilities in this sphere. Acquisitions of EW systems and advanced avionics to enhance aircraft survivability have influenced overall preservation of power. Still, this is highly dependent on operational planning and personnel quality.

To conclude, the Egyptian Air Force is constantly and determinedly improving, and with it are the country's military strength and political clout. In the near future, it will probably procure additional new and advanced systems. From the point of view of weapon systems, the military-technological gap between the Egyptian and Israeli Air Forces is gradually narrowing. However, in terms of creating an internally coherent system of systems, Egypt still lags far behind the IAF and may even be losing ground.

Yet while the Egyptian Air Force is still no match for the IAF, it could block maritime routes to and from Israel's harbors in both the Mediterranean Sea and the Red Sea. It has also built a substantial deterrent image. Nor would Israel be able to ignore the Egyptian Air Force in the event of hostilities on its eastern front, even if Egypt were to refrain from direct involvement. Despite the overall inferiority of the Egyptian Air Force when compared to the IAF, it would constitute *the* pivotal factor in a struggle involving an Arab coalition. The combined impact of Egypt's geo-strategic position and the strength of its force means that Israel's political leadership must do everything at its disposal to prevent the emergence of a two-front air coalition.

Syria

Decades of combat with the IAF, and its longtime pursuit of strategic parity with Israel, are two factors that have influenced past Syrian decisions on force development, including its arrays of SAM systems. While its air doctrine developed along Soviet lines, Syria gained valuable operational experience in numerous engagements with the IAF and in the Gulf War. However, since the disintegration of the Soviet Union, Syria has been largely unable to modernize its air force, and gaps between its air force and the IAF have grown considerably.

Offensive air superiority: Syria's potential for achieving offensive air superiority has become insignificant. The main reasons for this are a lack of precision munitions, modern C^4I capabilities, modern doctrine, and training. Growing awareness that its aircraft would be unable to inflict serious damage upon penetrating Israeli airspace has led Syria to revise much of its military doctrine. SSM systems have replaced attack aircraft, much as interceptors had given way to SAM systems twenty years earlier. The trend toward acquiring more and better SSM systems was accelerated after seeing Israel's sensitivity to ballistic missile attacks in the Gulf War. On the other hand, the SSM systems in Syrian arsenals have certain inherent limitations: most notably, their inaccuracy makes them unreliable for hitting key point targets.

Were a war to break out between Syria and Israel, the Syrian Air Force could be expected to provide close air support for ground troops. Like many other air forces, Syrian commanders have recognized the potential of attack helicopters against armored vehicles, and these platforms are being assigned an increasingly active role. Syria's fleet of attack helicopters enhances the air force's ability to support ground units, and to advance other combat operations as well.

One of the main lessons from the Gulf War for Syria was a reaffirmation of the importance of achieving air superiority over the battlefield. However, a lack of resources has prevented it from acquiring improved materiel. Syria would thus be hard-put to maintain a sustained offensive air campaign.

Defensive air superiority: As noted previously, Syria's acknowledgment of its air force's technological and operational inferiority vis-à-vis the IAF led it to concentrate on surface-to-air systems. Highly successful in the 1973 War, such systems suffered a crushing defeat some ten years later in Lebanon. Currently, the defense of Syria's airspace and of its ground forces is largely based on a combination of SAM systems and aircraft, mostly obsolete and limited to thwarting IAF offensive operations. As a result, this study concludes that the Syrian Air Force has failed to attain strategic parity with the IAF.

With regard to systems, the Syrian Air Force's order-of-battle includes large numbers of old and outdated systems and weapons. Its acquisitions have provided three major elements for air defense. For long range surface-to-air defense, Syria presently deploys aging SA-5 systems; these, however, are of rather limited capability. Syria has also acquired a small number of MiG-29s, which in some respects equal Israel's F-15s and F-16s. However, its planes provide no match for the IAF's stocks of advanced air-to-air missiles. In terms of offensive capabilities, Syria has acquired some Su-24 strike aircraft, which have sufficient range and payload to attack deep inside Israel. Its C^4I system has suffered persistent difficulties in modernization and deployment, and it lacks real-time intelligence gathering systems. Narrowing the intelligence gap will take many years, not least because Syria's limited relations with post-Soviet Russia have meant a decline in access to intelligence data from that quarter.

An additional inadequacy is manpower quality, where the Syrian Air Force suffers a long-standing weakness. Exposure to Western technologies and training is considered essential for improvement in this sphere, but this has not yet occurred. Thus, the disparities with the IAF may be expected to continue for years to come.

Capabilities in system of systems are inadequate. The Syrian Air Force can barely deploy for missions that are planned well in advance. In the event of an offensive that were to take an unexpected turn, or were the need to arise for ongoing improvisation and revision, its system of systems might easily break down when it would be most needed.

In conclusion, this study finds that the Syrian Air Force suffers from major shortcomings vis-à-vis the IAF. Many years and billions of dollars would be needed to substantially shift that balance. With that, it is important to remember that Syria's strategic depth constitutes an important contribution to its preservation of power. Although most of its airpower, including airfields and SAM systems, are concentrated in southern Syria, there are enough rear-echelon airfields, C^4I posts, and SAM batteries to resist the complete destruction of the Syrian armed force. Though its deterrent capability is poor, Syria does possess an SSM capability, and is developing and deploying chemical and biological warheads. This could compensate for the inability of its air force to compete with the IAF in terms of deterrence.

Jordan

Jordan's air doctrine derives from its security concept, which is essentially defensive. The major role of the air force (including its SAM defenses) is defensive air superiority, i.e., defense of the country's airspace and its strategic assets. A second role is to support its ground forces in repulsing an invading army or in counter-attacks. The Jordanian Air Force is in any case quite small, and is not engaged in an attempt to compete with the IAF in any fashion except defensive air superiority.

In the area of systems, Jordan's F-1s, F-5s, and Cobra helicopters are all outdated, as are the avionics and fire-control systems. It has, however, recently deployed much more advanced platforms, in the form of the F-16 A/B. Moderate early warning capability exists thanks to systems received from the United States. Aerial intelligence gathering is very limited due to old systems. Its C^4I system, while not the most advanced, apparently suffices for the defensive needs of a small corps with limited tasks.

The present study shows that the Jordanian Air Force rests on two potent elements: SAM systems and high-quality aircrews. Its program for air defense successfully combines Western and Eastern systems: early warning systems and an impressive number of Improved Hawk SAM systems, coupled with Russian SA-8, SA-13, and SA-14 systems for short range defense, create an array that could severely impair aggression from the air.

The manpower of the Jordanian Air Force has the potential to exploit advanced systems fully as they are acquired and deployed. While Jordanian pilots might be hard-pressed to match the IAF, they would likely acquit themselves well against Syrian and Iraqi pilots.

Jordan relies heavily on the US for maintaining the quality of its air force. In the wake of Jordan's peace treaty with Israel, the United States resumed delivery to Jordan of weapon systems such as the F-16, and renewed joint maneuvers. These have enhanced the quality of Jordan's aircrews, its defensive capabilities, and its ability to provide support for ground forces with attack helicopters. However, the Jordanian Air Force does not have the capability to achieve even a temporary offensive superiority. Its contribution to the strategic level of war depends on its ability to maintain defensive air superiority until the cessation of hostilities by means of reversion to political negotiations.

Finally, the Jordanian Air Force has only a limited capability in the area of preservation of power, and it lacks an efficient system of systems. In sum, should Jordan join an alliance against Israel, its operational contribution would be by virtue of its strategic deployment and its possession of infrastructure along Israel's long eastern border, rather than because of its own offensive capabilities.

Chapter 4

Sensitivity Analysis

The methodology of the model presented in this study is built upon two kinds of sources. The first is numerical data, such as quantities of weapon systems, air bases, and other elements of power. The second is the set of estimates of the importance, or *weight*, of each element of airpower, as assessed by experts from various fields. However, despite the size and diversity of the group of experts, their assessments, susceptible to miscalculations and biases, do not carry the same kind of certainty as would objective facts. Moreover, some of the elements – such as the quality of manpower – are not quantifiable physical assets, and the experts must estimate with regard to them as well. In addition, since the nations being studied keep numerical data on their orders-of-battle behind a heavy curtain of secrecy, even those quantitative figures that are obtained are not always accurate.

These limitations make it essential to determine the sensitivity of the model to potential inaccuracies in both the raw data fed into it, and to the misperceptions of the experts who were asked to interpret this data. To do this, techniques of *sensitivity analysis* were used. Sensitivity analysis allows the results obtained by means of the model to be measured against possible inaccuracies, variations in the value of individual assessments, or the weight assigned to each element. Sensitivity analysis examines the influence of a given change or set of changes in the weight of an element or category of elements on the overall results obtained by the model. When a substantial change in the weight of an element does not significantly influence the overall assessment of the model, it means that the sensitivity of the model to such variations or inaccuracies is low, i.e., that the model's overall results are less vulnerable to errors in the assessments of the professionals or to inaccurate and incomplete data. The lower the sensitivity of the model, the higher its validity may be presumed to be.

The present analysis began with the tree-like structure of the model. Its primary categories of elements (systems, infrastructure, and so on) break off into progressively more specific sub-categories, groups, types, and parameters, each with a correspondingly smaller influence on the final results. The critical analysis of the model that this chapter seeks to undertake thus begins with the main categories of elements that combine to determine airpower. Following this, it examines the influence of smaller branches of each category on the end results.

Sensitivity to Systems

Figure 18 opens the analysis as it illustrates the model's sensitivity to changes in weight of a primary category, systems. In addition, the explanatory notes provide a useful example for how to read and understand the use of sensitivity analysis as it relates to this model.

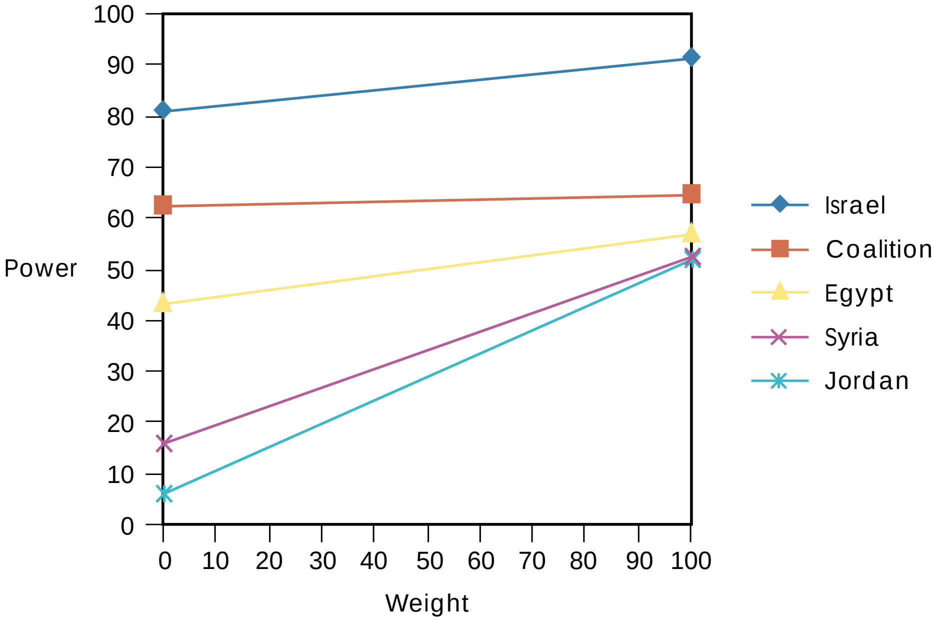


Fig. 18. Sensitivity to Systems

Explanation of Figure 18:

- The horizontal axis shows the weight of the element (in this case, systems) from 0 to 100.
- The vertical axis shows the overall power of the air forces in question, from 0 to 100.
- The colored lines show the change of the power of each air force as the relative weight of systems is changed.
- As the chart indicates, when the systems category receives a weight of zero (i.e., when the influence of systems is reduced to zero), the IAF's power is rated at

about 80. When systems receives 100 (i.e., when the influence of the systems category determines 100% of the weight attributed to overall airpower), IAF power is enhanced to more than 91.

To understand this analysis fully, it should be noted that hypothetically enhancing the weight of systems takes place at the expense of the weight accorded to other categories and their components. That is, if it is to be hypothetically assumed that the systems category bears a 100% influence on overall power, then it is essentially being argued that all other factors have no influence at all. Conversely, when the overall influence of systems is reduced, the influence of other categories is correspondingly increased. When the weight of systems is rated at 80%, the influence of all the other categories *combined* can only be 20%. These interrelated changes play an important role in the understanding of the influence of changes of weight on power.

An additional assumption for analyzing sensitivity is that the maximum deviation in the weight that should be accorded to any given element is within 20% of the weight accorded to it by the model. That is, given that the model assesses the weight of systems at 40%, the maximum deviation between the weight accorded to it and its "true" weight is 8%, from 32% to 48%. Referring back to Figure 18, it is apparent that when the weight of systems is shifted within this margin of deviation, the overall effect on the result – the ratio of power between the between the coalition and the IAF – impacts only negligibly. Moreover, as the weight of systems is enhanced, the overall power of each air force decreases, with the exception of that of the coalition, which does not undergo significant changes. Some air forces are influenced by this change to a greater degree than others – the Syrian Air Force, for example, is more strongly influenced than either the Egyptian Air Force or the IAF. Most important, however, is that *the IAF is significantly stronger than the coalition regardless of any changes in the weight of systems.* This means that the results of the model are not sensitive to changes in the weight of systems.

Sensitivity to Manpower

Figure 19 illustrates the sensitivity of changes in the weight of manpower, and resembles the previous graph in many ways. The main difference is that the weight of manpower has a positive influence on power for *all* air forces. This means that as the weight attributed to manpower increases, the overall power of each air force – Israeli, Egyptian, Syrian – increases.

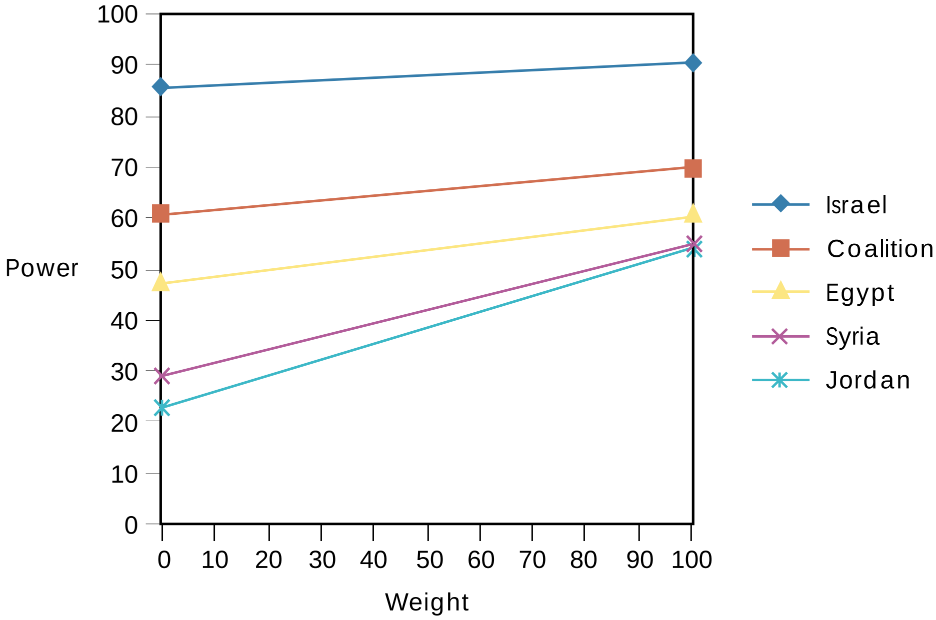


Fig. 19. Sensitivity to Manpower

In terms of sensitivity, the end results show low sensitivity to changes in the weight assigned to manpower. Given that manpower was assessed at 35%, the maximum margin of deviation is assessed at 7%, i.e., between 28% and 42%. Figure 19 shows that, within this margin of deviation, the relative power between the coalition and the IAF is hardly affected. Most notable is the fact that the IAF would appear to be significantly stronger than the coalition, regardless of the changes in the weight of manpower. This shows that the results of the model are not sensitive to changes in the weight of manpower.

It may seem clear that given the IAF's emphasis on high-quality personnel, its overall relative power would increase as the weight of the manpower category is increased. However, despite the fact that the Syrian Air Force's manpower is considered to be of low quality, the graph shows that its power increases as well. How can this be? The answer consists of two reasons: first, enhancing the weight of manpower means reducing the weight given to other categories, in which the Syrian Air Force is notably weaker. Second, the manpower category factors in *both* quality *and* quantity in its overall assessment. Hence, the large number of personnel serving in the Syrian Air Force has a positive effect on its overall rating.

Sensitivity to Infrastructure

Infrastructure, as the previous chapter has shown, is one of the IAF's weakest categories. Figure 20 illustrates the sensitivity of changes in the relative weight given to infrastructure.

Figure 20 departs markedly from the previous two. The main difference is that the weight of infrastructure has a positive influence on the power of the coalition, but a negative one on the overall power of the IAF. The assessment that the model assigns to infrastructure is 6%, with a margin of deviation of 1.2%. Within this margin of deviation, Figure 20 clearly shows that the overall relative power of the IAF vs. the coalition is not significantly affected – or in other words, that the model has low sensitivity to changes in the weight accorded to infrastructure.

Moreover, when examining Figure 20 carefully, it appears that the point of intersection between the coalition and the IAF – the point at which their overall power becomes equal – occurs only when the relative weight of infrastructure reaches 82% – roughly 14 times more than it is presently weighted in the model. Given that this would leave the total combined influence of the remaining primary categories (systems, manpower, and system of systems) at 18% (instead of 94%, as they are presently), this possibility seems extremely unrealistic.

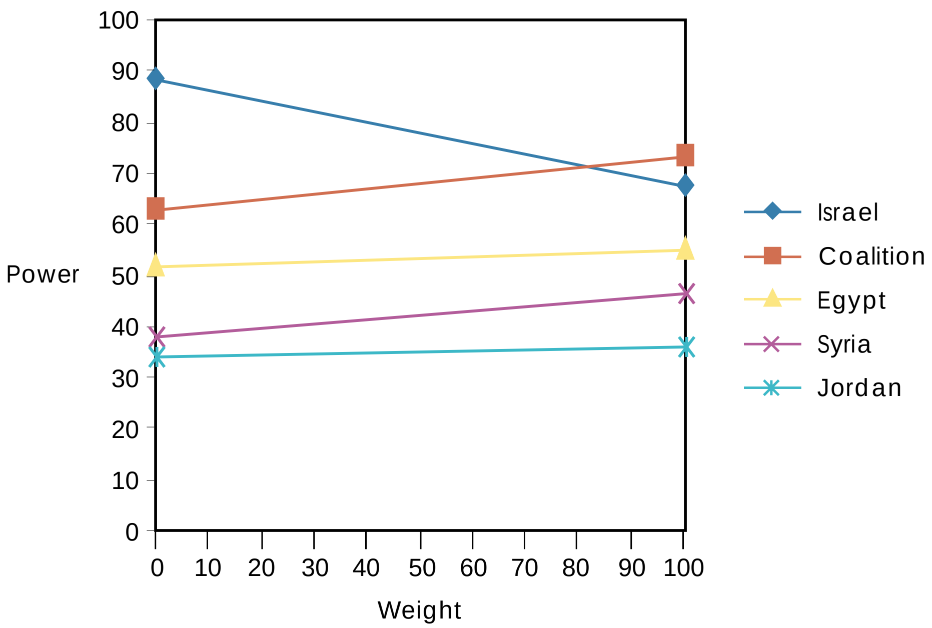


Fig. 20. Sensitivity to Infrastructure

Sensitivity to System of Systems

The IAF's advantage over the coalition is most dramatic in the category of system of systems. Figure 21 illustrates the sensitivity of changes in the weight of system of systems.

Figure 21 differs from all of the previous figures, inasmuch as increasing the weight accorded to system of systems positively influences the power of the IAF and the Syrian and Jordanian Air Forces, while negatively influencing the power of the coalition slightly. Regarding sensitivity, the relative weight given to system of systems is 20%, with a margin of deviation of 4%. As Figure 21 shows, when the relative weight of system of systems is adjusted within this spectrum, there is no significant effect on the overall power between the coalition and the IAF. The results thus show a low degree of sensitivity to changes in system of systems.

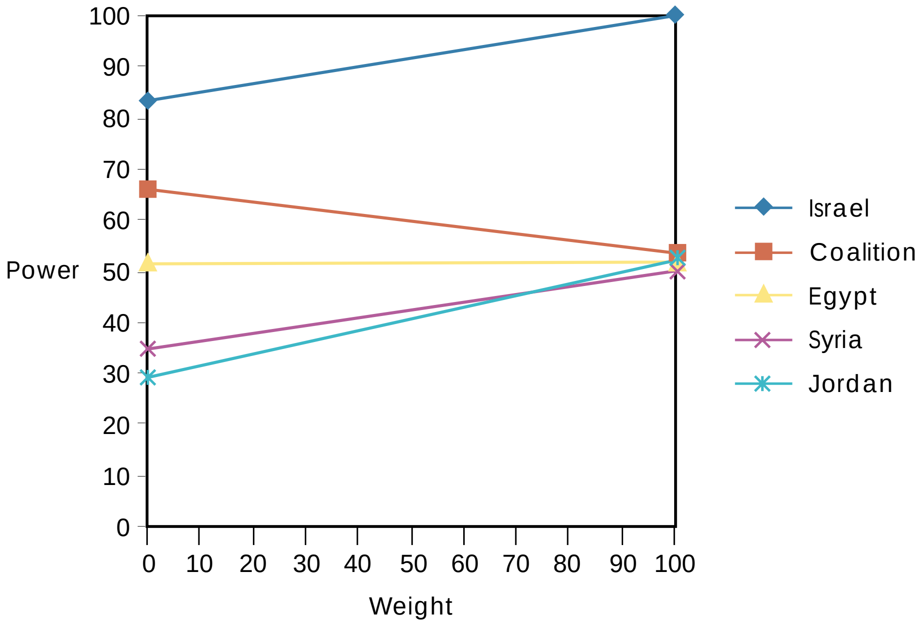


Fig. 21. Sensitivity to System of Systems

As a primary category, system of systems has unique characteristics when compared to the others that are used in this model. The power of other categories is a combination of both quantitative and qualitative factors. For example, to determine the strength of a given air force in PGMs, the model takes into consideration both the number and the quality of missiles. In contrast, the elements measured in the system of systems category are purely qualitative. This explains why, in most other cases, the IAF's advantage over the coalition gradually decreases as the weight of the category is increased.

Given the different nature of system of systems, the methodology for quantifying its various components is also different. To return to the example of PGMs, it is clear that both quantity and quality play a role on a number of levels, inasmuch as more advanced missiles are presumably more capable than less advanced ones. If, however, different members of the coalition have different stocks of missiles, it is still possible to add up total quantities, as long as accommodation is made for the divergences in the capabilities of each. However, given that system of systems is composed solely of qualitative factors, it is calculated by taking the average of the different elements that comprise it. For example: the Egyptian Air Force rates 6 on a scale of 10 in synergy, while the Syrian Air Force rates about 4, and the Jordanian Air Force about 5. The average of these ratings comes out to 5, and this is the rating that was given to the coalition overall.

Analysis of Modernization

Modern air forces have acquired some significant new characteristics. Among them are emphases on advanced weapon systems, space warfare, and information warfare, rather than fighting platforms, such as aircraft and helicopters. Defining the distinction between "developed" air forces and "developing" ones (like the distinction made between states) is important for present and future assessments. Given that developed air forces may be expected to accelerate the race toward excellence at the expense of acquiring larger numbers of less advanced and less capable systems and manpower, they will presumably widen the quality gap when compared to developing air forces.

Since PGMs are leading indicators of modern air forces, the focus of the analysis shifts here to the influence of changes in the weight of precision munitions for aircraft in air-to-air missions (as shown in Figure 22) and air-to-ground missions (Figure 23). Both show that the advantage of the IAF grows significantly as the weight of precision weapons is enhanced. In contrast, Figure 24 illustrates the influence of changes in the weight of aircraft, which at present play a limited role in the Revolution in Military Affairs.

The Influence of Advanced Air-to-Air Munitions

The importance of advanced air-to-air munitions will be analyzed by measuring their influence on overall power and the ratio of power among the rival air forces. Figure

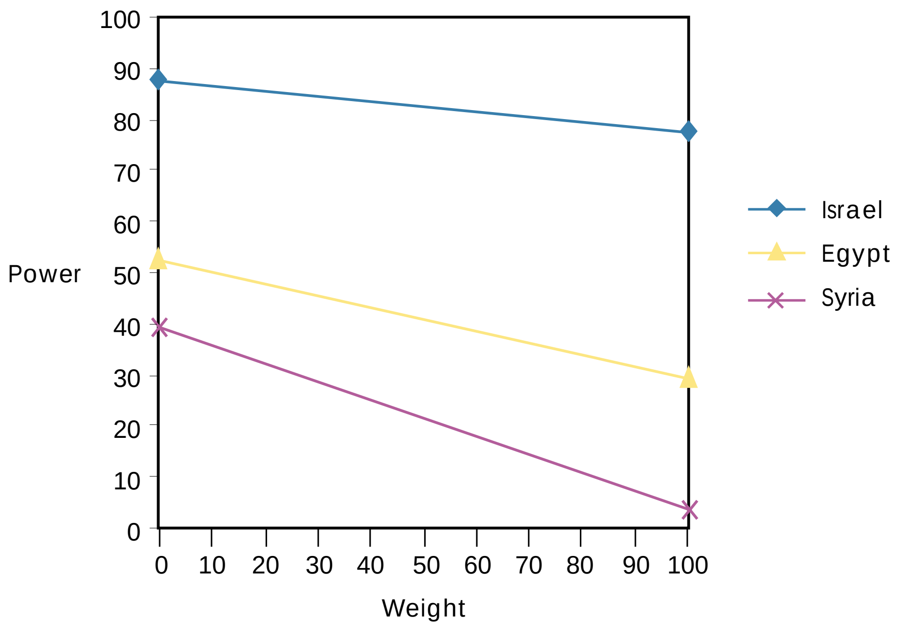


Fig. 22. Sensitivity to Air-to-Air Munitions

22 demonstrates changes in power, while Table 4 below shows the changes in the ratio of power.

Figure 22 portrays the influence of the weight of air-to-air munitions in power. The Arab air forces are at different levels of modernization, and the less modern the force in question, the steeper the angle of declination observed. As modernization is given greater emphasis, overall Syrian airpower declines from 39.2 to 3.4, while IAF power declines from 88 to 78. Even more interesting is Table 4, which translates these results into ratios of power.

Table 4. Ratio of Power, by Changes in the Relative Weight Assigned to Air-to-Air Munitions

Air Forces	**Ratio of Power: Syria = 1**		
	Weight 1	Weight 100	Ratio 100:1
IAF	2.2	22.5	10.2
Egyptian Air Force	1.3	7.5	5.8
Syrian Air Force	1	1	1

This table shows that as the weight of air-to-air munitions is enhanced, the ratio of power grows in favor of those air forces that have successfully modernized. The force ratio between the IAF and the Syrian Air Force (which as previously noted has not modernized its force) jumps from 2.2 to 22.5 – a factor of 10.2! At the same time, the relative force ratio between the currently modernizing Egyptian Air Force and the Syrian Air Force rises only from 1.3 to 7.5 – a factor of 5.8. While the Arab air forces have a distinct numerical advantage in air-to-air munitions, the overall advantage, as before, still goes to those forces with a *qualitative* advantage. Both the IAF, and to a lesser but still significant extent, the Egyptian Air Force, confirm their advantage over the Syrian Air Force.

The Influence of Advanced Air-to-Surface Munitions

The importance of advanced air-to-surface munitions will be analyzed by the same methodology as were air-to-air munitions. Figure 23 demonstrates changes in relative power, and Table 5 shows the changes in the ratio of power between the IAF and rival air forces.

Figure 23 shows the influence of the weight of air-to-surface munitions on the relative power of the air forces. As the weight of air-to-surface munitions is enhanced, the gaps of power between air forces increase decidedly in favor of more modern forces.

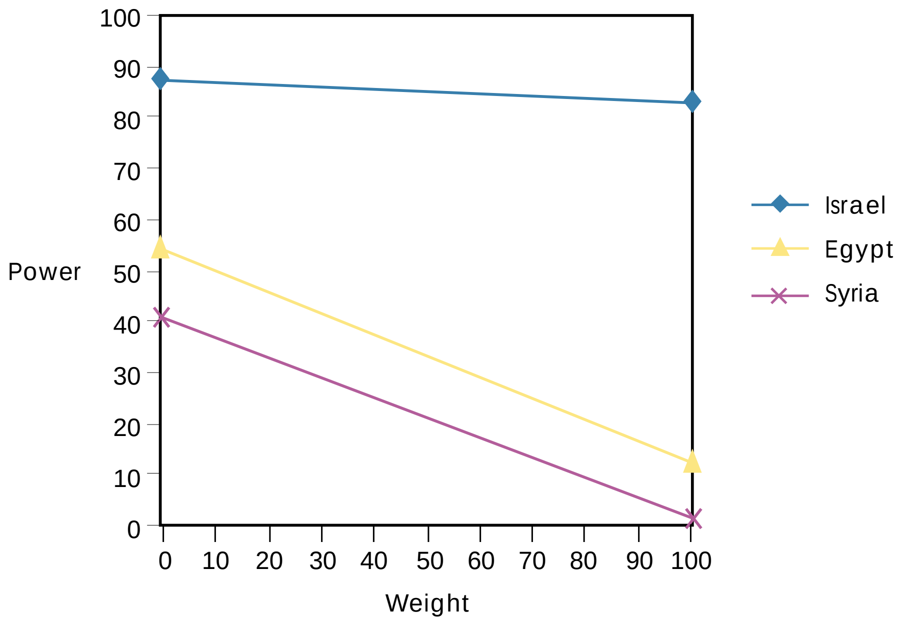


Fig. 23. Sensitivity to Air-to-Ground Munitions

As in the previous figure, Figure 23 shows that despite its notable quantitative advantage, the power of the Egyptian and the Syrian Air Forces decreases sharply as the relative weight accorded to air-to-surface munitions grows. The IAF's overall power, in contrast, does not decline significantly. As the emphasis on precision munitions grows, the gap between the IAF and its rivals widens noticeably.

Table 5. Ratio of Power, by Changes in the Relative Weight Assigned to Air-to-Surface Munitions

Air Forces	**Ratio of Power: Syria = 1**		
	Weight 1	Weight 100	Ratio 100:1
IAF	2.1	83.0	39.5
Egyptian Air Force	1.3	12.4	9.5
Syrian Air Force	1	1	1

This table bolsters the concept that was discussed above. As the weight of air-to-surface munitions is enhanced, the ratio of power grows in favor of more advanced air forces. The results that can be seen in Table 5, however, are even more prominent. For example: the ratio between the IAF and the Syrian Air Force jumps from 2.1 to 83.0 (a factor of 39.5) while the ratio between the Egyptian Air Force and the Syrian increases from 1.3 to 12.4 (a factor of 9.5). Once again, despite the significant numerical advantage of the Arab air forces, the qualitative advantages of the IAF's advanced munitions (and those of Egypt's over Syria's) provide it with a considerable advantage.

The Influence of Aircraft

An analysis of the importance of aircraft, employing the same methodology as used above for precision munitions, produced some surprising results. Figure 24 demonstrates the influence of the weight of aircraft, while Table 6 shows the changes in the ratio of power.

Figure 24 reveals a different picture than Figures 22 and 23: the changes in power when assessing the influence of aircraft are much smaller than were the changes in munitions. The data shows that, when compared to the Syrian Air Force, the advantage of the IAF narrows significantly as the weight accorded to aircraft in overall airpower is enhanced. The IAF's advantage changes slightly when compared to the Egyptian Air Force, and grows only in comparison with the Syrian Air Force, which lags in the modernization race.

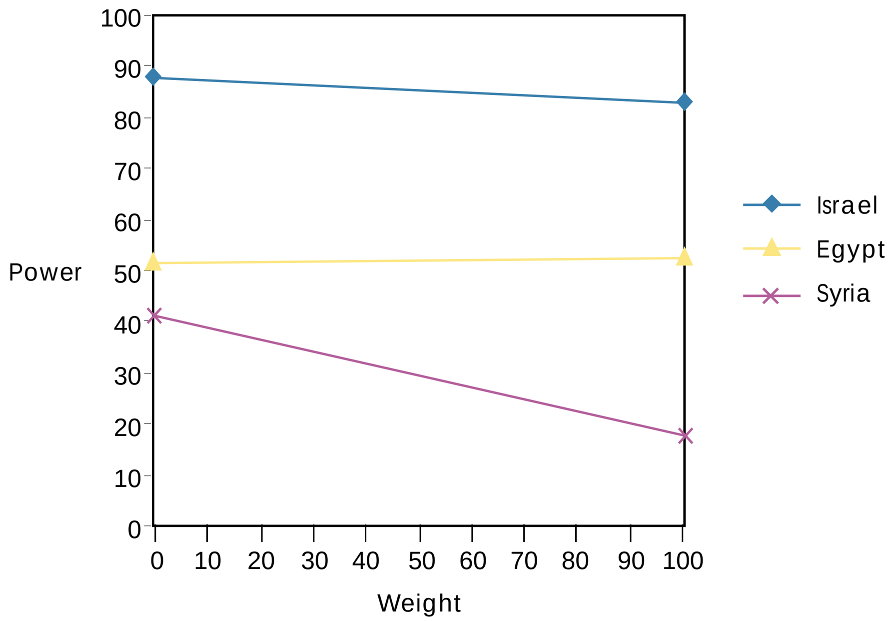


Fig. 24. Sensitivity to Aircraft

Table 6. Ratio of Power, by Changes in the Relative Weight Assigned to Aircraft

Air Forces	**Ratio of Power: Syria = 1**		
	Weight 1	Weight 100	Ratio 100:1
IAF	2.1	4.8	2.3
Egyptian Air Force	1.3	3.0	2.3
Syrian Air Force	1	1	1

Table 6 shows the same trend as the previous ones, but to a lesser degree of magnitude. As the weight of aircraft is enhanced, the ratio of power grows in favor of modern air forces. However, here the results are less dramatic: the ratio between the IAF and the Syrian Air Force increases from 2.1 to 4.8 (a factor of 2.3). The ratio between the Egyptian Air Force and the Syrian Air Force increases from 1.3 to 3.0 (a factor of 2.3) – nearly the same as the IAF. However, the most interesting result is that the influence of the weight of aircraft on the ratio of power is limited in comparison to the influence of munitions. These results corroborate claims that the importance of aircraft on the overall power of modern air forces has decreased, while the importance of advanced munitions in modern air forces has risen. The ramifications of this trend represent a phenomenon that may be evaluated in more depth in the future.

Chapter 5

The Model Applied to Regional Conflict Dyads

This chapter applies the present model to other potential conflict dyads in the Middle East. By exploring these potential conflicts through the prism of the model, it will be possible to gain some insights into the underlying dynamics of these conflicts, and into the various forces at the disposal of each of the parties.

The chapter will explore five potential conflict dyads: Iraq and the states of the Gulf Cooperation Council (GCC); Turkey and Syria; Iran and Iraq; Libya and Egypt; and Morocco and Algeria.

The Gulf States and Iraq

Although Iraq retains sizable ground forces, its air force suffered a scathing defeat in the Gulf War. Moreover, the UN embargo imposed on Iraq has prevented it from rebuilding or modernizing its armed forces.

Recognizing the Iraqi threat, the Gulf States have stressed the modernization of their air forces and the need for inter-force coordination. Figure 25 illustrates the relative power of the combined air forces of the GCC set against the capabilities of the Iraqi Air Force. The two left-hand columns show the ratios of power and capabilities as they relate to defensive power. The two right-hand columns show the ratios of power and capabilities with regard to offensive power.

The most significant conclusion that may be drawn from this figure is the substantial advantage of the GCC air forces in both the defensive (1.5:1) and offensive (1.3:1) roles. This would likely deter Iraq from attempting incursions in the future. Taken together, the GCC's air forces are superior both in quantity and quality of aircraft, advanced munitions, airborne support systems, and the quantity of active aircrews. Figure 26 illustrates the ratio of power of the main categories of offensive airpower elements.

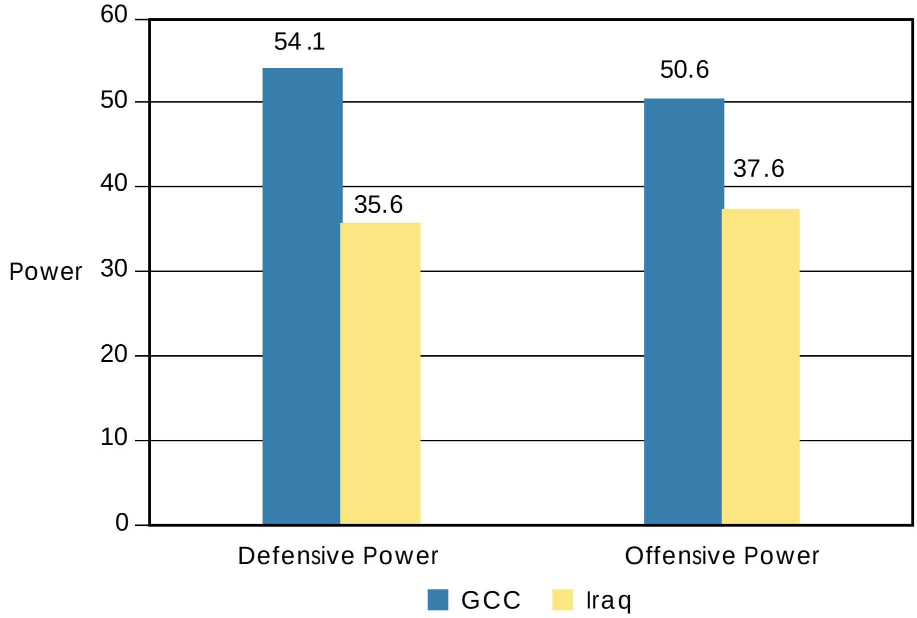


Fig. 25. GCC vs. Iraq: Balance of Power

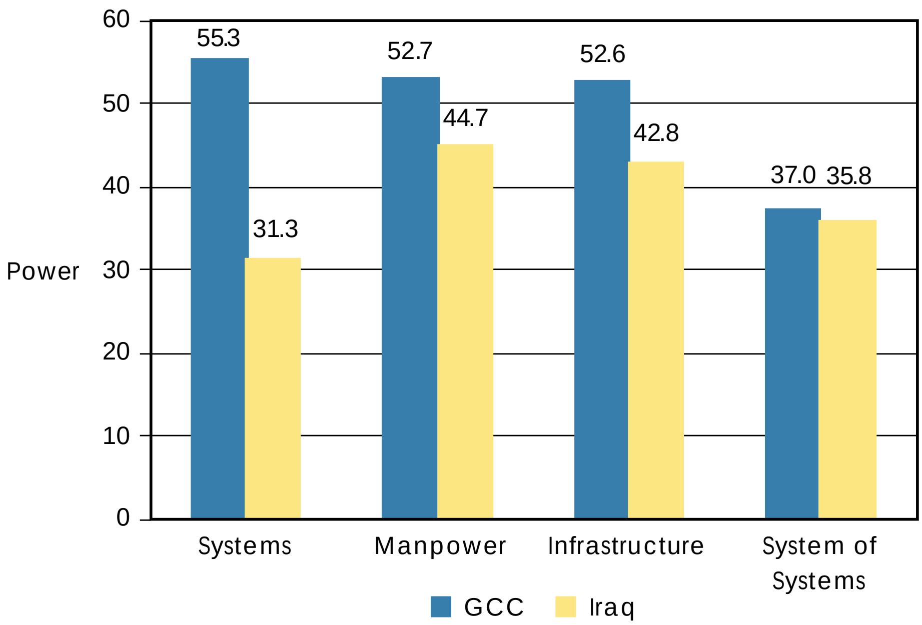


Fig. 26. GCC vs. Iraq: Offensive Superiority Main Categories

Systems: GCC forces have a decisive advantage (1.7:1) in systems over the Iraqi Air Force. While the Iraqi Air Force maintains an advantage in the numbers of aircraft, this does not significantly influence the ratio of forces, due to the unquestioned qualitative advantages of the GCC. GCC members have the requisite financial resources, determination to modernize, and access to Western military suppliers. They continue to modernize their air forces in order to deter Iraq from attack, and would be able to defend themselves if such an attack were to take place. The leaders of these countries have apparently learned the lessons of the Gulf War, and consider their air forces central to deterring or winning the next war (although some programs have been canceled due to budget constraints).

Manpower: The approximate ratio of numbers of aircrews is 1.8:1 in favor of the GCC, but the quality of both sides is difficult to estimate. However, close relationships with Western air forces and defense industries probably provide GCC air forces with better training and doctrine. The platforms-to-aircrews ratio is roughly equal, meaning that the rate of missions per aircraft and helicopters is about the same, if logistical factors do not come into play. Hence, the GCC's advantage in manpower is derived from a quantitative superiority, rather than a qualitative one.

Infrastructure: The infrastructure of both sides is about equal, though the quality of GCC facilities is probably higher than those of Iraq. This may serve to enhance both preservation of force in case of an Iraqi surprise attack, and the rate of operations in defensive and offensive warfare.

System of systems: Neither side has a strong system of systems capability. The Iraqi Air Force cannot, given the embargo, train qualified manpower or acquire modern C^4I systems. The Gulf War was a major setback, and the embargo has doubtless taken its toll concerning synergy, rate of operations, and preservation of power.

Conclusions: The model supports the assumption that the Gulf States have the capabilities needed to defend themselves against an Iraqi aerial attack. More than that, they have built a deterrent capability that may help to stabilize the Gulf politically. Iraq, which lost most of its offensive superiority in the Gulf War, cannot dominate the battlefield by means of its air force. Therefore, any ambitions it may harbor regarding Kuwait or its neighbors will likely be held in check over the coming years. With that, the creation of physical assets – platforms, munitions, and so on – is only part of the equation; the GCC's determination to face down possible threats, and the durability of the alliance, is the other. On paper, the Gulf States have acquired the *means* to deter and to counter an Iraqi invasion, but their ability to win an actual "shooting war" would be dependent upon additional, extra-military questions.

Turkey and Syria

Turkey is in a unique position in the Middle East. It is a full member in the North Atlantic Treaty Organization (NATO), and has close relations with the European Union. It also maintains a client state in Northern Cyprus. Its relations with its neighbors – Greece on the western side, Russia to the north, and Syria, Iraq, and Iran to the east – remain fraught with potential flash points. Turkey has also developed close relations with Israel, which may spark tensions with its Arab neighbors. A few of its air bases are used by the USAF for operations against Iraq, and by the IAF for training.

A military clash with Syria represents a potential conflict that could entangle Turkey and commit it to fighting without US assistance. In the wake of the war in Lebanon in the last decades of the twentieth century and the disintegration of the Soviet Union, Syria has done very little to modernize its air force, which was built and deployed mainly for confronting the IAF. Indeed, the question of a possible Syrian-Turkish confrontation has arisen only in recent years. While a detailed discussion of the Syrian Air Force appears in previous chapters, this was confined to the context of a potential war with Israel; additional detail is needed to understand the balance of airpower between Turkey and Syria.

Figure 27 illustrates the relative power of the Turkish Air Force and the Syrian Air Force. The two columns on the left of Figure 27 display the defensive ratio of power and capabilities. The two columns on the right relate to offensive power.

A significant conclusion that may be drawn from Figure 27 relates to the compatibility of doctrine and power: currently, the Syrian Air Force's primary role is defensive. The calculations presented here delineate the implications of that doctrine, namely, the defensive gap is negligible, while the offensive gap is considerable (1.2:1). This is particularly interesting when we consider that quantitatively, the Turkish Air Force is inferior in total number of aircraft, attack helicopters, and aircrews; its advantage derives from its qualitative edge.

Figure 28 illustrates the ratio of power of the main categories of elements.

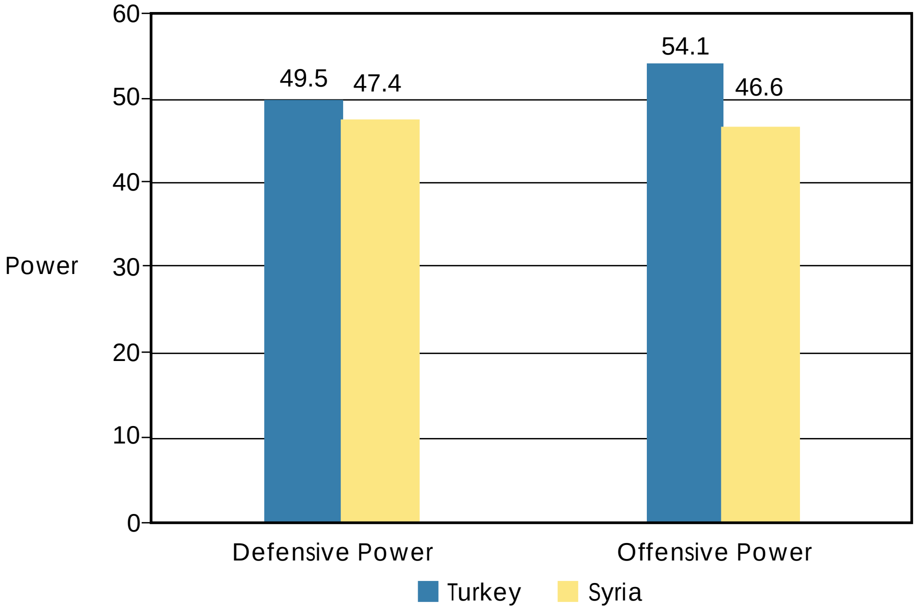


Fig. 27. Turkey vs. Syria: Balance of Power

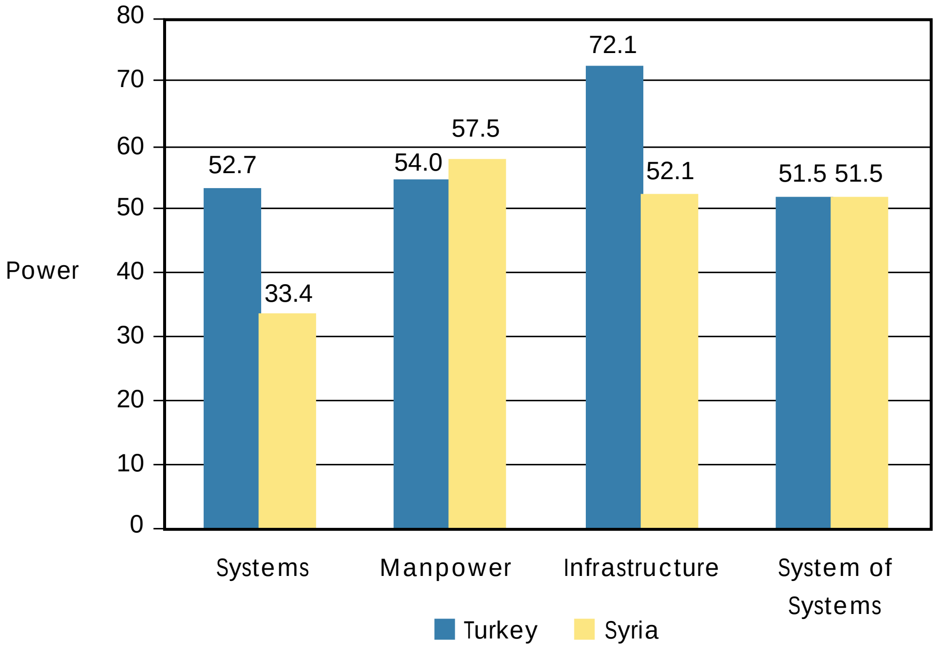


Fig. 28. Turkey vs. Syria: Offensive Superiority Main Categories

Systems: The Turkish Air Force has a notable advantage in platforms – 1.6:1. This advantage stems mainly from its qualitative edge: 175 multi-role aircraft with no Syrian match-up, and airborne support systems that are almost three times stronger than those of the Syrian Air Force. Moreover, the model shows that the defensive air doctrines of the two air forces are remarkably divergent. Turkish air doctrine, according to these results, seems to be based on an integration of fighters and SAM arrays, and emphasizes the use of aircraft. The Syrian doctrine emphasizes the use of SAM systems. Fighters are a definite second priority, relegated to guarding the flanks. Figure 29 illustrates the different power of aircraft and SAM systems in the defensive air superiority role.

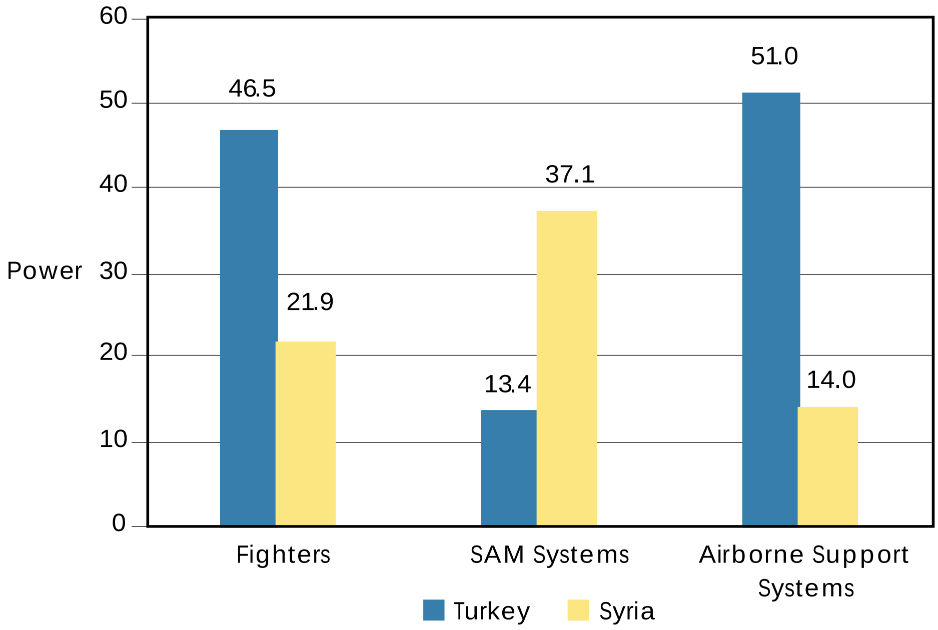


Fig. 29. Turkey vs. Syria: Defensive Air Superiority Elements

Conventional assessments, based on comparing numbers of platforms, would find that the aircraft ratio is 1:1.2 in favor of the Syrian Air Force. However, when evaluated by the present model, the more telling force ratios become apparent: the Turkish Air Force's advantage over Syria in fighters is 2:1. In addition to its advantage in platforms, the Turkish Air Force enjoys a decisive advantage (3.6:1) in airborne support systems, which enhance the defensive power of its fighters. In SAM systems, the advantage goes to Syria. However, here too, the advantage of the present model's quality-based approach is apparent, for while a comparison based on quantity shows a slight advantage (1:1.2) in favor of Syria, the model's qualitative measures show that in fact Syria's advantage is even more pronounced (1:2.8). These results demonstrate the advantages of the model in tailoring analyses and evaluations of airpower around the doctrines of the forces in question.

The Turkish Air force has historically been dependent on the US for assistance, systems, and training. However, Turkey has recently cultivated an additional source for advanced airborne systems: a number of Israeli defense contractors have been awarded contracts for supplying the Turkish Air Force with some advanced systems. Developed in the wake of the IAF's operational experience gained in wars against the Syrians, these may further increase the relative power of the Turkish Air Force over its Syrian counterpart.

Manpower: A definite shortcoming of the Syrian Air Force is manpower quality. Unlike the Syrians, however, the Turkish Air Force has adopted western standards and methods, and trains its manpower accordingly. While there is no way at present to judge how effective its manpower actually is, it seems reasonable that Turkey's relations with the West would yield at least a modest influence on the quality of its manpower.

Infrastructure: Infrastructure is the second category in which the Turkish Air Force has a substantial advantage, specifically, 1.4:1. This advantage stems from the improvements to its logistical systems made during Operation Desert Shield and in the years following in order to meet the requirements of the US forces deployed there, which were intended mainly to enhance Turkey's offensive potential. The measurement of defensive air superiority, however, reveals an interesting outcome. When viewed from a defensive point of view, the Syrian Air Force has the advantage in infrastructure, by a ratio of 1:1.2. The divergent results from measuring offensive and defensive power may be explained by the advantage of the Syrians in the logistical array that serves its many SAM batteries.

System of systems: The two air forces present fairly equally in their system of systems capabilities. Both can certainly execute operations that are planned in advance. However, in the event of a surprise attack, their system of systems capabilities could break down. Further data would be needed for a more detailed analysis of this category.

Conclusions: Syria has built its air force on the assumption that its main rival is Israel. The recognition of the inherent inferiority of its force has led to an emphasis on build-up of a defensive aerial power, and concentration on SAM systems for air defense. Questionable, however, is whether the organization, doctrine, and weapon systems of the Syrian Air Force are suitable for conflicts with its northern neighbor.

The Turkish Air Force, thanks to capabilities acquired from the US and Israel, appears to have improved its capabilities in recent years and will likely continue to do so. At the same time, the relative equality of the Syrian and Turkish Air Forces serves to ensure mutual deterrence. The present stalemate may stabilize the shaky ground between Turkey and Syria, reducing the potential for violence. This bolsters the presumption that air forces are built to deter wars, and to fight them only if that primary role fails.

Libya and Egypt

Relations between Libya and Egypt have faced various ups and downs since Muammar al-Qaddafi's rise to power. While the present study does not consider how an actual shooting war might erupt between Libya and Egypt, such a conflict is certainly conceivable. Figure 30 illustrates the relative powers of the Libyan Air Force and the Egyptian Air Force. The two columns on the left display the defensive ratio of power. The two right-hand columns display the offensive ratio of power.

Figure 30 shows the unequivocal dominance of the Egyptian Air Force in both defensive and offensive roles. Egypt's overwhelming superiority is indicated clearly by the comparison of the main elements of each air force.

As Figure 31 shows, the Egyptian Air Force is unchallenged in every main category: systems, manpower, infrastructure, and system of systems. Its dominance is based on qualitative advantages in weapon systems, manpower, and synergy. Consequently, the Egyptian Air Force holds a decisive advantage in deterring potential Libyan attacks on Egypt.

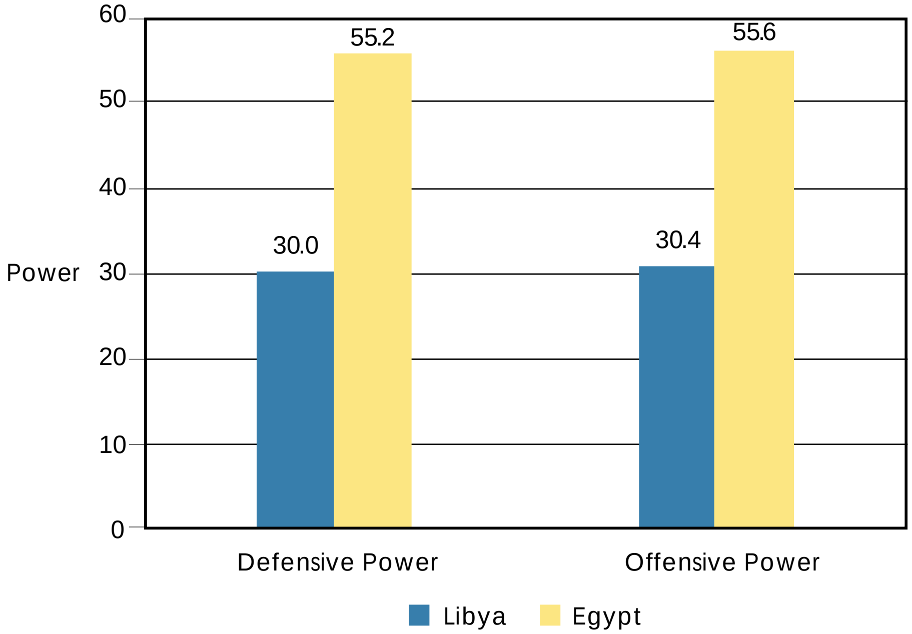


Fig. 30. Libya vs. Egypt: Balance of Power

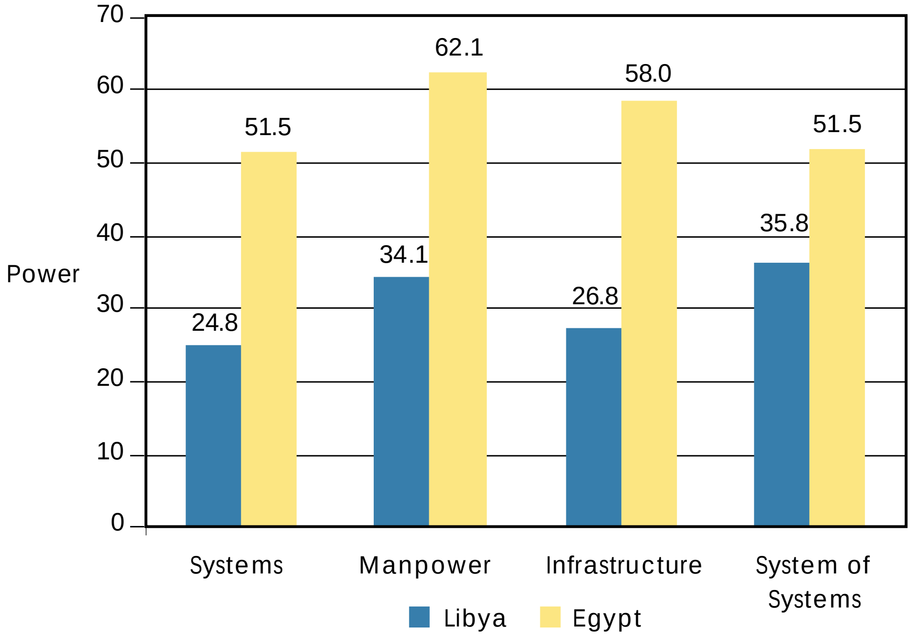


Fig. 31. Libya vs. Egypt: Offensive Superiority Main Categories

Iran and Iraq

Opinions differ over the probability of renewed military conflict between Iran and Iraq. However, a complete balance of power assessment could hardly ignore such a possibility, given the decade-long war of the 1980s. Figure 32 illustrates the relative powers of the Iranian and Iraqi air forces. The two left-hand columns display the defensive ratio of power and capabilities; the two columns on the right display the offensive ratio of power.

Figure 32 displays general equivalence in both defensive and offensive roles. However, deeper observation reveals a more complex picture: Figure 33 illustrates the ratio of power of the main categories, indicating a sensitive, intricate balance of power. The Iraqi Air Force is stronger in systems and infrastructure, while the Iranian Air Force has an advantage in manpower and system of systems.

How can we explain this? The Iraqi lead in attack helicopters (2.1:1) is the main factor in its advantage in systems, while the ratio of air bases (1.8:1) explains its advantage in infrastructure. On the other hand, slight qualitative edges account for Iran's advantage in manpower and system of systems. These advantages stem from Iranian R&D and production facilities, which are able to manufacture artillery and ammunition, and develop or assemble training aircraft, helicopters, satellites, and boats. Such technological infrastructure has slowly but steadily improved the quality of Iranian manpower. Moreover, the passive role forced upon the Iraqi Air Force following its defeat in the Gulf War, and its inability to challenge subsequent American and British operations in its airspace, have undoubtedly had a negative influence on the morale and quality of Iraqi manpower.

Nevertheless, overall the two forces seem to be evenly matched. The equality of the two countries' air forces will likely deter both from initiating military operations against the other. At the same time, airpower is only one factor in these states' overall calculus, given that both the Iraqi and the Iranian operational concepts relegate airpower to a secondary role, behind ground forces.

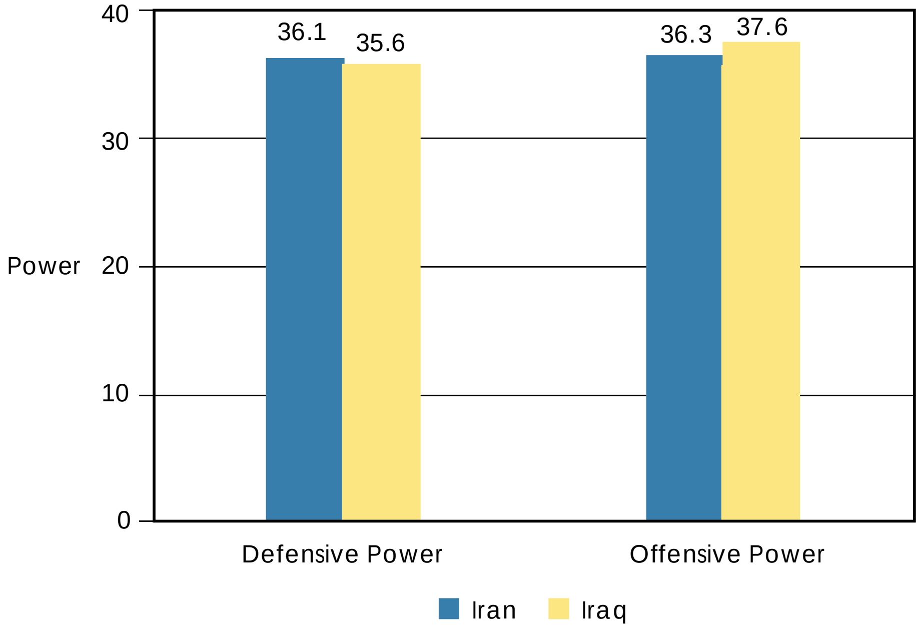


Fig. 32. Iran vs. Iraq: Balance of Power

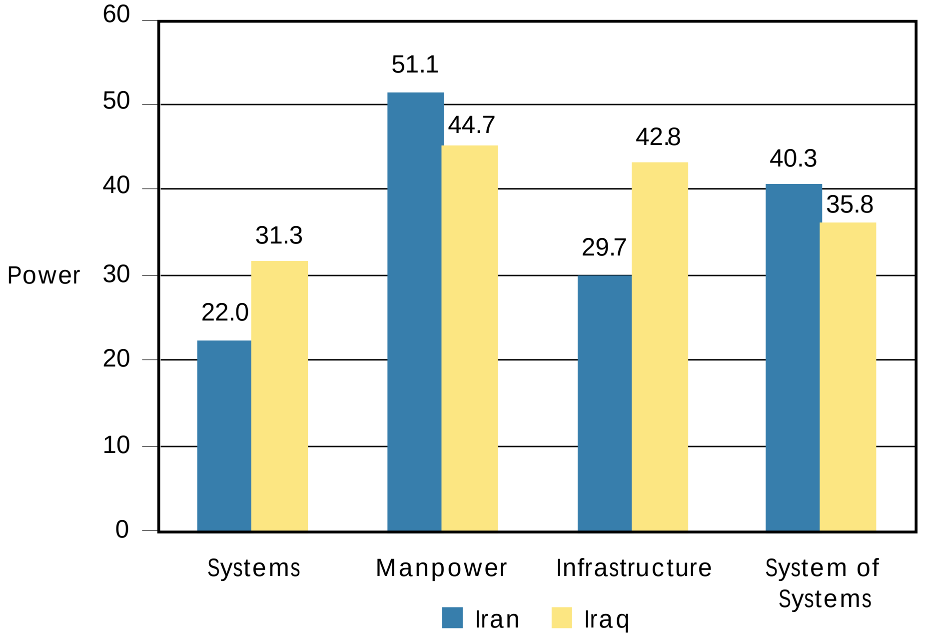


Fig. 33. Iran vs. Iraq: Offensive Superiority Main Categories

Morocco and Algeria

At the western edge of the region there is yet another conflict zone, encompassing Morocco and Algeria. The ongoing conflict there could potentially change in character from a low-intensity conflict to a high-intensity conflict in a short period of time. The air forces of both countries would probably play a central role in any type of military conflict, and in deterring one another from escalating hostilities. Figure 34 illustrates the relative powers of the Moroccan and Algerian Air Forces. The two left-hand columns refer to the defensive ratio of power and capabilities, and the two right-hand columns refer to the offensive ratio of power.

The chart shows that the capabilities of the two air forces are essentially equal, a conclusion that is reinforced when comparing the main elements of each force (Figure 35).

The general equivalency between the Moroccan and the Algerian Air Forces no doubt discourages either side from attacking the other, and encourages stability. But it should be remembered that as with Iran and Iraq, capabilities from the air are not the primary measure of power for either state. To see the real balance of power between them, the balance of ground forces would have to be considered as well.

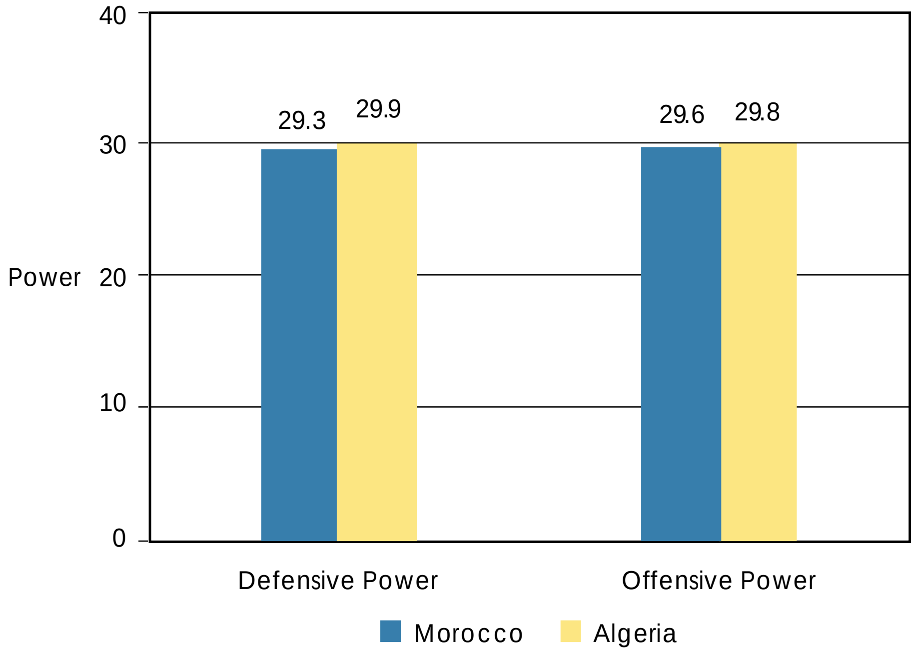


Fig. 34. Morocco vs. Algeria: Balance of Power

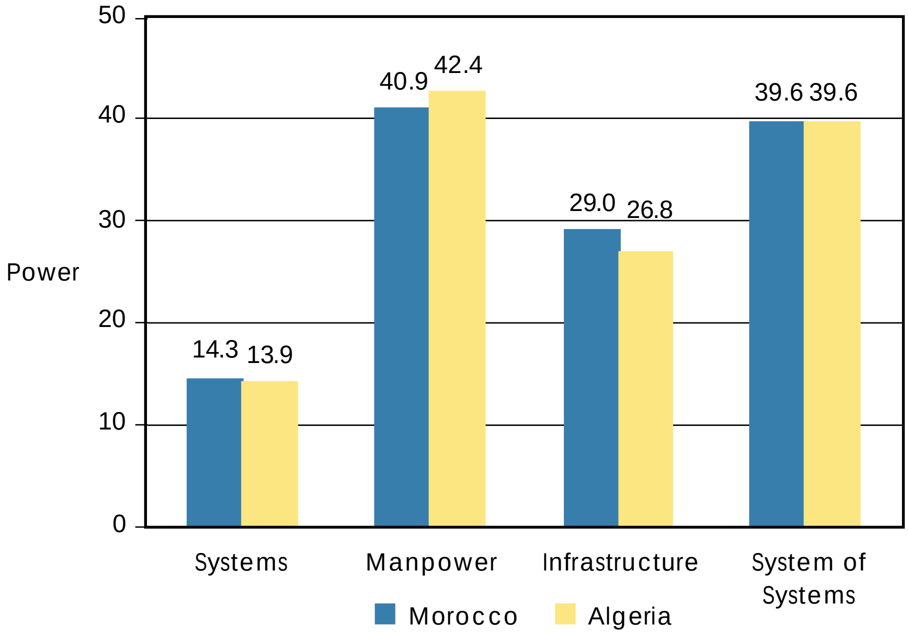


Fig. 35. Morocco vs. Algeria: Offensive Superiority Main Categories

Chapter 6

Conclusions

Air forces are complex organizations whose mandates encompass various roles and missions. The present assessment is limited to two pivotal roles: offensive superiority on the battlefield and defensive air superiority. By definition, these functions diverge in their focus on targets. Offensive superiority focuses on the enemy's ground forces, C^4I systems, SSMs, and strategic assets. Defensive air superiority, however, focuses on intercepting the enemy's incoming aircraft. Designed to address these complementary objectives, the two roles are also associated with different requirements in weapon systems, intelligence gathering systems, platforms, doctrines, tactics, and training. Analyzing these two roles must form the minimum undertaking for any serious attempt to estimate the regional balance of airpower. The estimate undertaken in this study demonstrates that the air forces in the Middle East have developed a more or less balanced composition of forces, allowing them roughly equal offensive and defensive capabilities.

The intricacy of the model presented here confirms one of the initial premises of the study, namely, building a comprehensive model to quantify all military power and factor in qualitative assessments would be beyond the scope of any one enterprise. Thus, this research has correctly concentrated on developing a methodology for assessing the relative capabilities of air forces in the Middle East. It has been based on the quantity and performance of major weapon systems, C^4I systems, platforms, electronic warfare, surveillance and other systems, presumed capabilities of human factors, and most importantly, the comparative assessments of a variety of professionals.

This methodology may be useful in providing a tool for policymakers to assess operational requirements, doctrine, force structure, and allocation of resources; for comparisons of air forces and assessments of airpower balances; and as a baseline methodology for future development. Furthermore, the study encourages further dimensions and avenues of research. These include the incorporation of a broader population of professionals; expanding the list of elements to include information warfare and space warfare; evaluating all other roles and capabilities of air forces in different environmental conditions; and validating the results by means of different methodologies such as war games, simulations, and operational research.

More specifically, two major areas invite additional research: deterrence and the role of SSMs, and economic influences on aerial power.

Deterrence

A major factor in deterrence is the ability to project an image of power. Military deterrence is achieved by persuading a putative opponent not to initiate a military action because the perceived benefits do not justify the estimated costs and risks (Mearsheimer 1983). Deterrence is of several kinds: against total war, against a limited war and operations, and against special operations. In practice, deterrence involves preventing an enemy from violently altering the status quo by threatening to inflict punishment if it does so. The success of deterrence by airpower depends on sufficient early warning, flexibility in deployment options, the availability of advanced weapon systems, and other capabilities.

Deterrence against the use of airpower is not necessarily achieved by means of matching a rival's airborne capabilities with equal and opposite ones. That is, the decision to attack a rival state is based not only on estimated airpower, but on the overall military strength of would-be rivals. Recent years have seen the addition of a salient deterrent element in the form of SSMs. These systems often compensate for the lack of offensive and deterrent power of some states' air forces, as is the case with Iran, Iraq, and Syria. For these states, SSMs are an affordable "equalizer" to counteract the offensive superiority of their rivals. Equipped with these weapons, they and even countries with relatively rudimentary air forces can launch deep strikes into enemy territory. Although such attacks have so far failed to inflict large-scale damage or heavy casualties, they can affect morale significantly. Consequently, these weapon systems play a significant deterrent role.

At the same time, new systems – defensive and offensive – are being developed to counter the SSM threat. Deterring the threat of SSMs is accomplished by improving methods of homeland defense, and by creating counter-force and counter-value capabilities. In the coming decade, technological competition and operational contests between SSM systems and an array of weapon systems, data gathering systems, and C^4I systems designed to reduce their potential, will become a crucial element in the regional balance of power. Therefore, future phases of evaluating airpower should incorporate deeper discussions of SSMs in their assessments.

Finances and Allocation of Resources

Due to the absence of sufficient data, the model presented here does not directly take into account the allocation of resources as a measure of airpower. Generally, though, we can observe that the size and quality of most of the air forces in the Middle East have not significantly changed since the early 1990s. This stems in large part from the severe economic constraints to which most states in the region have been subject. While in the past these constraints were overcome by the willingness of the two superpowers to provide military and economic assistance to their respective allies, assistance coming from the former USSR has vanished.

Hence another potential important area of study relates to the question of financial considerations and the allocation of resources. There are at least three issues that should be analyzed in the context of this framework. First, the correlation between the cost of systems and their effectiveness must be examined, particularly among weapon systems that belong to the same category (such as air-to-air missiles or attack helicopters). In addition, the correlation between expenditures on training and welfare of air force personnel and their performance, particularly core groups of aircrews and commanders, must be explored more comprehensively. Finally, attempts should be made to develop ways to study resource allocation, which could potentially serve as a particularly salient indicator of the avowed preferences of decision makers, as well as of their unstated priorities.

APPENDICES

Appendix 1

Abbreviations and Acronyms

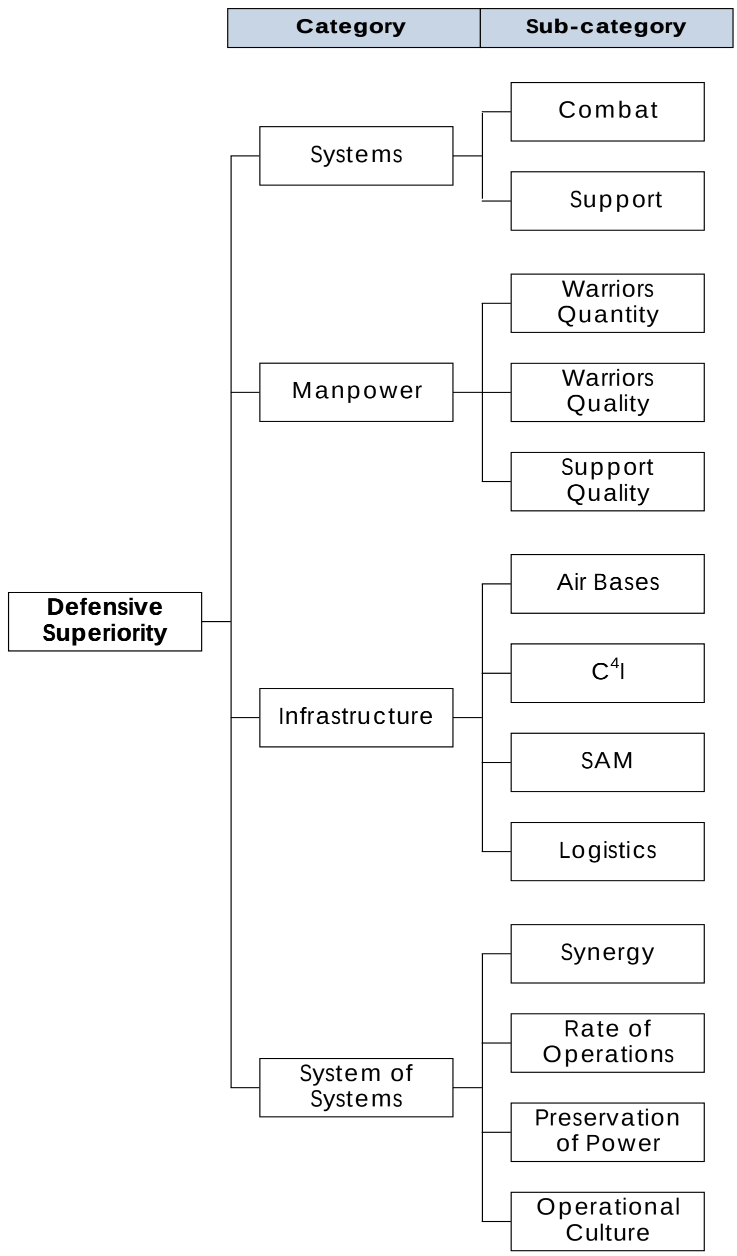
AA	Air-to-Air
AAA	Anti-Air Artillery
A/C	Aircraft
ACV	Armored Combat Vehicle
AG	Air-Ground
AH	Attack Helicopter
ARM	Anti-Radiation Missile
ASM	Air-to-Surface Missile
ATBM	Anti-Tactical Ballistic Missile
AWACS	Airborne Warning and Control System
CAS	Close Air Support
CFE	Conventional Armed Forces in Europe Treaty
CSCE	Commission on Security and Cooperation in Europe
C^4I	Command, Control, Communication, Computers, and Intelligence
DOD	Department of Defense (US)
DSS	Decision Support System
EM	Electromagnetic
EW	Electronic Warfare; Early Warning
HIC	High-Intensity Conflict
IAF	Israel Air Force
IDF	Israel Defense Forces
IOC	Initial Operational Capability
IR	Infrared
JSTARS	Joint Surveillance Target Attack Radar System
LANTIRN	Low Altitude Navigation and Targeting Infra-Red for Night
LIC	Low-Intensity Conflict
MBFR	Mutual and Balanced Force Reductions
MIC	Medium-Intensity Conflict

NATO	North Atlantic Treaty Organization
PGM	Precision Guided Munition
R&D	Research and Development
RAF	Royal Air Force (UK)
RMA	Revolution in Military Affairs
RPV	Remote Piloted Vehicle
RTD&E	Research, Development, Testing, and Evaluation
SAM	Surface-to-Air Missile
ShAM	Ship-to-Air Missile
SSM	Surface-to-Surface Missile
UAV	Unmanned Airborne Vehicle
USAF	United States Air Force
WMD	Weapons of Mass Destruction
WTO	Warsaw Treaty Organization

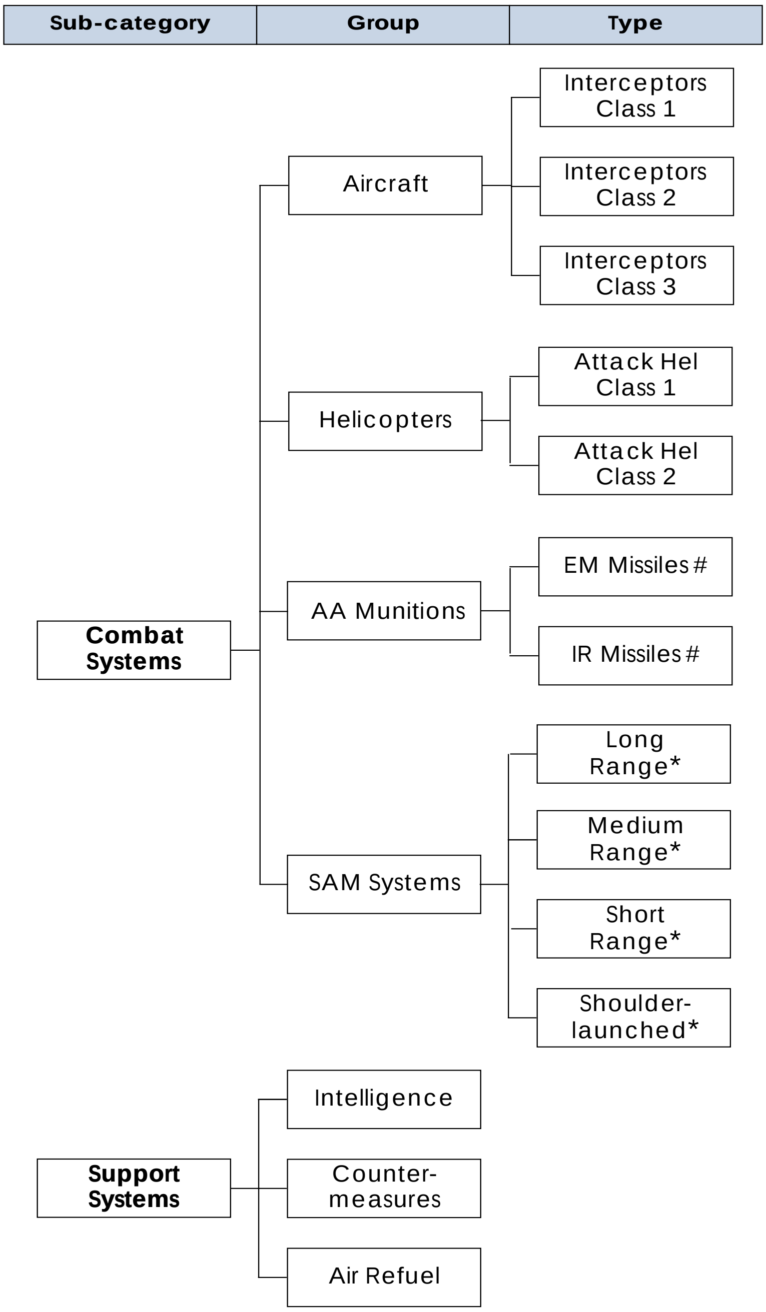
Appendix 2

Defensive Air Superiority

Appendix 2a. Categories of Defensive Air Superiority Capability



Appendix 2b. Defensive Air Superiority: Systems



* 2 classes of quality
\# 3 classes of quality

Appendix 3

Classification of Weapon Systems

Offensive Superiority Role

Aircraft

Multirole: F-15E, F-16, F-18

Interceptors

Class 1: F-14, F-15, Su-27, MiG-29, Mirage 2000, Rafale, Eurofighter, Gripen

Class 2: F-4, Mirage 3, Mirage 5, Tornado, MiG-21

Attack Aircraft: SU-24, SU-7, Skyhawk, Tornado, Mirage F-1, Kfir

Attack Helicopters

Class 1: Apache

Class 2: Cobra, Gazelle

Aircraft Air-to-Surface Munitions

Medium Range

Class 1: Popeye-1

Short Range

Class 1: EOGB

Class 2: AGM-65 Maverick

Anti-Radiation Missiles: Standard ARM, Shrike, Harpy, ARMAT

Anti-Ship: Harpoon, Gabriel, Exocet, Kelt, AS-30, AS-4, AS-6

Helicopters Air-to-Surface Munitions

Medium Range

Class 1: New Rafael-made missile, Hellfire

Class 2: AS-14

Short Range

Class 1: New Rafael-made missile

Class 2: BGM-71D TOW-2, BGM-71A TOW, HOT Milan, AS-11, AS-12

Anti-Ship: Harpoon, Gabriel, Exocet

Air-to-Air Munitions

Electromagnetic Missiles

Class 1: AMRAAM

Class 2: AIM 7F, AIM-7M, AA-11

Class 3: AIM-7E, Matra 530, AA-7

IR Missiles

Class 1: Python 4, AA-12

Class 2: AIM-9M, AIM-9N, Python 3

Class 3: AIM-9 D, Atoll, Shafrir 2, AA-8

Defensive Air Superiority Role

Aircraft

Interceptors

Class 1: F-14, F-15, F-16, F-18, Su-27, MiG-29, Mirage 2000, Rafale, Eurofighter, Gripen

Class 2: F-4, Mirage F-1, Mirage 3, Mirage 5, Tornado, MiG-21, MiG-23MF, MiG-25, F-7

Class 3: Aircraft with a limited air-to-air capability: SU-20, SU-7, Skyhawk, F-6, MiG 23

SAM Systems

Long Range (counted by batteries and missiles)

Class 1: Patriot, SA-10, SA-12

Class 2: SA-5, Nike

Medium Range (counted by batteries)

Class 1: I-HAWK, SA-6, 11

Class 2: SA-2, SA-3

Short Range (counted by battalions of 4 batteries each)

Class 1: SA-8, Improved Chaparral (with AIM-9L), SA-13, SA-15, Roland-2, Crotale

Class 2: Chaparral, SA-9, Rapier, Aspide, Roland-1

Shoulder-Launched (counted in battalions of 20 batteries each)

Class 1: Stinger, SA-18

Class 2: SA-7, Redeye, SA-14

Anti-Aircraft Artillery (counted in battalions of 50 guns each)

Appendix 4

Quantities of Assets for Offensive and Defensive Power

I. Offensive Power

Element	Israel	Coalition	Egypt	Syria	Jordan	Iraq (20%)
Systems						
Platforms*	878	1736	711	776	146	103
Aircraft (Total)	503	1113	489	490	91	43
Multi-role	270	211	195	0	16	0
Interceptors						
Class 1	73	41	18	20	0	3
Class 2	0	465	150	295	0	20
Attack Aircraft	160	396	126	175	75	20
Helicopters	232	516	143	260	53	60
Attack (Total)	107	243	101	90	22	30
Class 1	42	36	36	0	0	0
Class 2	65	207	65	90	22	30
Assault	125	273	42	170	31	30
Aircraft Air-Ground Munitions						
Medium Range						
Class 1	300	0	0	0	0	0
Class 2	0	0	0	0	0	0
Short Range						
Class 1	300	0	0	0	0	0
Class 2	1160	894	824	0	0	70
ARM	1100	150	60	0	0	90
Anti-Ship	0	197	90	0	0	107
Helicopter Air-Ground Munitions						
Medium Range						
Class 1	300	0	0	0	0	0
Class 2	775	1427	1419	0	0	8
Short Range						
Class 1	200	0	0	0	0	0
Class 2	4248	22595	13595	5400	2060	1540
Anti-Ship	0	69	62	0	0	7

* *Total includes aircraft, helicopters, and airborne support systems*

Offensive Power – cont.

Element	Israel	Coalition	Egypt	Syria	Jordan	Iraq (20%)
Air-to-Air Munitions						
EM Missiles						
Class 1	114	0	0	0	0	0
Class 2	320	649	553	0	96	0
Class 3	376	1870	190	1346	204	130
IR Missiles						
Class 1	400	0	0	0	0	0
Class 2	1700	6187	5747	0	440	0
Class 3	2636	3466	400	2314	542	210
Airborne Support Systems	143	107	79	26	2	0
Intelligence Systems	34	48	32	14	2	0
Countermeasures	9	4	2	2	0	0
UAVs	100	55	45	10	0	0
Support Quality	9	5	6	4	4	3
Manpower						
Warriors Quantity	1229	2429	995	1086	204	144
Warriors Quality	9	5.5	6	5	6	4
Support Quality	8	5	5	5	5	4
Infrastructure						
Air Bases	11	58	29	21	6	2
C^4I	9	5	5	5	5	3
Logistics	8	4.5	5	4	4	3
System of Systems						
Synergy	9	4	4	4	4	3
Rate of Operations	8	5	4	5	5	4
Preservation of Power	8	4.5	5	4	4	3
Operational Culture	9	5	5	4	5	3

II. Defensive Power

Element	Israel	Coalition	Egypt	Syria	Jordan	Iraq (20%)
Systems						
Combat Systems*	644	1396	608	598	117	73
Interceptors	488	1086	462	490	91	43
Class 1	328	217	178	20	16	3
Class 2	100	580	240	295	25	20
Class 3	60	289	44	175	50	20
Attack Helicopters	107	243	101	90	22	30
Class 1	42	36	36	0	0	0
Class 2	65	207	65	90	22	30
AA Munitions						
EM Missiles						
Class 1	80	0	0	0	0	0
Class 2	320	553	553	0	0	0
Class 3	376	1870	190	1346	204	130
IR Missiles						
Class 1	200	0	0	0	0	0
Class 2	1700	6087	5747	0	340	0
Class 3	2636	3466	400	2314	542	210
SAM Systems						
Long range						
Class 1	4	0	0	0	0	0
Class 2	0	8	0	8	0	0
Medium range						
Class 1	17	107	42	50	14	1
Class 2	0	203	93	100	0	10
Short range						
Class 1	12	29	0	7	12	10
Class 2	0	20	3	5	0	12
Shoulder-launched						
Class 1	25	54	0	25	27	2
Class 2	25	143	100	25	12	6
AAA	18	130	74	37	3	16
Airborne Support Systems	49	67	45	18	4	0
Intelligence	34	53	37	14	2	0
Countermeasures	9	11	5	4	2	0
Air Refuel	6	3	3	0	0	0
Warriors Quantity	902	1954	851	837	164	102
Air Bases	11	58	29	21	6	2

* *Total includes aircraft, helicopters, and airborne support systems*

Appendix 5

The Calculation Model[1]

The purpose of this appendix is to explain the mathematical functions that the decision support system (DSS) uses to perform its calculations. While the reader need not be familiar with the terms and functions described below, he or she may find the information useful when using the DSS and looking at the calculations and recommendations displayed by the program.

A number of terms used in this section must now be defined. *Raw values* denote those values that are entered by the user into the alternatives table (input mode), for *each final node* in the decision tree.

When the user requests *calculated data* (output mode), the expert system performs the following:

- It *normalizes* each final node row in the table that contains raw values. The purpose of normalization is to create a “common denominator” for the values in all the rows.
- It *weights* the other rows in the tree (non-final nodes). The purpose of this calculation is to summarize the score values of the nodes in each branch, using the relative weights of the nodes.

When working with tables, the user must choose either the SAATY or DELPHI calculation methods (note: this study used the DELPHI method). The two methods differ in the type of normalization functions they use for the calculation:

- The SAATY method uses the *sum of all raw values* in each row that it normalizes.
- The DELPHI method uses *highest and lowest values* of each row that it normalizes.

However, weighting is fixed for each branch within the decision tree. Therefore, the score of alternative j in each branch (including the tree root) is calculated using the following formula:

$$Vj = (V1j * W1 + V2j * W2 + ... + Vnj * Wn)$$

This formula calculates the score of an alternative in the table for a sub-tree row by adding the scores and multiplying the result by the row’s relative weight. For this

[1] This explanation was taken from the manual of the DSS. See Ross (1988) and Saaty (1980).

purpose, a sub-tree can also be a final node (with normalized values) or any other type of node in the tree.

Normalizing Raw Values Using the SAATY Method

For normalizing a set of values (Vector Vi), a mathematical formula is used to create another set of values (Vector Ni), which preserves the ratios in the original value set. The purpose of normalization is to create a common denominator or set of measurement units among different sets of raw values, so that they can be compared. Note that the values of the normalized vector have the following features:

- The ratios among the normalized values are equal to the ratios among the original (raw) values.
- The normalized values are independent of the measurement scale and are independent of the measurement unit used in the original value set (currency, weight, height, distance, volume, etc.).

The following example illustrates these features:

Vector [30, 45, 90] represents the distance in miles from New York to three other cities. Vector [2700, 3000, 2500] represents the engine capacity of three cars. Vector [35000, 55000, 40000] represents the price of three fashion items.

Using normalization, a common denominator can be created so that these disparate values can be processed in a meaningful way.

Prior to normalizing a raw value vector, the user must specify the direction setting of the normalization. If the highest score value is preferred, the user must set the normalization to "upwards." The highest normalized value will then match the highest raw value. If the lowest score value is preferred, the user must set the normalization to "downward." The lowest normalized value will then match the highest raw value.

Using the above-mentioned example, the user would presumably set the normalization direction of the price vector to downward (because one would naturally prefer to pay less), and the engine capacity vector to upward (assuming that one would prefer higher engine capacity).

The upward normalization calculation formula looks like this:

Ni = 100 * V~ (V1 + V2 +... Vn)

The formula calculates a normalized value by dividing the raw value by the sum of all the raw values. Note that the sum of all normalized values is 100. Using the above example, it would then appear as follows:

Example: Specify upward normalization for the vector [30, 45, 90]. The resulting vector is [18.18, 27.27, 54.55].

The downward normalization formula is slightly more complicated:

Ni = 100 * (1 / Vi) / (1 / V1 ~- 1 / V2 +... 1 / Vn)

This formula is similar to the upward normalization formula, with one exception: the raw values are inverted. The resulting vector is [50.00, 33.33, 16.67].

Downward Normalization for Zero Values (SAATY Model)

The downward normalization formula raises a possible problem: What happens when one of the values is zero? In theory, this would result in division by zero. Clearly, this is an undesirable possibility, and a different action should be taken to avoid it. When choosing downward normalization, the program will identify a zero raw value and replace it with a value that is "very close" to zero, before performing its calculations.

A common source of confusion thus occurs when one (or more) of the raw values is zero. For example, assume the vector [0, 2700, 3000] represents the price of three different computers. The first computer is offered to us "free of charge," and hence its price is zero. Note the normalization results:

Upward normalization: [0.00, 47.37, 52.63]
Downward normalization: [100.00, 0.00, 0.00]

The upward normalization vector makes sense. A raw value of 0 is converted to a normalized value of 0, and the remaining values keep the same proportions that existed in the raw data.

In contrast, the downward normalization result appears odd. Note that the raw value of 0 has been converted to a normalized value of 100, while the remaining values are 0. Therefore, we might conclude that this normalized vector apparently does not keep the original proportions that existed between the raw values. However, this is not the case.

The problem that occurs may be understood in two ways: From a *mathematical viewpoint*, the number 1 / 0 (resulting from an inverted calculation of 0) is infinitely large, and therefore, when calculating the normalized value of 0, the resulting number will be very close to 100:

[(a very large number) / (a slightly larger number)] *100

For the same reason, the normalized values of the non-zero numbers are "close" to 0:

[(a "regular" number) / (a very large number)] * 100

From a *logical* viewpoint, the following explanation is suggested: we prefer to pay as little as possible, so the alternative that offers no charge (the price of 0) is clearly the most preferred over the other ones. Therefore, the cheapest alternative is the one that receives a value that is very close to 100, and the remaining alternatives receive a very low normalized value, i.e., almost 0.

Note also that when downward normalization is calculated and zero values appear in the table of alternatives, the resulting normalized values are shown as zeros. Pressing the "Enter" key on these cells will display an input dialog with the precise value of this "zero."

What happens when more than one raw value is equal to zero?

- All the values that are not zero will be normalized to zero.
- All the zeros will receive the same normalized value; the value depends on the number of zeros: a single zero is converted to 100; two zeros are converted to 50; three zeros are converted to 33.33, and so forth.

As explained earlier, normalization of raw values enables us to convert groups of scores and values that are provided in different measurement units (currency, weight, etc.) to groups of values that do not have a measurement unit, and can therefore be weighted. The normalization function is used after entering the raw values (which are already known) for each criterion.

Another potential problem can occur when the analyst must rely on raw information that is not available, cannot be verified, or is given only partially. Here, there is no recourse. The analyst must use experience and common sense in order to evaluate the ratios that exist between the raw values.

The Difference between SAATY and DELPHI Normalizations

The table below lists the differences between the normalization formulas used by the SAATY and DELPHI methods:

Model	**Direction**	**Function**
SAATY	Upwards	Ni = 100 * Vi / (V1+V2 + ... +Vn)
DELPHI	Upwards	Ni = 100 * Vi / (MAX Vi)
SAATY	Downwards	Ni = 100 *1 / Vi I (1 / V1 + 1 / V2 + ... 1 / Vn)
DELPHI	Downwards	Ni = 100 * MIN Vi / Vi

Note: DELPHI defines the *highest score* as 100.
SAATY defines the *sum of all scores* as 100.

Finally, it should be stressed that methods themselves are not at issue here. Each analyst may use the normalization method that is most convenient for his or her needs. However, it must be recalled that in DELPHI the *highest value* displayed is 100, while the SAATY model always shows the *sum* of the results as 100. In any case, it is recommended that results of both models be checked in order to identify “make or break” situations such as the example described above.

Appendix 6

Arsenal of Precision Munitions

Classification of the types of weapon systems, according to their operational capabilities, was part of the writing of this study. Classification of systems plays a fundamental role in the methodology of the model, and as it has a substantial influence on the outcomes, it is a subject that should be approached with care. Moreover, it should be updated every few years, in order to reflect the developments and procurements of new systems.

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
Egypt					
Aircraft Air-to-Surface Munitions					
Medium Range					
Class 1					
Class 2					
Short Range					
Class 1					
Class 2	600	AGM-65A Maverick	ASM	1980	600
	144	AGM-65D Maverick	ASM	1988	144
	40	AGM-65D Maverick	ASM	1991	40
	40	AGM-65G Maverick	ASM	1991	40
ARM	60	ARMAT	Anti-radar missile	1984	60
Anti-Ship	40	AM-39 Exocet	Air-to-ship missile	1982	40
	50	AS-5 Kelt	Air-to-ship missile	1970	50

Source: *SIPRI Yearbook 2002*

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
Helicopters Air-to-Surface Munitions					
Medium Range					
Class 1	492	AGM-114A Hellfire	Anti-tank missile	1990	492
	927	AGM-114K Hellfire	Anti-tank missile	1996	463
Class 2					
Short Range					
Class 1					
Class 2	3500	BGM-71D TOW-2	Anti-tank missile	1988	3500
	695	BGM-71D TOW-2	Anti-tank missile	1992	695
	2372	BGM-71D TOW-2	Anti-tank missile	1996	2372
	1440	HOT	Anti-tank missile	1981	1440
	1440	HOT	Anti-tank missile	1975	1440
	4150	Milan	Anti-tank missile	1975	4150
Anti-Ship	20	AGM-84A / C Harpoon	Air-to-ship missile	1991	20
Air-to-Air Munitions					
Electromagnetic Missiles					
Class 1					
Class 2	282	AIM-7M Sparrow	Air-to-air missile	1987	282
	271	AIM-7M Sparrow	Air-to-air missile	1996	271
Class 3	70	AIM-7E Sparrow	Air-to-air missile	1979	70
	120	Super-530F	Air-to-air missile	1984	120

Weapon System	**Ordered**	**Designation**	**Type**	**Year Ordered**	**Delivered**
IR Missiles					
Class 1					
Class 2	300	AIM-9L Sidewinder	Air-to-air missile	1982	300
	150	AIM-9L Sidewinder	Air-to-air missile	1983	150
	560	AIM-9L Sidewinder	Air-to-air missile	1986	560
	300	AIM-9L Sidewinder	Air-to-air missile	1982	300
	37	AIM-9P Sidewinder	Air-to-air missile	1986	37
	250	AIM-9P Sidewinder	Air-to-air missile	1979	250
		AIM-9P Sidewinder	Air-to-air missile	1988	4150
Class 3	120	R-550 Magic-1	Air-to-air missile	1983	120
	180	R-550 Magic-1	Air-to-air missile	1977	180
	100	AIM-9E Sidewinder	Air-to-air missile	1979	100
SAM Systems					
Long Range					
Class 1					
Class 2					
Medium Range					
Class 1	489	MIM-23B HAWK	SAM	1979	489
	150	MIM-23B HAWK	SAM	1989	150
	180	MIM-23B HAWK	SAM	1996	20
	250	SA-6A Gainful/3M9	SAM	1973	250
	1200	SA-3B Goa/5V27	SAM	1970	1200

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
	250	SA-6A Gainful / 3M9	SAM	1971	250
	250	SA-6A Gainful / 3M9	SAM	1972	250
Class 2					
Short Range					
Class 1	128	R-440 Crotale	SAM	1976	128
	64	R-440 Crotale	SAM	1982	64
	64	R-440 Crotale	SAM	1982	64
	432	MIM-72H Chaparral	SAM	1990	432
	34	RIM-66B Standard-1MR	ShAM	1996	34
	40	RIM-66B Standard-1MR	ShAM	1996	40
	54	RIM-66B Standard-1MR	ShAM	1998	54
	514	RIM-7M Seasparrow	ShAM	1984	514
Class 2	48	Aspide Mk-1	ShAM	1983	48
	576	Aspide Mk-1	SAM	1982	576
	450	MIM-72F Chaparral	SAM	1984	450
Shoulder-Launched					
Class 1	100	FIM-92A Stinger	Portable SAM	1990	100
Class 2	9999	SA-7B Grail / Strela-2M	Portable SAM	1968	9999

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
Iraq					
Aircraft Air-to-Surface Munitions					
Medium Range					
Class 1					
Class 2					
Short Range					
Class 1					
Class 2	70	AS-30	ASM	1968	70
	270	AS-30L	ASM	1984	270
ARM	450	ARMAT	Anti-radar missile	1983	450
Anti-Ship	60	AM-39 Exocet	Air-to-ship missile	1978	60
		AM-39 Exocet	Air-to-ship missile	1983	280
	100	C-601 / CAS-1 Kraken	Air-to-ship missile	1987	100
	24	AS-4 Kitchen / X-22	Air-to-ship missile	1983	24
	36	AS-4 Kitchen / X-22	Air-to-ship missile	1972	36
	36	AS-6 Kingfish	Air-to-ship missile	1983	36
Helicopters Air-to-Surface Munitions					
Medium Range					
Class 1					
Class 2	40	AS-14 Kedge / X-29T	ASM	1988	40
Short Range					
Class 1					
Class 2	2050	HOT	Anti-tank missile	1974	2050
	1000	HOT	Anti-tank missile	1979	1000

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
	600	HOT	Anti-tank missile	1977	600
	1000	AS-11	ASM	1974	1000
	365	AS-11	ASM	1971	365
	600	AS-12	ASM	1974	600
	64	AS-12	ASM	1971	64
	40	AT-2a Swatter / 3M11	Anti-tank missile	1976	40
	2000	AT-4 Spigot / 9M111	Anti-tank missile	1986	2000
Anti-Ship	36	AM-39 Exocet	Air-to-ship missile	1989	36
Air-to-Air Munitions					
Electromagnetic Missiles					
Class 1					
Class 2					
Class 3	200	AA-7 Apex / R-24R	Air-to-air missile	1984	200
		AA-7 Apex / R-24R	Air-to-air missile	1986	96
	60	AA-6 Acrid / R-40R	Air-to-air missile	1984	60
	300	Super-530F	Air-to-air missile	1977	300
IR Missiles					
Class 1					
Class 2					
Class 3	200	AA-8 Aphid / R-60	Air-to-air missile	1984	200
	144	AA-8 Aphid / R-60	Air-to-air missile	1986	144
	160	AA-8 Aphid / R-60	Air-to-air missile	1985	160
	534	R-550 Magic-1	Air-to-air missile	1977	534

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
SAM Systems					
Long Range					
Class 1					
Class 2					
Medium Range					
Class 1	1050	SA-6A Gainful / 3M9	SAM	1979	1050
	200	SA-6A Gainful / 3M9	SAM	1985	200
Class 2	108	SA-3B Goa / 5V27	SAM	1971	108
Short Range					
Class 1	432	SA-8B Gecko / 9M33M	SAM	1982	432
		Roland-2	SAM	1981	1100
Class 2	240	SA-9 Gaskin / 9M31	SAM	1982	240
Shoulder-Launched					
Class 1	100	SA-16 Gimlet / Igla-1	Portable SAM	1990	100
Class 2	100	HN-5A	Portable SAM	1985	100

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
Israel					
Aircraft Air-to-Surface Munitions					
Medium Range					
Class 1		Popeye- 1	ASM	1995	300
Class 2					
Short Range					
Class 1	300	EOGB	ASM	1978	300
Class 2	600	AGM-65A Maverick	ASM	1979	600
	200	AGM-65A Maverick	ASM	1973	200
	360	AGM-65A Maverick	ASM	1975	360
ARM	100	AGM-78B Standard	Anti-radar missile	1973	100
	200	AGM-45A Shrike	Anti-radar missile	1978	200
	200	AGM-45A Shrike	Anti-radar missile	1974	200
	300	AGM-45A Shrike	Anti-radar missile	1973	300
	300	Harpy	Anti-radar missile	1996	300
Anti-Ship					
Helicopters Air-to-Surface Munitions					
Medium Range					
Class 1	300	EO Missile	ASM	1996	250
	525	AGM-114A Hellfire	Anti-tank missile	1990	525
Class 2					
Short Range					
Class 1					
Class 2	96	BGM-71A TOW	Anti-tank missile	1977	96

Weapon System	**Ordered**	**Designation**	**Type**	**Year Ordered**	**Delivered**
	144	BGM-71A TOW	Anti-tank missile	1981	144
	500	BGM-71A TOW	Anti-tank missile	1973	500
	3000	BGM-71A TOW	Anti-tank missile	1974	3000
	508	BGM-71A TOW	Anti-tank missile	1985	508
Anti-Ship					
Air-to-Air Munitions					
Electromagnetic Missiles					
Class 1	100	AIM-120 AMRAAM	Air-to-air missile	1998	80
Class 2	170	AIM-7F Sparrow	Air-to-air missile	1978	170
	150	AIM-7M Sparrow	Air-to-air missile	1983	150
Class 3	376	AIM-7E Sparrow	Air-to-air missile	1975	376
IR Missiles					
Class 1	300	Python 4	Air-to-air missile	1995	200
Class 2	600	AIM-9L Sidewinder	Air-to-air missile	1979	600
	200	AIM-9L Sidewinder	Air-to-air missile	1983	200
	300	AIM-9S Sidewinder	Air-to-air missile	1990	300
	400	Python 3	Air-to-air missile	1981	400
Class 3	2000	AIM-9D Sidewinder-1C	Air-to-air missile	1973	2000
	336	AIM-9D Sidewinder-1C	Air-to-air missile	1971	336
	300	AIM-9J Sidewinder	Air-to-air missile	1975	300

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
SAM Systems					
Long range					
Class 1		Arrow	SAM	1998	
Class 2	57	MIM-104 PAC-2	SAM	1991	57
	64	MIM-104 PAC-2	SAM	1990	64
Class 3					
Medium Range					
Class 1	36	MIM-23A HAWK	SAM	1973	36
	128	MIM-23A HAWK	SAM	1968	128
	50	MIM-23A HAWK	SAM	1970	50
	194	MIM-23A HAWK	SAM	1971	194
	60	MIM-23A HAWK	SAM	1976	60
	120	MIM-23A HAWK	SAM	1973	120
	100	MIM-23B HAWK	SAM	1979	100
	200	MIM-23B HAWK	SAM	1982	200
	60	MIM-23B HAWK	SAM	1978	60
Class 2					
Short Range					
Class 1	250	MIM-72C Chaparral	SAM	1980	250
	500	MIM-72C Chaparral	SAM	1996	500
Class 2	288	MIM-72A Chaparral	SAM	1972	288
	828	MIM-72A Chaparral	SAM	1977	826

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
Shoulder-Launched Class 1 Class 2	500 882	FIM-43A Redeye FIM-43A Redeye FIM-92A Stinger	Portable SAM Portable SAM Portable SAM	1974 1976 1993	500 882 344
Jordan					
Aircraft Air-to-Surface Munitions Medium Range Short Range Class 1 Class 2 ARM Anti-Ship *Helicopters Air-to-Surface Munitions* Medium Range Class 1 Class 2 Short Range Class 1 Class 2	1920 141 6000 1800	BGM-71A TOW BGM-71A TOW BGM-71A TOW BGM-71A TOW	Anti-tank missile Anti-tank missile Anti-tank missile Anti-tank missile	1982 1992 1973 1980	1920 141 6000 1800

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
Anti-Ship					
Air-Air Munitions					
Electromagnetic Missiles					
Class 1					
Class 2	96	AIM-7M Sparrow	Air-to-air missile	1998	96
Class 3	102	R-530	Air-to-air missile	1982	102
	102	Super-530F	Air-to-air missile	1979	102
IR Missiles					
Class 1					
Class 2	340	AIM-9P Sidewinder	Air-to-air missile	1979	340
Class 3	100	R-550 Magic-1	Air-to-air missile	1982	100
	100	R-550 Magic-1	Air-to-air missile	1979	100
	342	AIM-9J Sidewinder	Air-to-air missile	1974	342
SAM Systems					
Long range					
Class 1					
Class 2					
Medium range					
Class 1	752	MIM-23B HAWK	SAM	1976	752
Class 2					
Short range					
Class 1	1032	SA-8B Gecko / 9M33M	SAM	1981	1032
	206	SA-8B Gecko / 9M33M	SAM	1984	206
Class 2	555	Tigercat	SAM	1969	555

Weapon System	**Ordered**	**Designation**	**Type**	**Year Ordered**	**Delivered**
Shoulder-Launched					
Class 1					
Class 2	300	FIM-43A Redeye	Portable SAM	1975	300
	200	SA-14 Gremlin / Strela-3	Portable SAM	1987	200
	200	SA-7 Grail / Strela-2	Portable SAM	1981	200
	100	SA-7 Grail / Strela-2	Portable SAM	1984	100
Syria					
Aircraft Air-to-Surface Munitions					
Medium Range					
Class 1					
Class 2					
Short Range					
Class 1					
Class 2					
ARM					
Anti-Ship					
Helicopters Air-to-Surface Munitions					
Medium Range					
Class 1					
Class 2					
Short Range					
Class 1					
Class 2	1000	HOT	Anti-tank missile	1977	1000
	4400	Milan	Anti-tank missile	1977	4400
	950	AS-12	ASM	1975	950

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
Anti-Ship					
Air-to-Air Munitions					
Electromagnetic Missiles					
Class 1					
Class 2					
Class 3	920	AA-7 Apex / R-24R	Air-to-air missile	1982	920
	276	AA-7 Apex / R-24R	Air-to-air missile	1986	276
		AA-6 Acrid / R-40R	Air-to-air missile	1984	150
IR Missiles					
Class 1					
Class 2					
Class 3		AA-8 Aphid / R-60	Air-to-air missile	1984	850
	1464	AA-8 Aphid / R-60	Air-to-air missile	1986	1464
SAM Systems					
Long Range					
Class 1					
Class 2	96	SA-5C Gammon / S-200	SAM	1982	96
Medium Range					
Class 1	270	SA-11 Gadfly	SAM	1983	270
	1260	SA-6A Gainful / 3M9	SAM	1978	1260
	1500	SA-6A Gainful / 3M9	SAM	1973	1500
Class 2		SA-3B Goa / 5V27	SAM	1981	220
		SA-3B Goa / 5V27	SAM	1972	1000
	480	SA-2 Guideline	SAM	1967	480

Weapon System	Ordered	Designation	Type	Year Ordered	Delivered
Short Range					
Class 1	720	SA-13 Gopher / 9M37	SAM	1984	720
	1200	SA-8B Gecko / 9M33M	SAM	1982	1200
Class 2	16	SA-N-5 Grail / Strela-2M	SAM	1984	16
		SA-9 Gaskin / 9M31	SAM	1978	384
	32	SA-9 Gaskin / 9M31	SAM	1974	32
Shoulder-Launched					
Class 1	1500	SA-14 Gremlin / Strela-3	Portable SAM	1985	1500
		SA-8A Gecko / 9M33	SAM	1978	476
Class 2	3000	SA-7B Grail / Strela-2M	Portable SAM	1978	3000
	4000	SA-7B Grail / Strela-2M	Portable SAM	1973	4000
	7000	SA-7B Grail / Strela-2M	Portable SAM	1969	7000

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