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Deep Attack Weapons Mix Study (DAWMS) Case Study

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IDA Document D-2706

Deep Attack Weapons Mix Study (DAWMS) Case Study

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PREFACE

Many studies are not as effective as they could be because the analyst does not thoroughly understand the needs of those using the analyses to make decisions. Likewise, other studies have only a marginal impact because the supported senior official does not have a clear understanding of the limits and capabilities of analysis. In an attempt to help increase the usefulness of studies, IDA sponsored a Central Research Project to develop an instructional course based on case studies of military analysis that could be incorporated into DoD's senior executive training schools and analyst educational curricula.

This case study is the second of a series[1] of papers that describe already completed studies that may prove useful to those who use analyses to support major decisions, those who design and conduct analyses, or those who review analytical studies.

The general approach taken in all these papers is to (1) explain the issues underlying an important decision in the recent past, (2) describe how the issues were studied analytically, and (3) indicate the decisions that ensued. But these papers provide more than just a summary of the findings reported in earlier work. They also explore the different perspectives of the various players, how perceptions changed over time, unexpected turns in the analyses, disappointments, blind alleys, lessons learned, and other features that are a part of any real-life study, although they are rarely documented in final reports. Familiarity with these organic, dynamically changing features can help decisionmakers and analysts alike better realize the value and limits of analyses. At the same time, senior managers, equipped with realistic expectations and an awareness of analytic constraints on analyses, can better avoid predictable pitfalls and help structure the analysis so that it generates the insights needed to inform their decisions.

This case study is for the Deep Attack Weapons Mix Study conducted from 1995 to 1997.[2] It provides basic background to describe the key issues and data used in the conduct of the analysis. The case study does not cover every aspect of the analysis, which would require a much more lengthy treatise. Also, the description below simplifies some aspects of the analysis to avoid the use of classified inputs and results. The focus of this paper is on the overall study process.

The case study ends with a series of questions that could be used as the basis for discussion in the classroom.

Finally, we would like to thank the reviewers, Dr. Ron Enlow and Dr. Geoffrey Koretsky, for their useful insight and helpful suggestions.

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1 The first case study developed was for the C-17 Cost and Operational Effectiveness Analysis (COEA). See IDA Document D-2688, *C-17 COEA Case Study*.

2 There was a follow-on to DAWMS called *The Deep Attack Study (DAS)* that updated the databases and improved the models.

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I. BACKGROUND

A. INTRODUCTION

In 1995 the Report of the Commission on Roles and Missions (CORM) of the Armed Forces[1] recommended that the Department of Defense (DoD) conduct a study *...focused on finding the appropriate combination and quantities of deep attack[2] capabilities currently fielded and under development by all Services.*

The CORM report stated the following position on the Deep Attack issue:

> *…CINCs have available several different weapon systems that can attack land and sea targets at varying ranges. The Services field a mix of land-based ballistic missiles, sea-based cruise missiles, and a growing inventory of precision guided weapons and standoff weapons delivered by aircraft. All of these capabilities are useful. No CINC proposed eliminating any of these capabilities…." However, it is not clear that DOD has the correct balance of these various weapons. Currently, no one in DOD has specific responsibility for specifying the overall number and mix of deep attack systems… Consequently, we [the CORM] recommend prompt initiation of a DOD-wide cost-effectiveness study focused on finding the appropriate combination and quantities of deep attack capabilities currently fielded and under development by all Services. Only by approaching capabilities in the aggregate, from the CINCs' perspective rather than the Services', can this particular 'who needs what' question be answered.*

The DoD Authorization Bill for Fiscal Year 1996 required the Secretary of Defense to perform an analysis of the full range of precision-guided munitions (PGMs) in production and in research, development, test, and evaluation (RDT&E) in order to

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1 *Directions for Defense,* Commission on Roles and Missions (CORM), May 1995, UNCLASSIFIED.

2 Deep Attack refers to all of the combat activity beyond the close battle area. A formal definition is provided in section D.

determine the need for accelerated funding of PGMs and, if needed, determine priorities and procurement objectives.

The above guidance resulted in the Deep Attack Weapons Mix Study (DAWMS).[3] It was the major study conducted by the Department of Defense during the 2-year period starting in August 1995. Its objective was to *...determine the most cost-effective mix (quantity and composition) of air-to-surface and surface-to-surface munitions for deep attack operations.* Each year the Services individually develop recommended weapons purchases based on targets allocated to them in the various approved CINC warplans. DAWMS was the first coordinated attempt by the Department to jointly influence the planned weapon mix across the Services. It involved all four Services and was one of the few studies to be overseen by the Joint Requirements Oversight Council (JROC). Because it departed from the traditional approach to allocating and purchasing weapons, and because it addressed equities of all CINCs, Services, and those portions of the Office of the Secretary of Defense (OSD) with plans and acquisition oversight responsibilities, the study became highly controversial.

B. THE PARTICIPANTS

1. Overview

How the study team is organized and the interface the study leaders have with the customers (senior DoD officials) can play a major part in the success and impact of the analysis. The study organizational structure is summarized in Figure 1 and then discussed in greater detail in this section.

2. Study Team

The study leader was an 0-6 from the Joint Staff (J-8) whose deputy was an 0-6 from OSD policy. Over the course of the study both the study leader and the deputy transitioned due to the normal rotation associated with military change of assignments. Most of the direct analytical support was provided by analysts from the Institute for

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[3] This case study concerns only DAWMS, Part 1. There was a DAWMS, Part 2. The objective of Part 2 was to determine the appropriate force size and mix for deep attack operations. More specifically, it examined trade-offs among long-range bombers (including additional B-2s), land- and sea-based tactical aircraft, and missiles that are used in deep attack operations.

Defense Analyses (IDA) and the Joint Staff (J-8), although each of the Services conducted parallel study activities and made much of their work available to the IDA study team members.

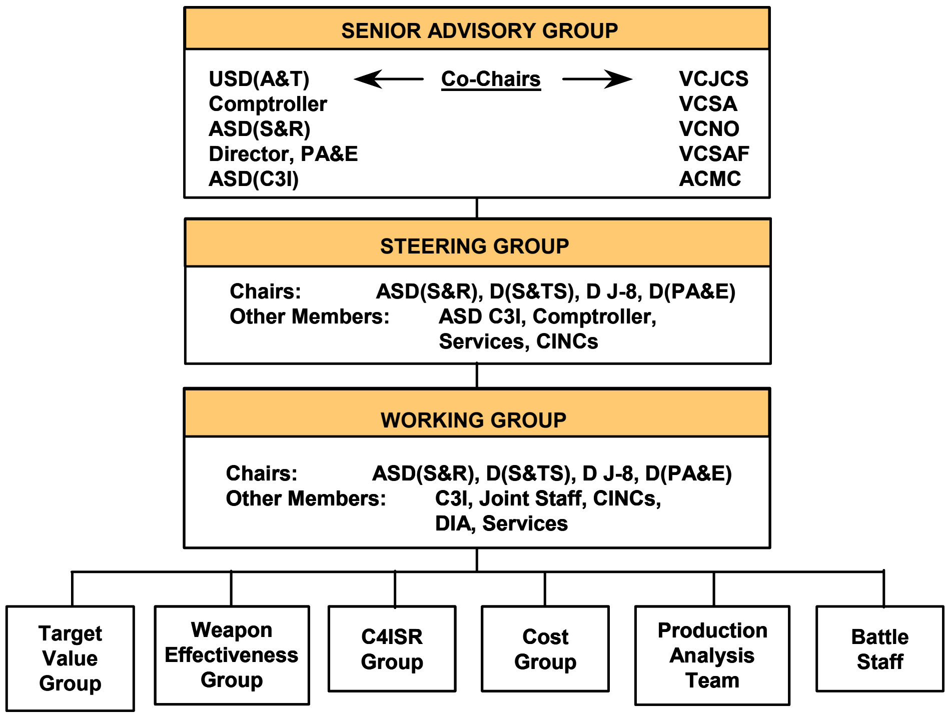

Figure 1. Deep Attack/Weapons Mix Study Organization

The study involved the use of a methodology intended to extend beyond single Service optimization and depended on the development of a detailed database to which all the Services contributed. Several groups[4] helped facilitate this data collection and ensure consistency across Service inputs:

- The Target Value Group coordinated with Service planners to establish values for killing red targets as a function of target type, location, and time (phase of the war).

[4] IDA analysts played a major role in all parts of the study and had key members attending the Working Group, Steering Group.

- The Weapon Effectiveness Group developed consistent definitions of the targets together with estimates of the effects each weapon type would have against each target type.
- The Command, Control, Communication, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Group provided both the approach and the data needed to incorporate C4ISR effects in the study. In fact, capturing these C4ISR effects was a major reason for the study since individual Service weapon mix studies did not include an in-depth treatment of how C4ISR might impact weapons and their effectiveness in various applications. It was one of the first to fully integrate C4ISR factors into a campaign analysis.
- The Cost Group developed the cost estimates for all of the weapons.

Another group, called the Production Analysis Team, was established to oversee the analysis portion of the study. It was co-chaired by an O-6 from J-8 and an analyst from IDA, and it met at least weekly during most of the study. Members included representatives from all four Services who were able to review firsthand the methodology used, the exact data being entered into the models, the results produced, and analytic insights. The Service members approved the use of all data from their Service and often suggested changes to the analytical approaches or sensitivities to be explored to help reviewers gain confidence in the results.

Another group was established to ensure that the study was consistent with Service doctrine and operational practices. This group was called the Battle Staff and consisted of senior 0-6s from each of the Services. In addition to helping translate Service doctrine and tactical concepts into model inputs for the various simulations used in the study, these members helped establish such important inputs as the pace of the joint suppression of enemy air defense (JSEAD) campaign.

3. Oversight

The study structure included three levels of oversight: working group, steering group and senior advisory group (SAG). The study director reported to the working and steering groups every 4-6 weeks during the middle and later phases of the study. The Working Group was co-chaired by the study leader from J-8 and representatives from the policy, acquisition, and program analysis and evaluation offices. Members were primarily senior 0-6s or their equivalents from OSD, the Joint Staff, the Services, DIA, and the CINC staffs.

The Steering Group had similar membership except that the members were typically 0-8s or their civilian equivalents, chaired by the Assistant Secretary of Defense for Strategy and Requirements.

The Senior Advisory Group met every 3-4 months over the course of the study and more frequently toward the end. It was co-chaired by the Under Secretary of Defense for Acquisition and Technology and the Vice Chairman of the Joint Chiefs of Staff. Members included the Service Vice Chiefs, Comptroller, ASD (C3I), ASD (S&R), and the Director PA&E.

C. THE INITIAL PHASE: A QUICK LOOK BY IDA AND A REVIEW OF STUDIES

The remainder of this case study will focus on what the study team provided the senior decision makers and the issues and questions that ensued. The study started with a "quick look" by IDA using existing tools and databases that had been developed for the Heavy Bomber Force Study conducted by IDA for OSD in 1994. This was followed by a review of the major Service-sponsored weapon mix studies together with the IDA quick look. A formal “quick look” and review of studies is not typical. Often the study team will perform these activities for their own benefit, but the formal reporting and documenting that took place in DAWMS is not typical. It did, however, prove to be very beneficial to the data collection and methodology selection process, as will be seen below. The studies reviewed were:

- Deep Attack Weapons Mix Study Quick Look, IDA, October 1995.
- Non-Nuclear Consumables Annual Analysis, (NCAA), HQ USAF/XOFW, June 1995.
- U.S. Navy (Including Marine Air) Non-Nuclear Ordnance Requirements (NNOR), Dept of the Navy, June 1995.
- Air Force Conventional Weapons Program Assessment, Air Force Studies and Analyses Agency, (AFSAA), September 1995.

- Weapon Mix Study for Joint Strike Assessment-Revised, Naval Air Warfare Center – Weapons Division, (NAWC-WD), China Lake, October 1995.

The purpose of the review was to gain insight into the inputs, methodologies, and results of these studies. This effort was a significant help for establishing a methodology and data collection process for DAWMS. When there was a common approach among the studies DAWMS often adopted it. This allowed the DAWMS study team to focus on those areas where previous studies had diverged in the way they handled specific aspects of the analysis. The review also helped identify the key drivers for the weapon mix problem, which, in turn, helped the study team stress the important aspects of the problem in their research. Finally, it provided a starting point for developing the large database that was ultimately needed by the study. In accomplishing this review, the analysts were careful to present their findings in constructive ways—the review was not intended to be a critique of the studies, but rather a way to build upon the earlier work.

1. The Weapon Types Considered

One needs to understand a little about the weapons considered in order to understand the results of the review. A brief overview of the weapons is contained in Table 1. None of the studies incorporated all of the weapons listed in Table 1.

The IDA Quick Look study did not consider the Army/Marine helicopter launched weapons [Hellfire; tube-launched, optically tracked, wire-guided missile (TOW)]. The Air Force studies considered only weapons they use or plan to buy and therefore excluded ship-launched Tomahawk land attack missiles (TLAMs), Joint Standoff Weapons (JSOWs) (unitary), and the Standoff Land Attack Missile Enhanced Response (SLAM-ER). The Navy excluded Air Force developed weapons such as the Conventional Air-Launched Cruise Missile (CALCM), and the Wind-Corrected Munition Dispenser (WCMD) system.

2. Summary of Previous Study Results

Table 2 summarizes the results of the study review expressed in terms of the aggregate levels of weapons expended. In the actual study numerical results were provided that cannot be displayed here because of their classification. Instead, the unclassified description of the results is displayed in Table 2 with "High" corresponding to a study that uses the most of this type of munition and “Low” reflecting the study that used the least amount. None of the studies included helicopter weapons. There is considerable variation in the results.

Table 1. Weapon Descriptions

Weapon Class	Examples	Characteristics
Iron Bombs	MK-82 / 83 / 84 BLU-109	500 – 2000 lb. "dumb" bombs used to attack fixed targets.
Laser-Guided Bombs	GBU – 10 / 12 / 15 / 24 / 27 / 28 Maverick	Very accurate 500 – 2000 lb. weapons that guide the bomb to a laser spot. Used to attack both fixed and moving targets. The GBU-28 is a 5,000-lb. earth-penetrating weapon delivered by an F-15E.
Cluster Munition	CBU – 52 / 58 / 87 MK-20	Consists of canisters of bomblets that explode upon impact. Used to attack personnel and soft targets.
GPS Guidance Kits	JDAM[a]	Kits that attach to the iron bombs to significantly increase their accuracy.
Sensor-Fuzed Weapon (SFW)	SFW[a] and SFW P^3I	Specially designed to kill tanks by sending a projectile through the engine.
INS Guidance Kits	Wind Corrected Munition Dispenser (WCMD)[a]	Uses inertial navigation to help guide canisters containing cluster munitions or SFWs to the desired target.
Medium-Range Standoff Munitions	JSOW (CEM)[a] JSOW (SFW)[a] JSOW (Unitary)[a]	Enables aircraft to deliver cluster, SFW, and unitary (iron bomb) weapons without penetrating medium-range terminal air defenses.
Long-range Standoff Munitions	SLAM-ER AGM-130 AGM-142 JASSM[a]	Enables the aircraft to stand off beyond long-range terminal air defenses when delivering ordnance. They deliver unitary warheads only.
Very-Long-Range Weapons	TLAM CALCM ATACMS I /Ia /II[a] /IIa[a]	The launch platform for these weapons is not engaged by any defenses. The TLAM is launched by a ship or submarine, the CALCM by a B-52, and ATACMS by an Army Multiple Launch Rocket System (MLRS). The TLAM and CALCM primarily carry unitary warheads. The ATACMS can carry an antipersonnel weapon (ATACMS I/Ia) or an antitank munition called BAT (ATACMS II/IIa). The "a" versions have a smaller warhead and longer range.
Helicopter Weapons	Hellfire Tow Longbow-Hellfire[a]	Hellfire is the primary antiarmor munition used by the Army. The Longbow-Hellfire provides an adverse weather fire-and-forget capability.

[a] These weapons were still in development at the time of the study.

Table 2. Aggregate Levels of Weapon Expenditures in Recent Major Studies

Weapon Class	Study				
		Air Force		Navy	
	IDA	NCAA	AFSAA	NNOR	NAWC
Iron Bombs	Moderate	Low	Low	Moderate	High
Laser-Guided Bombs	Moderate	High	Moderate	Low	Moderate
Cluster Munitions (unguided or with WCMD or JSOW)	Moderate	High	High	Low	Moderate
GPS Guidance Kits (JDAM)	Low	High	Moderate	Low	Moderate
SFW (using WCMD or JSOW)	High	Moderate	Moderate	Moderate	Moderate
Long-range Standoff Munitions	High	Moderate	Moderate	Low	Low
Very-Long-Range Weapons	High	Moderate	Low	High	Moderate

3. Reasons for Differences

The differences among the studies were significant. The IDA Quick Look Study favored standoff weapons while the Air Force studies (NCAA and AFSAA) tended to favor precision overflight weapons. The Navy studies, in general, resulted in fewer weapons expended. The differences could be traced to the differences in methodologies and data used in each of the studies.

One reason for study differences concerned the methodologies, and, in particular, where the study placed its priorities. All of the methodologies used to select a preferred weapon mix included three key parameters: weapon effectiveness against the targets in the target set, attrition to the delivery platforms, and the cost of the weapons. Each study handled these parameters differently. For example, both Air Force studies maximized target value destroyed for a given dollar investment in weapons. The NCAA study assigned dollar cost values to aircraft and attempted to minimize the cost of aircraft attrition associated with killing a target. The AFSAA study organized this differently, using budget and aircraft attrition limits as constraints in a linear program whose objective was to maximize the target value destroyed. Both Navy studies focused on minimizing cost [in terms of aircraft attrition, operations and maintenance (O&M), and weapons expended] to kill the targets. The IDA Quick Look study used a linear program to minimize aircraft attrition while requiring certain targets to be killed in a fixed time period and within a limited budget for new weapons.

A second reason for study differences is associated with the target set used by each study. All of the Service-sponsored studies used the DIA outyear threat report together with the CINC apportionments to their Service as the basis for their target requirement. The IDA target set included a large number of vehicles (trucks, armor, etc.) which drove a high use of cluster munitions and JDAMs. The Navy target set tended to be smaller than the others, which in turn supported their smaller expenditure of weapons. In addition, the studies used very different descriptions of the targets. For example, an airfield had four times as many elements in the Air Force target set compared with the Navy set. Reconciling the target set was a major requirement for the study team, since the targets themselves were major drivers of weapon requirements and a key input for the next phase of DAWMS.

A third cause of study differences was the required probability of damage (PD) that each study required to meet that study's predetermined warfighting goals. Achieving a high PD requires either a large number of less accurate weapons or a smaller number of very accurate weapons. The Air Force's use of high PDs contributed to their higher number of weapons expended. The Army uses low PDs in their weapons requirement process. Setting appropriate PDs was another area that received considerable attention in DAWMS.

A fourth reason for study result differences was the weapon effectiveness assumed for each munition. The Expected Number of Kills per Sortie (EKS) is the typical measure of weapon effectiveness, and this varied by study. The relatively high EKS used by IDA for the Sensor Fused Weapon (SFW) contributed to that system's preference in the IDA study.

How each study handled costs also led to differences in the results. The IDA and AFSAA efforts considered only the costs of new weapons and used a budget constraint to limit the expenditure of these weapons. The two Navy studies included replacement costs for strike and support aircraft attrition as well as aircraft Operational and Support (O&S) as part of its total war cost and then orchestrated the target attacks in order to minimize the total war cost. IDA and the Air Force studies did not include aircraft attrition as a part of the cost equation and instead implemented constraints for maximum allowable attrition rates for various aircraft during the various phases of the campaign.

While the above paragraphs detail the primary reasons for study differences, there were several other areas where the studies differed, including the specifics of the Blue force structure, the sortie rates used for different classes of Blue aircraft, the weapon loads carried by each aircraft, the availability of inventory weapons in theater, and the restrictions each study associated with weapon usage. This last category included doctrinal or Service planner inputs that would exclude a specific weapon from being used to strike a specific target type, e.g., certain Air Force platform/weapon mixes were not authorized to attack enemy ships.

D. GENERAL GUIDELINES FOR THE DEEP ATTACK WEAPONS MIX STUDY

The IDA Quick Look and the review of studies provided useful background for DAWMS. The objective of DAWMS, as specified in the study guidance, was to "determine cost-effective mixes (quantity and composition) of air-to-surface and surface-to-surface munitions for deep attack operations." In addition, the OSD leadership issued general guidance concerning the conduct of the study. This guidance included:

- Use established joint doctrine for deep attack operations.
- Use a two-Major Regional Conflict (MRC) scenario (northeast Asia and southwest Asia) for the study baseline.
- Analyze force and weapon mixes in 1998 and 2006.
- Use the baseline force structure outlined in FY 1996 President's Budget (1998) and Defense Planning Projection (DPP) (2006).
- Base force arrivals and beddown on the Joint Staff Nimble Dancer II-2005 Wargame.
- Use forces in accordance with 1996 defense plans.
- Use enemy threats outlined in the DIA Outyear Threat Report and Futures Intelligence Program.
- Consider weapons in current inventory, in production, and in development.

A major issue that was resolved at the first meeting of the steering group was the definition of deep attack. Eventually, the study advisors agreed to the following definition:

> *Deep attack operations encompass the entire spectrum of joint activity conducted beyond close supporting fires. For the purposes of DAWMS, "deep" is defined as beyond 40 km (22 nmi). However, DAWMS covers the entire battle area from the FEBA[5] on forward.*

Some wanted to exclude the forward battle from the analysis. This would require setting aside weapons (both inventory and new procurements) for the close battle. Which enemy forces would be engaged in the close battle depended in some cases on how many of those forces first transitioned through the deep area to the close area and how successful the deep attacks were. Likewise, there was no easy way to determine which of the new weapons would be used in the close battle since that would depend on the severity of the attack and the capability of the Blue forces to effectively engage. Rather than draw artificial lines and not allow weapons set aside for one aspect of the battle to be used in the other, even if the result would be beneficial, it was decided that DAWMS would include all air- and surface-delivered direct fire weapons that attacked targets beyond the FEBA.

E. THE METHODOLOGY

Often the study customer pays little attention to the methodology used to accomplish the study, relying on the expertise of the analysts to develop an acceptable one. Still, the senior official who develops some understanding of how the results are obtained will often have more confidence and be more likely to use them in the right way. In this section we provide a brief overview of the methodology used in DAWMS.

The DAWMS methodology involved the use of two major combat models. The Tactical Warfare Model (TACWAR)[6] is a two-sided simulation representing the entire

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[5] FEBA refers to Forward Edge of the Battle Area. Current terminology uses FLOT, Forward Line of Troops.

[6] TACWAR is the primary campaign model used by the Joint Staff (JS) and the CINCs. It was first developed in the 1970s by IDA and has been extensively modified over the years, especially in the area of chemical warfare.

campaign for both Red and Blue air-to-ground attacks, air-to-air engagements, and the ground combat force interactions. Its key measures of merit are movement of the FEBA and combat forces attrited. The Weapon Optimization and Resource Requirements Model (WORRM)[7] is a one-sided model representing an attack of Blue aircraft and standoff missiles against a Red ground-based target set and defenses. It uses an optimization technique called linear programming to allocate Blue platforms such as aircraft, ships, and MLRS and the weapons they fire against Red targets to achieve a user-defined objective.

The objectives used in DAWMS were initially to minimize aircraft and helicopters attrition [no attrition was assumed for ships and Multiple Launch Rocket Systems (MLRSs)], and then to maximize target value destroyed. The overall approach was to use TACWAR to set scenario conditions such as suppression of enemy air defenses (SEAD) drawdown rates, aircraft attrited, FEBA movement, etc., which could then be applied in WORRM to generate cost-effective weapons mixes for the U.S. forces. WORRM is described in greater detail next so that the reader may more fully understand the later results.

1. WORRM Description

WORRM uses range bands on the Red side of the FEBA. These range bands can be selected to correspond to various aircraft and ATACMS tactical ranges. Each target is in a range band and target kill goals may be specified by range band. Aircraft attrition depends on the Red defenses assumed to be in the range bands that the attacking aircraft must pass through as well as the defenses associated with the target itself. WORRM does not include Red air attacks against Blue forces or air-to-air combat, nor does it model ground combat and artillery.

The campaign consists of five phases, each consisting of a specified number of days: early halt, late halt, build and pound,[8] counter-offensive early, and counter-

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7 WORRM was initially formulated to support the Bottom Up Review (BUR) in 1991-92 and has subsequently been used in several major studies.

8 The build and pound phase is also called the buildup phase. During this phase there is almost no ground combat as the focus is on preparing for the counteroffensive by attriting the enemy forces using primarily aircraft delivered weapons.

offensive late.[9] Force arrivals and target kill goals vary according to these phases while weather patterns can also change in each phase. In addition, there was a fixed time separation between the start of combat in the first and second theaters.

The linear programming formulation[10] of WORRM either minimizes aircraft attrition or maximizes target value destroyed subject to the following constraints:

- **Constraint 1:** Number of targets killed cannot exceed total number of targets available (although the model does provide for some target regeneration).
- **Constraint 2:** A specified number of targets by type must be killed in each time period and range band.
- **Constraint 3:** Aircraft attrition by aircraft type will be limited to a specific percentage to ensure that no one aircraft type suffers significantly more than its share of attrition.
- **Constraint 4:** The budget that can be used to buy weapons is limited.
- **Constraint 5:** The number of weapons used by type cannot exceed the existing inventory (defined as available inventory plus additional systems purchased as of the time of the study in 1996).

Over one million variables were used in the DAWMS formulation of WORRM with 31 platform types, 62 weapon types, and 205 target types represented in the model. When provided with a weapons budget and weapon procurement alternatives with their costs, WORRM will compute a preferred weapon mix. The weapons budget was $10.6 billion over the roughly 10-year look into the future. To preclude dividing the budget between theaters, as would be needed if the optimization were done sequentially, the oversight groups directed the weapon buy to be optimized across both theaters. Several major enhancements were made to WORRM during the course of the study. Two of the most significant added multiple weather states and enhanced the treatment of C4ISR. Both will be discussed further in a later section.

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9 Later the two counter-offensive phases were combined and a separate SEAD phase was added before the early halt.

10 A detailed mathematical description of the model appears in IDA Document D-2360, *A Description of the Weapon Optimization and Resource Requirements Model,* August 1999, UNCLASSIFIED.

WORRM produces a rich set of outputs. With regard to weapons it provides the number purchased and the amount of already available inventory weapons used in the two-MRC conflict. It identifies the targets they struck, the weather state, the platform type that delivered them, and, for aircraft, the release altitude. WORRM post-processors also calculate the target value destroyed by target type and display the amount of target regeneration that occurred. Finally, for each aircraft type it calculates the attrition and sorties flown by weather state, delivery altitude, depth of penetration, weapon standoff range, and target types struck.

An optimized force allocator[11] like WORRM can be used to provide inputs to two-sided campaign models like TACWAR. For example, WORRM can generate the allocation of aircraft to missions, an important input that defines how aircraft are used in models like TACWAR.

2. Modeling Process

TACWAR was used to provide a "realistic" overview of a two-sided campaign and WORRM was then implemented to generate a suggested weapon buy. As such, it was important that these two models work effectively together. This was done using a three-stage process.

Stage 1: Use TACWAR and the current planned weapon program for 2006 to fight the campaign in the two MRCs. From the TACWAR results, four key outputs are passed to WORRM:

- Timing for the different phases of the conflict
- Blue ground force (except helicopter and ATACM) kills of Red targets (used to reduce kill requirement in WORRM)

[11] There are several other models that have structures similar to WORRM. The Combat Forces Assessment Model (CFAM) is used by the Air Force in weapon and aircraft studies. The Conventional Targeting Effectiveness Model (CTEM) has been used by PA&E and J-8. All of these models are based on a linear objective function and linear expressions of constraints. WORRM differs from these models in many ways, especially in its in-depth treatment of C4ISR and aircraft attrition. An earlier weapon optimization code used a quadratic expression in the objective function. It did not provide any additional insights and the solver was slower with more limited dimensions than comparable LP solvers.

- Blue and Red air-to-air combat kills (reduces Blue forces available and Red aircraft targets)
- Blue aircraft attrition to Red surface defenses (used to adjust the aircraft attrition rates in WORRM).

Stage 2: Use WORRM, with adjusted inputs, to determine a preferred weapons buy for a fixed budget. This was done using a two-run sequence. In Run 1, WORRM determined the minimum number of aircraft lost subject to staying within the weapons budget and satisfying the CINC target kill goals. Target value was not used, and no aircraft type is permitted to lose a disproportionate share.[12]

Run 2 maximizes target value destroyed using a bound on aircraft lost that is 25 percent higher than the minimum established in Run 1. For example, if the minimum attrition run lost 200 aircraft, then the maximize target value run could lose 250. This second run was done to provide a margin to protect against CINC target kill goals that were too low.

Stage 3: Rerun TACWAR with this new weapons mix to ensure that it makes operational sense.

Figure 2 summarizes the process.

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[12] Mathematically, the linear program minimized (A+B) subject to attrition constraints for each aircraft type of the following form:

$$\Sigma \left[\text{Platform attrition for aircraft type j}\right] \leq \text{A (average number of type j a/c in NEA)}$$

$$\Sigma \left[\text{Platform attrition for aircraft type j}\right] \leq \text{B (average number of type j a/c in SWA)}$$

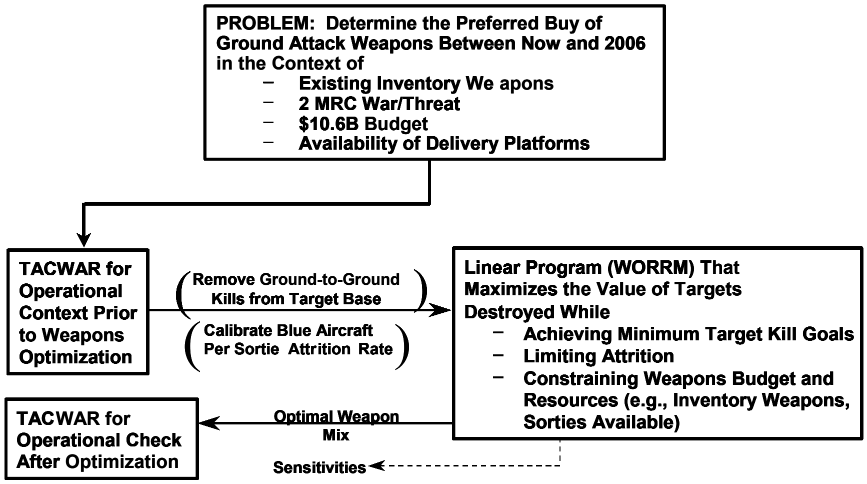

Figure 2. Overview of the Analysis Process

F. INPUT SOURCES

It is critical for the study team to develop accurate, dependable inputs. When studies prove to be invalid, it is usually the inputs that are to blame. It is critical that the study's customers develop confidence that the inputs used are both technically and operationally correct. More than 9 months of the 2-year study were spent developing inputs for the models, mostly for WORRM since it was the primary tool used to recommend a weapon mix.[13] When the same types of data were needed by both models (e.g., order of battle, weapon effectiveness, etc.) either the same data or consistent data were used.[14]

13 TACWAR runs were done by the Joint Staff (J-8). Their database was an updated version of the one used in the just completed Nimble Dancer II. WORRM runs were made by IDA.

14 For example, WORRM with its "pure" weapon loads (one type of munition per sortie) uses a different weapon effectiveness input than TACWAR with its average weapons load. Consistency is maintained by ensuring that both inputs came from the same basic source.

1. Scenario Characteristics

As mentioned earlier, the study was directed to use a two nearly simultaneous Major Regional Contingency (MRC) scenario.[15] The first MRC addresses an attack against allied forces in Northeast Asia. The environment was characterized by mountainous and forested terrain, poor weather, many hard and deeply buried targets, a relatively unsophisticated air defense threat, large CINC target goals, a significant U.S. presence prior to hostilities, and a large allied force to help in the warfight (especially in the ground war). On the other hand, the Southwest Asia MRC involved an attack by a hostile power against friends in the region and was characterized by desert terrain, good weather, mobile ground forces, a modernized air defense, medium CINC target goals, a minimal U.S. presence, and a small allied military.

2. Delivery Platforms

Table 3 lists the launch platforms used in the study by Service. The table includes fixed and rotary wing aircraft, MLRS, and naval sea forces. Each of the aircraft possess the following characteristics:[16]

- Time of arrival in theater
- Number of sorties per day (surge and sustain)
- Weapon load that varies by weapon type and range of the target
- Maximum depth of penetration (helicopter targets can only strike moderately deep targets).

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[15] There was some early concern that these 2 MRCs were atypical in that they:
- Both had large in-place infrastructures for our forces.
- Neither had a significant air threat.
- Neither involved a significant naval threat.

In the end no additional scenario was analyzed.

[16] Several delivery platforms could perform more than just strike missions. For example, the F-16 and F-18 can also be used as air-to-air fighters. These multimission aircraft were allocated to their various missions and only the strike allocation was used in WORRM.

Table 3. DAWMS Aircraft and Other Launch Platforms

Service	Launch Platforms
Army	AH-1 Cobra, AH-64 Apache, RAH-66 Comanche Multiple Launcher Rocket System (MLRS)
Navy	F-14, F/A-18 C/D, F/A-18 E/F Submarines, Surface Combatants
Air Force	B-1B, B-52H, B-2 A-10, F-15, F-16, F-22, F-117
Marine Corps	AH-1W AV-8B Harrier, F/A-18 A/C/D

The submarines and surface combatants are the launch platforms for TLAMS. The MLRS launches the various versions of ATACMS.

The arrival rates were provided by the Joint Staff and are similar to those used in earlier studies. They were adjusted to reflect the lift projected to be available in 2006. Each Service felt that the warfight would go better if their Service was allocated a larger portion of the airlift available to allow them to arrive earlier. Despite these arguments, the Joint Staff did not reallocate any lift. The sortie rates and weapon loads were provided by the Services for their systems. Considerable time was devoted to ensuring that all Service inputs were developed using consistent assumptions.

3. Cost

Considerable effort was expended to estimate the cost of each new weapon [e.g., Joint Air-to-Surface Standoff Missile (JASSM), SLAM-ER, JSOW] and of each existing weapon with an active production line (e.g., GBU-24, Hellfire II, TLAM). The life cycle costs included RDT&E, procurement (based on the learning curve for the planned buy), platform integration, and O&S. All costs were estimated in FY96 dollars with all prior year costs considered sunk. Thus, there was no cost associated with using weapons already in the inventory. A 5-percent discount rate was applied to costs over the 25-year period from FY97-FY21. Initial plans called for multiple WORRM runs with each new run reflecting the learning curve associated with the recommended procurement in the previous run. Early tests of this procedure proved cumbersome and time consuming, and the results showed little change from run to run. Since the emphasis of DAWMS was on identifying general trends and preferences for weapon procurement and not on providing a point estimate, this approach was abandoned.

4. Weapon Budget

All FY96 and prior year costs were considered sunk when determining the budget available to buy additional weapons. The budget was calculated by first determining the programmed weapon purchases in the FY97 President's Budget for the next 10 years. The total planned buy was then multiplied by the estimated unit cost to obtain the weapon budget. The FY06 budget reflected planned weapon procurement and deliveries through the end of FY06. It was adjusted to account for withholds, testing, and training. The "combat" weapons budget used in WORRM for 2006 was $10.6 billion.

5. Weapon Inventory

It was surprisingly difficult to determine how many weapons of each type the Services maintained in their current inventories. It is a number that is constantly changing as new production becomes available and expenditures (usually for training) occur. An estimate was made of the inventory at the end of FY96 and a percentage of that inventory, by weapon type, was made available to fight the two-MRC conflicts. This percentage varied by weapon type and was an input provided by the Services. The weapons were assumed to arrive in theater with the platforms that would deliver them. This assumption was necessary because the weapon composition depended on the WORRM "buy" decisions. The flow of forces into theater does include the weapons in the programmed force. Basically, the study assumed that the flow would be adjusted to reflect the mix of weapons purchased and that no additional expenditure of lift resources would be needed.

6. Exclusions

In an effort to add doctrinal constraints and operational realism to the calculations each of the Services provided exclusions to the study team. An exclusion prohibits a specific weapon or platform from attacking a specific target. For example, as previously noted, Air Force platforms were excluded from attacking deployed Red Navy forces (making this a Blue Navy target) and there was a prohibition against using laser-guided bombs (LGBs) in bad weather.

7. Targets

The target set (types, numbers, and locations) was provided by the JS/J8. Excluded from the target set were personnel, mortars, and submarines. The JS, using inputs from the CINCs, provided the time-phased target kill goals.[17] Some of these goals were specified by location (e.g., kill 5 in range band 1 in the early halt phase) and others did not specify location, thus letting the LP determine where to kill the target. They were adjusted to ensure that the number of kills required by the SEAD campaign were achieved. Finally, the targets were permitted to regenerate at rates determined by the Joint Staff in collaboration with the intelligence community. About 200 target types were considered in the study, ranging from mobile targets such as tanks to fixed targets such as production facilities and hardened command bunkers.

8. Weather

Historical records suggest the two scenarios spanned the gamut with regard to weather. In Northeast Asia (NEA) the weather was often bad, restricting the use of some weapons and decreasing aircraft availability. Southwest Asia (SWA), on the other hand, had mostly good weather. Each phase of the war had a percentage of bad weather determined from the historical weather characteristics in their area of operations. During periods of bad weather, some targets were designated as "must strikes," (e.g., tanks near the FLOT) while other strikes could be delayed until the weather improved (e.g., production facilities, airbases), provided enough sorties were available (i.e., kill requirements for these targets were given weather flexibility). The "must strike" targets tended to drive the procurement of all-weather weapons like those that use GPS for guidance.

9. Weapon Effectiveness

Each aircraft sortie with a specified payload and each surface-launched missile (ATACMS, TLAM) had an expected number of kills associated with each target. For example, when an aircraft sortie with four Joint Direct Attack Munitions (JDAMs)

[17] Late in the study there was an effort that compared these goals with some derived using "Effects Based" or "nodal targeting" criteria.

attacked a complex of buildings it was expected to destroy a predetermined number of buildings. This value, the EKS, depends on a large number of parameters and was a major factor in determining the weapon mix. The steps involved in developing this input are summarized below:

- Specify general target (e.g., airfield) (as defined by CINCs).
- Define target components (e.g., hangars, runway, revetments, ammunition storage facility, operations building).
- Associate each target with a target on the standardized target set used by weaponeers (this list contains about 200 targets).
- Use weapon delivery characteristics [e.g., Circular Error Probable (CEP), impact angle] and the required PD to determine the number of weapons by type needed to kill each target type.[18]
- Use aircraft weapon loads and number of kills per weapon to estimate the EKS. These values will vary by aircraft delivery profile and weather. DAWMS selected the best delivery profile for each of three altitudes (low, medium, and high) and two weather states (bad and good). Even after aggregating the 200 targets into 45 classes with similar weapon effects, the resulting input table was, by far, the largest in WORRM.
- As appropriate, adjust the EKS for other factors (e.g., the EKS for a standoff weapon attacking a moving target may be adjusted downward as compared to the same weapon being delivered via overflight).

10. Target Values

As mentioned earlier, the CINCs establish the minimum number of targets that must be killed over time to achieve their warfight goals (halt the enemy, prepare for the counteroffensive, etc). Often forces and weapons are available to strike and kill targets beyond these minimum goals. When this occurs, target values (i.e., the value of killing a target) are used to help decide which targets to attack. When target kill goals are not

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[18] A special working group chaired by J8 developed the required PDs. They were a compromise between the low values used by the Army and the high values used by the Air Force and Navy.

specified by range band, target value is one of the inputs, along with aircraft attrition rates and weapon effectiveness/costs used by the model to determine where to strike the targets. These target values were developed using a marginal utility scheme with the inputs coming from senior military warfighters from the four Services. They vary by theater (NEA or SWA), phase of the war (halt to counteroffensive) and, in some cases, location (the range band containing the target).

11. Weapon Standoff Ranges

The standoff range for air-delivered weapons influenced the attrition rates for their delivery platforms. The longer the standoff range the fewer the defenses encountered by the aircraft, and, usually, the more expensive the weapon. Standoff ranges modeled were:

- None (overflight—JDAM, LGBs)
- Medium-range, about 40 nmi (JSOW)
- Long-range, about 100 nmi (JASSM, SLAM-ER)
- Outside defenses (CALCM, ATACMS).

12. The Threat and Attrition Rates

The threat to Blue aircraft consisted of aircraft, surface-to-air missiles (SAMs), and anti-aircraft artillery (AAA).[19] The numbers, locations, and system characteristics were provided by the intelligence community. A major effort was undertaken to estimate the effectiveness of each Red threat against each Blue aircraft. Especially controversial were the appropriate degrade factors for Blue electronic countermeasures (ECM) and maneuver.[20] A separate mission planning (threat avoidance) model was developed to estimate the number of encounters a Blue aircraft would have with Red threats when

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[19] TACWAR did include air-to-air engagements, and adjustments were made to inventory levels in WORRM based on the results.

[20] More details are available in the study's classified report, *Department of Defense Deep Attack Weapons Mix Study (DAWMS),* JS/J8, October 1997. Several recent studies, e.g., *Analysis of Alternatives for the Joint Strike Fighter,* IDA Report R-407, August 2001, had developed estimates of these degrade factors. These studies were in general agreement. The issue concerned how to combine maneuver effects with the on-board ECM.

attacking a specific target. This depended on the standoff range of the weapon. Platforms delivering long-range standoff weapons would encounter fewer threats than those delivering overflight weapons. The attrition rates changed by phase to reflect the results of the SEAD campaign. These data, with adjustments (calibration) based on TACWAR results, were used to populate an attrition table in WORRM.[21] The SAM/AAA threats were assumed to have no capability against Stealth[22] aircraft (F-117 and B-2) and standoff weapons (JSOW, JASSM, ATACMS, TLAM, SLAM-ER, or CALCM) after they were released. Thus, the B-2 and F-117 could overfly targets with impunity and hence, had no reason to carry the more costly standoff weapons to enhance their survivability.

13. C4ISR

Many felt that C4ISR had been inadequately treated or not treated at all (perfect C4ISR) in earlier weapon mix analyses. As a result, C4ISR received considerable emphasis throughout the study. A C4ISR team composed of Service, IDA, JS, and OSD representatives met at least weekly during most of the study. The team provided a methodology and data (based on expert judgment) that accounted for the effects of C4ISR in both major models (TACWAR and WORRM). The methodology considered the target acquisition, battle management, weapon delivery, and battle damage assessment (BDA) elements of C4ISR. More specifically, the approach considered the following factors for targets:

- Target intelligence quality
- Target acquisition/identification probability (off-board cueing system)
- Target location accuracy
- Target velocity accuracy

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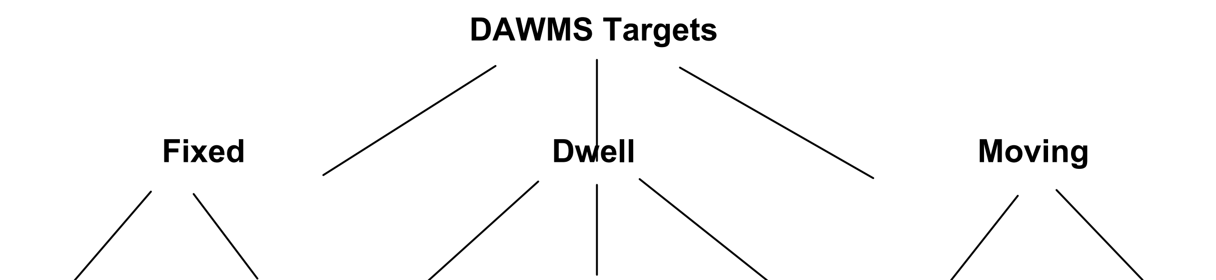
[21] Some argued that the better U.S. training should be reflected in the relative capabilities of the forces. This would apply mostly to the two-sided combat representation in TACWAR. There were no special adjustments made to WORRM inputs.

[22] There was little change in the 2006 results. This assumption would not be acceptable in 2014, when a larger portion of the force would be Stealth due to the addition of significant numbers of Joint Strike Fighters (JSFs).

- Sensor-to-shooter time delay
- Sensor-to-shooter information flow throughput
- Target acquisition/identification probability (onboard weapon platform)
- BDA quality (includes accuracy and timeliness).

There are three target motion categories (fixed, dwell, and moving) with dimension subcategories as indicated in Figure 3.



Large	Small	Large Long	Small Long	Short	Long Column	Short Column
Bunkers	Doors	Revetted A/C	SAMs	SSMs	Tanks	Tanks
POL	UG Bunker			Helos (open)	APC	APC
A/C Shelter	Tunnels			SAMs	SPG Column	SPG Column
Runway	Radar / EW /			Trucks	AAA	AAA
Taxiway	GCI sites				Rocket Lnchr	Rocket Lnchr
Bridge					Trucks	Trucks
Buildings						

Figure 3. C4ISR Target Categories

Two parameters were used to capture the effects of C4ISR:

- **Target Not Found (TNF).**[23] This parameter results in a sortie aborting its mission and returning to base with its ordnance. This occurs when the mission fails to find both its primary and secondary targets. It is a function of the cueing the aircraft receives from off-board sensors during the mission and

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[23] TNF is used in WORRM. In TACWAR the corresponding parameter is probability of detecting the target.

the ability of the aircraft's on-board sensors to detect a target, with and without the cueing.

- **Expected Kill per Sortie (EKS) Degrade.** When the target is found and weapons are expended they may not have their planned effectiveness. This is represented by a degrade to the EKS. Three factors contribute to this degrade:
  - **BDA.** The weapon may be attacking a target that has already been killed but BDA has misclassified as alive.
  - **Target Location Error.** This reflects either inaccurate coordinates for GPS weapons or improperly aimed standoff weapons due to unexpected changes in target movements.
  - **Target Information Quality.** This may result in a degrade if a target other than the intended target was found and attacked. In this case, the weapon may not be appropriate (e.g., cluster bombs are effective against trucks but not against tanks).

The two major factors defined above, TNF and the EKS degrades, vary according to the categories displayed in Figure 4. There was a separate numerical value for each combination of categories in the table (e.g., a platform with radar plus visual sensors delivering an unguided unitary weapon from high altitude to attack a large fixed target in the early halt in good weather in the first range band will have a unique factor). Long-range standoff weapons like TLAM and ATACM do not use sensors onboard their launch platforms to enhance their accuracy and hence, ships and the MLRS are not listed under the platform category. These weapon systems do, of course, use national assets to help with their targeting.

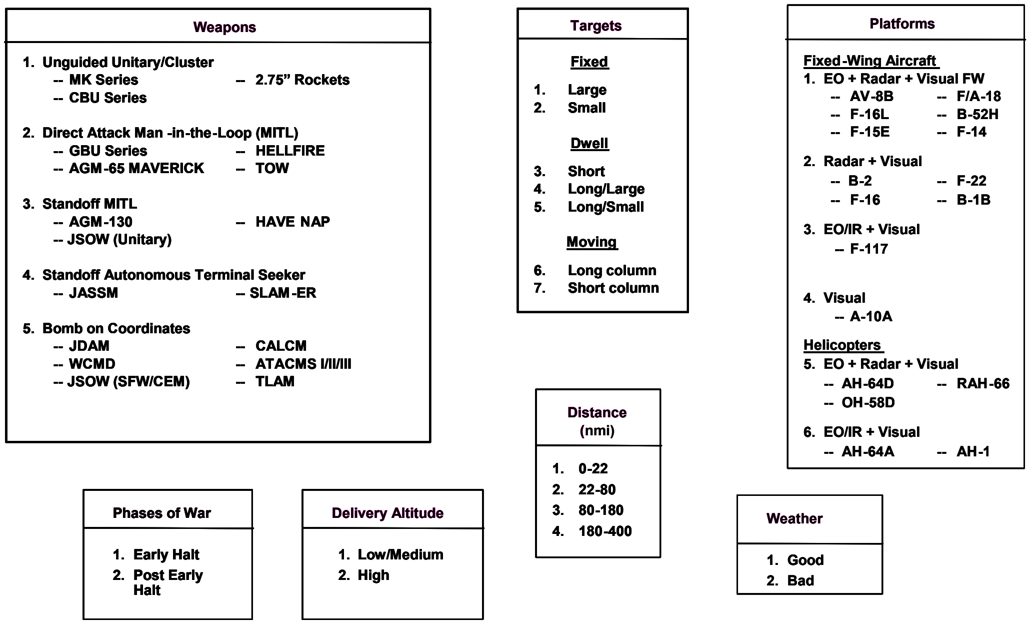

Figure 4. C4ISR Categories

II. RESULTS

It is important that the study sponsors monitor the study throughout. This includes early briefings on methodology and inputs followed by briefings of emerging results. It is through this process that mutual trust is built. This will help the senior officials challenge their intuition when study results disagree with it. This may result in either a key insight or in a change to a questionable input. In this section we present the results as they evolved over the course of the study.

A. PRELIMINARY RESULTS

Early Senior Advisory Group (SAG) briefings were progress reports. For example, the May 1996 briefing (about 10 months after the start of the study) focused on two areas:

- ***Status of the Models, WORRM in Particular.*** Initially, the Linear Program could not achieve feasible solutions due to an inability to kill very hard targets early (the only weapon suitable for the mission was the Air Force's 5,000-pound bomb (GBU-28) and the needed delivery platforms, F-15Es, had not yet arrived in sufficient quantity in theater) and the difficulty of killing targets in bad weather. To correct these problems more 5,000-pound bomb carriers were deployed early and the requirements to attack some targets in bad weather were relaxed (weather flexibility).
- ***Prioritizing Sensitivities.*** The SAG accepted study team recommendation to place the following priorities on sensitivity analyses:[24]
  - *High priority sensitivity analyses:*

[24] Some suggested that the time between the start of the two MRCs be decreased. This would require reflowing forces to the second theater, which was deemed too time-intensive to do correctly.

1. Days of warning time prior to D-Day (less warning time means fewer forces available when fighting starts—the fewer forces available early, the lower the probability of destroying all required targets in a given period of time)
2. Threat. There was considerable debate concerning the number of long-range SAMs in SWA—the sensitivity analysis was intended to show how Blue effectiveness and the associated weapons mixes changed with different numbers of Red SAMs.
3. Chemical attacks on airfields and ports and their potential impact on arriving Blue force flows
4. C4ISR probabilities of detection
5. Weapons budget (increase and decrease)
6. Weapons cost (increase for selected weapons)
7. Countermeasures to include GPS jamming to impact effectiveness of Blue platforms and GPS-guided munitions and dispersing vehicles to reduce the effectiveness of the SFW
8. Adding developmental costs (new weapons not in budget) to potential weapon procurements. Examples include the Low Cost Autonomous Attack System (LOCAAS) munition for attacking armor, JASSM with a combined effects bomblet (CEB) payload, a more accurate JDAM, etc.

– *Medium Priority*

1. Required probability of damage (impact of lower PDs to reflect Army use)
2. Logistics availability

– *Low Priority*

1. Weather (better or worse than baseline)
2. Adding forces

3. Swinging more forces between theaters (in the baseline, only some bombers and F-117s redeploy from the first theater to the second). All other forces deploying to the second theater originate in CONUS or Europe.
4. Target values
5. CINC target kill objectives.

B. DEFENSE SCIENCE BOARD REVIEW

Because the study could potentially impact Service munition budgets as well as indirectly measure the potential success of various force applications in two warfighting CINCs' areas of responsibility, it received high level attention both within and outside the Department of Defense. Both the White House and Congress mandated a review of the study and its methodology by a Defense Science Board (DSB) panel:

> *The Defense Science Board will be asked to form a special panel to provide an independent assessment of the analytical tests and models employed and make recommendations for improvements in the study's analytical approach.*
>
> (The White House, Statement by Press Secretary, 8 Feb 1996).
>
> *The Secretary of Defense shall establish an ad hoc review committee under the auspices of the Defense Science Board to establish the methodological approach to the tradeoff study, to establish a broad range of stressing scenarios of interest, and to review assumptions regarding the analysis to be conducted.*
>
> (Section 8111, FY 1997 DoD Appropriations Act)

The members of the DAWMS DSB panel were:

- Professor Walter E. Morrow, Chairman
- General Michael P.C. Carns, USAF (Ret.)
- General John W. Vessey, USA (Ret.)
- Admiral Leon A. Edney, USN (Ret.)
- Major General Ray M. Franklin, USMC (Ret.)
- Dr. John D. Christie, Logistics Management Institute (LMI)

- Mr. Robert J. Murray, Center for Naval Analyses (CNA)
- Mr. Michael D. Rich, RAND
- Honorable Harold Brown, Reviewer.

The initial meeting took place in Irvine, California, as part of the DSB's summer study series. After receiving inputs from the Services, department offices, and study team members, the DSB generally approved of the methodology used to estimate weapon needs and suggested a wide range of sensitivities designed to help address Service concerns. In addition, they recommended that the schedule be extended as necessary so as not to sacrifice quality to meet deadlines.

C. INITIAL RESULTS

1. Early Trends

In the fall of 1996, the emerging results for addressing two nearly simultaneous Major Regional Conflicts in 2006 suggested a significantly different weapons mix be pursued than that in the existing program. More specifically, the initial results suggested the following:

- Accurate overflight weapons
  - Maintain the JDAM program
  - Buy more LGBs (especially GBU-24s)
  - Buy more Hellfire IIs and fewer Longbows for helicopters
  - Decrease the WCMD program
- Accurate standoff weapons
  - Increase the JASSM buy
  - Increase the buy of ATACMS IIa [the extended range brilliant anti-tank (BAT) weapons version]
  - Decrease the buy of TLAMs and JSOWs (all versions)
- Submunitions
  - Decrease overall buy of SFWs with preference for SFW P3I
  - Use existing cluster munitions in WCMD kits.

2. Service Requests

These preliminary results suggested the acquisition of a greater number of Army weapons than programmed, suggested a change in the mix of Air Force weapons toward more GBU-24s and JASSMs and fewer JSOWs, and provided only limited support for Navy weapon programs. As is often true when a study suggests a change in a program, a major review of the methodology and inputs ensued. The following are some of the resulting requests and changes received from the Services:

- Air Force
  - Add the Airborne Laser (ABL) to the weapon mix
  - Increase the SAM threat in early halt
- Army
  - Zero the target value from infrastructure/strategic targets and trucks
  - Use Army probability of damage requirements for weapon effectiveness calculations
- Navy
  - Add the newly postulated arsenal ship with 500+ vertical launch cells to the baseline
  - Modify the standoff range for the SLAM-ER and add it to the list of weapons eligible for purchase
  - Triple the attrition for platforms delivering overflight weapons in the early halt phase
- Marines
  - Increase the SAM threat in the early halt phase.

3. Other Areas Needing More Analysis

In addition, there were several areas that were unsatisfying to many of the DAWMS study team members, to include:

- **Helicopter Attrition.** Many felt that a major weakness of the study was its inability to derive helicopter attrition rates in a manner consistent with the aircraft attrition rates. Attempts to estimate encounters with SAMs and AAA for deep strike missions failed. A special RAND study was commissioned to address this issue, but results were not available in time to support DAWMS. In the absence of an analytical approach, expert military judgment was used to set the helicopter attrition rates.

- **Uncertainty in Weapon Costs.** Sensitivity analyses were conducted for the costs of JASSM, ATACMS II, JSOW, SFW, JDAM, and WCMD.
- **Differences in Target Values Among the Services.** The initial results used the average of the Service-provided target values. Sensitivity runs were made with each Service's target values with surprisingly little change in weapons purchase recommendations.
- **Impact of the Size of Weapons Budget.** Excursions examined a 25 and 50 percent higher budget and a 25 percent lower budget.
- **Impact of the Joint Staff Added "Flexibility" Factors to the Target Kill Goals Provided by the CINCs.** The low use of some of the standoff weapons and a concern that the CINCs were too conservative in their estimates of required kills elevated this in priority relative to the initial list (see paragraph A). Runs were made with these smaller CINC goals, resulting in lower aircraft attrition and an increase in the use of standoff weapons.

D. REVISED RESULTS

By January 1997 the results of the wide range of excursions suggested the previous fall had been accomplished and the relevant data changes had been made. The results were briefed to the review groups and individually to the four Service vice chiefs. The new results are summarized in Table 4. The last column in the table contains the excursion that resulted in the largest purchase of each weapon type. In general, it was a relaxing of conditions (higher budget or fewer required kills) that resulted in the largest purchase. The new results did modify some of the earlier insights but not enough to satisfy all of the Services.

Basically, the optimization favored:

- Weapons with long standoff ranges (JASSM, SLAM-ER, ATACMS II) in the early halt phase when Red defenses were most effective

- Relatively inexpensive accurate unitary weapons (LGBs, JDAMS) to attack fixed relatively hard targets after Red defenses had been suppressed
- Hellfire and existing inventory weapons like TOW and Maverick to attack mobile targets [tanks, APCs, Infantry Fighting Vehicles (IFVs), artillery]
- ATACMS II, JDAM, JASSM, and SLAM-ER to attack targets in bad weather.

Table 4. New Results

Area	Program	Suggested Change to Programs		Most Favorable Sensitivity
		Initial Results	New Results	
Accurate Overflight Weapons	JDAM	Maintain	Maintain	Larger budget
	LGBs	Increase	Increase	Larger budget
	Hellfire	Increase	Increase	Higher budget
	Longbow	Decrease	Slight decrease	Lower target goals
	WCMD (both CEM and SFW versions)	Decrease	Decrease	Larger budget
Standoff Weapons	JASSM	Increase	Slight increase	Larger budget
	SLAM-ER	N/A	Increase	Several
	TLAM	Decrease	Decrease	None
	JSOW (CEM)	Decrease	Slight decrease	Lower target kill goals
	JSOW (SFW and Unitary)	Decrease	Decrease	Lower target kill goals
	ATACMS II (BAT)	Increase	Increase	Larger budget
	ATACMS-IA (APAM)	Decrease	Decrease	None
Submunitions	SFW	Decrease	Decrease	Larger Budget

Those weapons excluded, for the most part, were relatively expensive:

- Shorter range standoff weapons like JSOW and Longbow
- Longer range standoff weapons like TLAM
- Cluster munition delivery systems like ATACMS II
- Guidance kits like WCMD.

E. THE FINAL ROUND

The Services, especially the Navy, continued to object to the "new results." There was a renewed effort to reexamine every assumption with emphasis placed on "operational realism." In addition, new data arrived on weapon costs and many new sensitivities were suggested.

1. Key Changes

The spring of 1997 brought a number of key changes:

- **New Cost Data.** The Air Force provided new cost projections for the WCMD and JASSM. These projections significantly lowered the unit procurement cost of both programs. This new cost data was accepted after a careful review by the cost team.
- **Adjustments Based on Battle Staff Recommendations (operational realism focus)**
  - Revise the rates at which high and low altitude SAMs are destroyed through time.
  - Increase the emphasis on the suppression of enemy air defenses by adding a SEAD phase prior to the early halt. In this phase the primary targets would be air defenses. Adjust subsequent attrition rates accordingly.
  - Modify helicopter attrition rates to reflect survivability differences among platforms (AH-64A, AH-64D, AH-1W) and the weapons (Hellfire, Longbow) they are carrying.
  - Increase the restrictions on helicopter employments into deeper range bands.
- **Sensitivity Analyses Added**
  - More scenarios, especially a short warning scenario. In this scenario the U.S. is given less time to deploy its forces before the war starts.
  - Less emphasis on infrastructure targets by eliminating the possibility of attacking these targets once the CINC goals have been met.

2. Hybrid Results

The conditions for the new set of runs were referred to as the hybrid conditions and the results became known as “the hybrid results.” Some of the previous "reduced buy" weapon systems were found to be sensitive to the scenario assumptions. In other words, the study conclusions continued to evolve. They are summarized in Table 5. Included for weapon systems with modified recommendations from the previous round is a brief rationale as to the major factor that caused the change.

Several actions occurred which were at least in part motivated by the results displayed in Table 5. For example, it was reported that the Army delayed closing the Hellfire production line and was de-emphasizing the ATACMS Ia, that the Air Force was going to keep open the LGB production line, and that the Navy was going to explore new production of the SLAM-ER (over and above the SLAM to SLAM-ER upgrade program). In addition, the DoD had new insights with regard to the vulnerabilities of GPS-guided weapons to jamming, the effect of decoys, smoke and obscurants on the preferred weapons, and which weapons still under development showed the most promise.

Perhaps the most important result of the study was the observation that the programmed munitions investment budget between 1997 and 2006 is sufficient to provide the next-generation munitions needed to maintain the U.S. advantage over potential opponents. This was further supported by excursions with a smaller budget that proved to be unacceptable (the linear program was not able to generate a feasible solution).

Still, the critiques of the study continued as several Service-favored programs had not done as well as they expected. Some of the Services felt that the whole concept of DAWMS infringed upon their Title 10 authority to “organize, train and equip” their forces for the warfight. These final critiques are discussed next.

Table 5. Hybrid Results

Area	Program	Suggested Change to Programs		Hybrid Results
		Initial Results	New Results	
Accurate Overflight Weapons	JDAM	Maintain	Maintain	Maintain
	LGBs	Increase	Increase	Increase (but less than before due to survivability of platform)
	Hellfire	Increase	Increase	Slight decrease (due to survivability of platform)
	Longbow	Decrease	Slight decrease	Increase (due to better platform survivability)
	WCMD (both CEM and SFW versions)	Decrease	Decrease	Increase (due to cost decrease)
Standoff Weapons	JASSM	Increase	Slight increase	Increase (due to cost decrease)
	SLAM-ER	N/A	Increase	Increase
	TLAM	Decrease	Decrease	Decrease
	JSOW (CEM)[a]	Decrease	Slight decrease	Decrease
	JSOW (SFW)	Decrease	Decrease	Decrease
	JSOW (Unitary)	Decrease	Decrease	Maintain (all weather)
	ATACMS II (BAT)	Increase	Increase	Increase
	ATACMS-IA (APAM)	Decrease	Decrease	Decrease
New Submunitions	SFW/SFW P^3I	Decrease	Decrease	Maintain (replaces Hellfire)

III. CRITIQUES, CONTRIBUTIONS, AND LESSONS LEARNED

A. CRITIQUES OF THE STUDY

1. Service Involvement

During the course of the study the DAWMS study leaders in J-8 and OSD devoted considerable effort to keeping each of the Services informed and involved. This was important as it was the Services that would need to implement the study's recommendations. Examples of Service participation include:

- Each Service had final say on the characterizations used as inputs for their systems (e.g., sortie rates, weapon loads, etc.).
- The Services were included and encouraged to participate in all meetings.
- The Services provided most of the key operational inputs
  - Values of targets
  - Pace of the SEAD campaign (via the Battle Staff)
  - Sortie rates and weapon loadouts for aircraft
  - Exclusions in weapon/platform usage (e.g., Air Force platforms were precluded from attacking enemy ships outside port areas).
- Twice the Services were given the opportunity to specify run conditions for sensitivities (some of these were discussed earlier). The DAWMS study team would then accomplish the run and display the results to the group. In this way each Service could explore results using conditions favorable to that Service (e.g., the Army precluded heavy bombers from close-in range bands; the Marines and Navy directed higher than estimated JASSM costs, etc.)

2. Model Critiques

Still the study was severely criticized in some circles. Some of these criticisms focused on the models.

- For example, the following appeared in a national magazine:

Crazy Analytical Models

At one point [in the DAWMS], it looked as if we would be very foolish to buy any [Joint Stand-off Weapon], and we ought to buy as much [Wind-Corrected Munitions Dispenser] as we possibly could. As we looked at it, we said, 'Why would the model consistently choose wind-corrected munitions over the Joint Stand-off Weapon?' Finally, we realized it was because the model wouldn't distinguish between stand-off at altitude and stand-off horizontal. We had to go back in and say, 'There simply are targets that you don't want to fly over.' We had to try to find a way to tell the model that there are tactical needs for certain kinds of munitions. We never did get the model fixed.

Source: "The New View of Airpower," Maj Gen Charles Link, *Air Force Magazine,* August 1997.

In reality, the criticism was not warranted as the model had significantly lower attrition for standoff weapons (especially for the longer range, stand outside area defense weapons, like JASSM and SLAM-ER).

- Another model-related critique concerned the limited number of weather states. WORRM could incorporate two, good and bad weather. This forced some tough choices. Man-in-the-Loop weapons like SLAM-ER can be delivered in weather conditions that would preclude medium-altitude LGB delivery (e.g., low clouds would have little impact on the SLAM-ER). On the other hand, SLAM-ER would not be suitable for delivery in driving rain but a GPS-guided weapon would be unaffected. This criticism has merit and WORRM was upgraded in its later versions to include more weather states.

- Perhaps the most unusual critique concerned the WORRM linear program. The critiques stated that "Everyone speaks a special language called 'WORRM Speak' which is very complex and harder than most operators can comprehend." Linear programs can be subject to interesting shifts in allocation depending on how the model's objective and constraints are characterized, but such changes are well understood by the analytic community and usually clearly explainable to operators and decisionmakers. Perhaps part of the problem with explaining these results was due to the complexity of the process that evolved over time as the study team tried to accommodate a wide variety of operational and tactical considerations.

- Some complained that WORRM had not been properly verified and validated (V&V). Extensive verification was accomplished with each modification by the IDA team. In results validation the analyst varies inputs and checks to see if the results move in the right direction (i.e., make sense). This validation was done using the 750 runs accomplished during the study and the many runs made when earlier versions of the model were used to provide results for the *Major Aircraft Review*, the *Bottom Up Review*, and the *Heavy Bomber Force Study*.
- The Air Force felt that the TACWAR model did not adequately account for the effects of airpower and its ability to significantly influence the movement of the FLOT, especially the linkage between deep attacks and the ground battle. In particular, air strikes against logistics facilities and infrastructure will limit resupply of front line forces and impact the ground battle. Other criticisms of TACWAR included its inability to model flanking maneuvers and airborne assaults behind enemy lines.

3. Critiques of Model Inputs

Most of the critiques concerned model inputs. A few are summarized below with the specific complaint, often voiced in public meetings and publications followed by an explanation of what actually was implemented in the models. Occasionally an issue would be raised in one of the review forums or by the battle staff and corrected with model changes or addressed by sensitivity analysis in the next cycle. Unfortunately, the complaint would continue to be repeated for months after it was initially raised by individuals who had been briefed on the study but who had no first-hand knowledge of the process or the evolution of the results. Some of the more persistent complaints included:

- WORRM did not have a SEAD campaign. (The model implemented a joint SEAD campaign developed by the Battle Staff.)

- OH-58 Kiowa warriors killed a significant number of trucks with rockets. (Rockets were removed from the study during the preliminary phase.)
- Attrition rates were too low or too high. (The relative attrition rates across fixed-wing aircraft had a solid analytical basis that was agreed to by all of the Services. There was less support for the rotary-wing attrition rates and no clear analytic basis for the relative relationship between fixed- and rotary-wing attrition inputs although these issues were addressed through sensitivity analysis.)
- Sortie rates did not depend on base location. (In fact, sorties rates were based on averages of the aircraft at the specified beddown bases).
- Study inputs had no basis in fact. (The study used Service-derived characteristics based on historical data, detailed modeling outputs, and/or the best military judgments available.)

B. WHAT MADE DAWMS UNIQUE

1. The Problem

> *And let it be noted that there is no more delicate matter to take in hand, nor more dangerous to conduct, nor more doubtful in its success, than to set up as a leader in the introduction of changes.*
>
> Niccolo Machiavelli (1469-1527). Chapter VI, *The Prince*.

DAWMS was an attempt to change the way DoD looked at weapons procurement. Every year, each Service is given a part of the CINC target set and asked to develop a weapons program that is effective against this allocation. In DAWMS the analysis of weapon needs was done from a joint perspective. The target set was not partitioned into Service shares. Instead, the full target set was used and the Service weapon programs were judged on their ability to service all the targets. For the first time trade-offs between weapons developed by the individual Services were evaluated in terms of their contributions to overall CINC objectives. ATACMS, JASSM, JSOW, and TLAMs were directly compared with each other.

2. Oversight

Oversight was extensive and included an expanded JROC co-chaired by OSD A&T and the Vice Chairman, JCS, a senior steering group at the three-star level, multiple sponsors (J-8, Policy, Acquisition, PA&E), a DSB methodology review, and considerable Congressional interest. Oversight officials were often quick to challenge results that did not match previous analyses, even though the context in which the results were developed had changed. For example, results that were fully defendable in the context of a single Service destroying a selected portion of the target base might no longer show the same contributions when all targets were available for all Services to attack. Often the distinction between defending previous positions and gaining the greatest insight from the new process was blurred. To the extent that the study helped the community think through U.S. warfighting concepts and their implications for weapon acquisition, it was a significant success.

3. Service Participation

There was extensive Service participation at all levels as discussed above during most of the study.[25] This participation took place at the oversight, analytic, and Battle Staff levels. While the Service participants often did not agree on major elements of the study and therefore drove many of the sensitivity analyses to determine how differences in inputs and approaches would impact results, in the end the study orchestrated the most extensive cross-Service involvement ever encompassed in a DoD study.

4. Study Visibility and Openness

The DAWMS databases were available to all participants (several shadow studies were done by the Services during the course of the study using the databases). All participants had access to the models and ample opportunity to review the methodology. Finally, study results were briefed at least weekly to provide all participants with complete access to emerging results in a timely manner.

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[25] The exception occurred during the last month of the study when the final briefing was being prepared. The Services were excluded by the sponsors due to a mandatory deadline imposed by the Secretary of Defense. There was no time for extensive Service coordination.

C. ANALYTICAL CONTRIBUTIONS

1. Collaborative Study

DAWMS was one of the first (if not the first) major study conducted by DoD that was truly collaborative. It showed that Joint Collaborative Analysis (JCA) could really be done but at a price—in time, resources, complexity, number of cases, etc. Through this process each Service learned about the tactics and capabilities of the weapon systems of their sister Services.

2. Brought Analysis to Operators and Senior Managers

DAWMS brought analysis to the decision-makers. The senior officials really got "into" the analysis–examining data input, output, exploring dependencies and effects, and initiating new cases. In some cases, it was the first time some senior operators were exposed to analysis, including what it can and cannot do. In a few instances operators were horrified that the analysis made so many assumptions and that it really did not mirror the "real world." It was an important educational process.

3. Program Impact: The Positive View

Widely divergent opinions exist as to the value of DAWMS. These differences largely involve how the weapons program changed as a result of the study. Those with a positive opinion of DAWMS argue that DAWMS confirmed that our weapons investment program is about right in terms of its size and composition. It showed the importance of the use of precision weapons in modern warfare, including the use of JDAM, long before Kosovo. They also state that many programs were affected by the attention given by the study, resulting in some adjustments to the size of some programs and pressures to reduce costs in others. It showed the need for reducing the cost of JSOW, something the Navy undertook in earnest later in the program. It directly affected the Army's Hellfire II and ATACMS programs. It exposed the deficiency of DoD's ability to fight in bad weather because there were not enough all-weather precision weapons. Also, DAWMS may have indirectly caused LGB production lines to remain open longer than had been scheduled. In summary, DAWMS did recommend a "balanced" weapon mix that included all types of weapons, ranging from specialized accurate weapons for striking very hard targets to long-range standoff weapons used to attack well defended targets. It highlighted the importance of weather, C4ISR, and cost when deciding on the preferred weapons mix. It did not advocate a point solution, but rather it suggested areas that should receive either more or less emphasis.

4. Program Impact: The Negative View

Those opposed to the study argue that the thousands of staff-hours and millions of dollars spent in conducting DAWMS were ultimately an unnecessary diversion since the conclusions were essentially that the Services are handling the programs appropriately and any cost or programmatic changes would have occurred anyway.

5. Ancillary Products

Still, both groups generally agree that there were some useful ancillary study products, to include:

- Several fully developed two-MTW scenarios covering the years from 1998 to 2014.
- An improved deep attack modeling methodology that linked an optimizer (WORRM) with a combat model (TACWAR).
- The initial steps to integrate C4ISR systems in campaign modeling that later spurred on follow-on studies to further develop this capability.
- The large and detailed DAWMS database that was blessed by the Services and used in several important studies in succeeding years. Key parts of that database include:
  - Weapon effectiveness in the presence of countermeasures
  - Mobility and Blue force flows
  - Red orders of battle and Concepts of Operations (CONOPS)
  - Allied force inputs and host nation support
  - Unit weapon costs
  - Complete set of Service-derived target values and goals
  - Estimates of aircraft attrition rates with countermeasures.

D. LESSONS LEARNED

Acceptance of Results Depends on Acceptance of the Analytical Process. The DAWMS modeling process was complex. It involved two non-trivial models, each with very large databases and each with significant warfighting simplifications implemented to allow focus on broader issues. The DAWMS study team needed to do a better job "simply" explaining the process—and they needed to repeat it over and over again, both to reinforce changes implemented as a result of Service and other overseer input and to bring new participants from the various organizations up to speed on changes and new results.

Keep the Results in Context. The quantitative results were for a two-MTW warfight. It reflected the target set and defenses in those two scenarios. Weapons not favored in those scenarios may do well in others. For example, TLAMs have become the weapon of choice in several recent limited responses, and medium-range standoff weapons may do well in scenarios with fewer long-range SAM threats. In summary, other factors may lead the decision-maker to not precisely follow these recommendations of the study.

Data Developed by Committees Takes Longer and Can Generate Suspicion. Service one-upmanship sometimes led to overly optimistic data (e.g., sortie rates). At the same time, operators of current systems sometimes had difficulty developing tactics for future weapons. As a result, there may have been too much reliance on the last war to inform the way future conflicts will be conducted. Desert Storm experiences sometimes resulted in ground rules/assumptions that might not be robust against a differently equipped enemy fighting a different battle. New capabilities may be most effective with new tactics that have yet to be tested on the battlefield. However, operators are reluctant to accept these new tactics until after operational testing has occurred and demonstrated the superiority of these tactics. To ease the data burden, future joint studies could start with a JS or OSD defined data set that the Services could then challenge with appropriate supporting rationale.

A Collaborative Analytical Process Is Slow. Each Service developed its own data inputs and then checked the inputs of the other Services. Once this cycle was complete, the Services adjusted their data to reflect other Service comments and their own insights to ensure the analytic teams had a balanced and consistent starting point. Then, when results did not reflect preconceived notions, the participants adjusted data again to ensure the appropriate features were captured in a fair war. All this "data coordination" takes time. Sometimes bad ideas were unnecessarily tested, and good ideas often took several iterations to convince all levels of oversight in their viability. Even then, not all participants agreed to all the results of the study. Perhaps a benevolent study dictator could shorten the timeline.

Finally, some concluding thoughts on the DAWMS process that were presented to selected members of the DSB during their review:

Don't Expect Too Much. DAWMS will not (and should not) provide "the answer." It will not provide the number of each weapon system needed in the force. On the other hand, it should provide useful insight about which weapon features would contribute the most in what conditions.

But Don't Expect Too Little. DAWMS should help frame the debate—help the decision-maker ask the smart questions. It should also provide new insights—some of which may be significant departures from the present plan. These new insights will and should be challenged and must stand the test of logic.

Operational Realism Is Crucial But, we must *not* base our analysis on a dumb enemy. If the enemy gets smarter, we could then lose. Also, we must take advantage of U.S. operational and technical advantages using the technology available in 2006 together with appropriate tactics.

Models do not provide answers: analysts do. The DAWMS models could be improved, but if smartly used can provide the insights needed. Significantly better models do not exist. It is the data, not the models, that drive the results. Smart use of data can often overcome apparent model limitations.

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APPENDIX A

QUESTIONS

Appendix A
QUESTIONS

1. Does an elaborate management structure such as that used in DAWMS encumber a study? What are the advantages and disadvantages?
2. Was the IDA quick look and the review of existing studies useful? Did the review of studies take too much time, i.e., delay, the study too much? Was it useful in helping the analyst and decision-maker communicate with each other (so that the analyst knows what the decision-maker wants and the decision-maker has a better understanding of what the analyst can do)?
3. How important is "operational realism" in a study? Did the three-stage process described in the methodology achieve its desired effect?
4. What was the ultimate product of the study? Should the numerical results be used for budgeting?
5. Could the rapidly changing assumptions and inputs have been avoided? If so, how? If not, why not?
6. Some have said that an important by-product of DAWMS was the insights the analysts and Service decision-makers gleaned from understanding more about each others' weapon systems. For example, prior to the study few outside the Army felt that Army helicopters and weapons could be useful in the deep attack mission. What additional useful products beyond the final study recommendations did this study provide?
7. In the study the weapons budget included all planned procurements from 1997 to 2006. This budget could be used by any weapon type (and hence, Service) in the WORRM optimization algorithm. Considerable controversy ensued when the WORRM results suggested that weapons budget be reallocated among the Services. As an alternative to this approach the optimization model could have been provided three individual Service weapon budgets (Department of the Navy

buys munitions for the Marines). Then the optimization results may suggest a realignment of the weapon programs within a Service but would not suggest a reallocation among the Services. Is this separate Service weapon budget approach useful? Should it have been part of DAWMS?

8. There were many alternative Linear Programming (LP) formulations considered during the study. For example, one alternative added platform attrition costs to the objective function and dropped the aircraft attrition constraints. It was discarded due to the resulting uneven use of aircraft and resulting attrition. Can you identify other LP formulations that could provide useful insights?

9. What were the contributions made by DAWMS? Which ones do you feel were most important? Was the study worth the time and expenditures involved?

10. During the study there were numerous attempts to "game" the results. This occurs when one participant (often a Service) specifies inputs that it anticipates will put its programs in a favorable light. As a result, some members of the study team suggested that we get all of the Services to agree on the inputs, run the WORRM model and then treat the results as "final." Is this a reasonable approach to analysis?

APPENDIX B

GLOSSARY

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GLOSSARY

A/C	Aircraft
AAA	Anti-Aircraft Artillery
ABL	Airborne Laser
ACMC	Assistant Commandant of the Marine Corps
AFSAA	Air Force Studies and Analyses Agency
AGM	Air-to-Ground Missile
APAM	Antipersonnel/antimaterial
APC	Armored Personnel Carrier
ASD (C3I)	Assistant Secretary of Defense for Command, Control, Communications, and Intelligence
ASD (S&R)	Assistant Secretary of Defense for Strategy and Requirements
ATACMS	Army Tactical Missile System
BAT	Brilliant Anti-Tank Weapon
BDA	Battle Damage Assessment
BUR	Bottom Up Review
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CALCM	Conventional Air Launched Cruise Missile
CBU	Cluster Bomb Unit
CEB	Combined Effects Bomblet
CEM	Combined Effects Munition
CEP	Circular Error Probable
CFAM	Combat Forces Assessment Model
CINC	Commander in Chief
CNA	Center for Naval Analyses
COEA	Cost and Operational Effectiveness Analysis

CONOPS	Concept of Operation
CONUS	Continental United States
CORM	Commission on Roles and Missions
CTEM	Conventional Targeting Effectiveness Model
D (PA&E)	Director Program Analysis and Evaluation
D (S&TS)	Director Strategic and Tactical Systems
D J-8	Director for Force Structure Resources and Assessment (Joint Staff-8)
DAWMS	Deep Attack Weapons Mix Study
DIA	Defense Intelligence Agency
DoD	Department of Defense
DSB	Defense Science Board
ECM	Electronic Countermeasures
EKS	Expected Kills per Sortie
FEBA	Forward Edge of Battle
FLOT	Forward Line of Troops
GBU	Guided Bomb Unit
GCI	Ground Controlled Intercept
GPS	Global Positioning System
HBFS	Heavy Bomber Force Study
IDA	Institute for Defense Analyses
IFV	Infantry Fighting Vehicle
INS	Inertial Navigation System
JASSM	Joint Air-to-Surface Standoff Missile
JCA	Joint Collaborative Analysis
JDAM	Joint Direct Attack Munitions
JROC	Joint Requirements Oversight Council

JS	Joint Staff
JSEAD	Joint Suppression of Enemy Air Defense
JSOW	Joint Standoff Weapon
LGB	Laser-Guided Bomb
LMI	Logistics Management Institute
LOCAAS	Low Cost Autonomous Attack System
LP	Linear Program
MLRS	Multiple Launch Rocket System
MRC	Major Regional Contingency
MTW	Major Theater of War
NAWC-WD	Naval Air Warfare Center—Weapons Division
NCAA	Non-Nuclear Consumables Annual Analysis
NEA	Northeast Asia
NNOR	Non-Nuclear Ordnance Requirements
O&M	Operations and Maintenance
O&S	Operational and Support
OSD	Office of the Secretary of Defense
PD	Probability of Damage
PGM	Precision-Guided Munition
POL	Petroleum, Oil, Lubricants
RDT&E	Research, Development, Test, and Evaluation
ROK	Republic of Korea
SAG	Senior Advisory Group
SAM	Surface-to-Air Missile
SEAD	Suppression of Enemy Air Defenses
SFW	Sensor-Fuzed Weapon

SLAM-ER	Standoff Land Attack Missile-Enhanced Response
SPG	Self-Propelled Gun
SSM	Surface-to-Surface Missile
SWA	Southwest Asia
TACWAR	Tactical Warfare Model
TLAM	Tomahawk Land Attack Missile
TNF	Target Not Found
TOW	Tube-Launched, Optically Tracked, Wire-Guided Missile
UG	Underground
USD (A&T)	Under Secretary of Defense for Acquisition and Technology
V&V	Verified and Validated
VCJCS	Vice Chairman Joint Chiefs of Staff
VCNO	Vice Chief of Naval Operations
VCSA	Vice Chief of Staff Army
VCSAF	Vice Chief of Staff Air Force
WCMD	Wind Corrected Munition Dispenser
WORRM	Weapon Optimization and Resource Requirements Model

APPENDIX C

LIST OF FIGURES AND TABLES

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14. ABSTRACT

This report is part of a series of papers written to describe influential studies completed by the Institute for Defense Analyses (IDA) that may prove useful to others who must either conduct analyses or review analyses that support major decisions. More specifically, these papers can be used to either help train the junior analyst or educate a senior decisionmaker on how best to use analysis.

This report describes the process used to conduct the Deep Attack Weapons Mix Study (DAWMS) in 1995-1997. This case study focuses on the weapons being procured by the Services and whether a joint viewpoint would result in a more effective mix. This controversial study included all four Services, OSD, and the Joint Staff. It describes the events leading to the study, the analytical approach taken, the study participants, critical points in the analyses, study critiques and contributions, and lessons learned.

15. SUBJECT TERMS

DAWMS, WORRM, C4ISR, weapon mix, target values, weapon effectiveness, JROC, JDAM, JSOW, LGBs, GPS, TLAM, Hellfire, sensor-fuzed weapon, TACWAR, B-1B, F-15E, F/A-18, attrition, SAM, BDA

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