



FINAL TECHNICAL REPORT

**THEATER LEVEL EFFECTIVENESS ANALYSIS FOR
ADVANCED MATERIALS AND STRUCTURES**

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ABSTRACT

This is our final technical report, the purpose of which is to demonstrate our ability to estimate and compare the contributions of advanced materials and structures to effectiveness, at the theater level.

A Middle East scenario in the 2000-2010 timeframe was chosen for this demonstration. A notional advanced fighter was used for the example. Two advanced materials were selected for comparison - a conventional polymer-based composite for the aircraft skin which provides weight savings, and a high temperature ceramic for the engine hot section which allows increases in engine turbine inlet temperature. We also provided results for increased tank survivability, to demonstrate the flexibility of the model in assessing a range of weapons system.

By varying these characteristics against the base case, a set of parametric curves were developed which plot change in effectiveness vs. change in characteristic. By using these curves, the change in campaign effectiveness produced by each of the three materials was determined. A break even cost vs. change in material curve was then produced to enable estimates to be made of when a development program of stated risk should be undertaken compared to simply buying more aircraft of the stated characteristics.

In addition to this report, we are delivering the parametric curves developed for this demonstration on magnetic media. These will permit users at DARPA to see how easy it is to have effectiveness information available to them for the purpose of comparing the impact of various advanced materials and structures on campaign effectiveness.

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FINAL TECHNICAL REPORT

**THEATER LEVEL EFFECTIVENESS
ANALYSIS FOR ADVANCED
MATERIALS AND STRUCTURES**

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Slide Title: The Bottom Lines

Text: In today's world of shrinking budgets and force reductions, it is necessary for military planners to find new tools to assist them in making development and procurement decisions for existing and new technology.

The key benefit provided by any combat system is its effectiveness in projected conflict scenarios. A comparison of the combat effectiveness of different elements on the battlefield can only be performed using a theater-level campaign model.

To address this need for theater-level campaign analyses, STR has developed the Force Planning Analysis Framework (FPAF). The FPAF consists of:

- 1) Optimal Marginal Evaluator III (OME III), which models the air portion of a campaign over time
- 2) The Ground Battle Model (GBM) which models the ground portion of a campaign over time
- 3) A set of projected conflict scenarios
- 4) An integer linear program which determines which mix of options maximizes effectiveness within cost and other constraints.

OME III and the GBM are unique in that they use game theory and dynamic programming to determine the best force employment strategy for both sides -- hence overcoming the flaw in past theater level effectiveness analyses.

THE BOTTOM LINES

We have developed a comprehensive process for estimating the contributions of advanced materials and structures to campaign effectiveness at the theater level

This process can be used for analysis of any weapon system in the conventional theater

The key to the analysis is STR's structured Force Planning Analysis Framework (FPAF). Consists of the Kent "Strategy to Task" construct, within which operate:

- **Optimum Marginal Evaluator III (OME III) model - the CRUCIAL ELEMENT**
- **Ground battle model**
- **A set of projected conflict scenarios**
- **Tools for decision analysis (data bases, effectiveness and cost parametrics, mixed integer linear program, etc.)**

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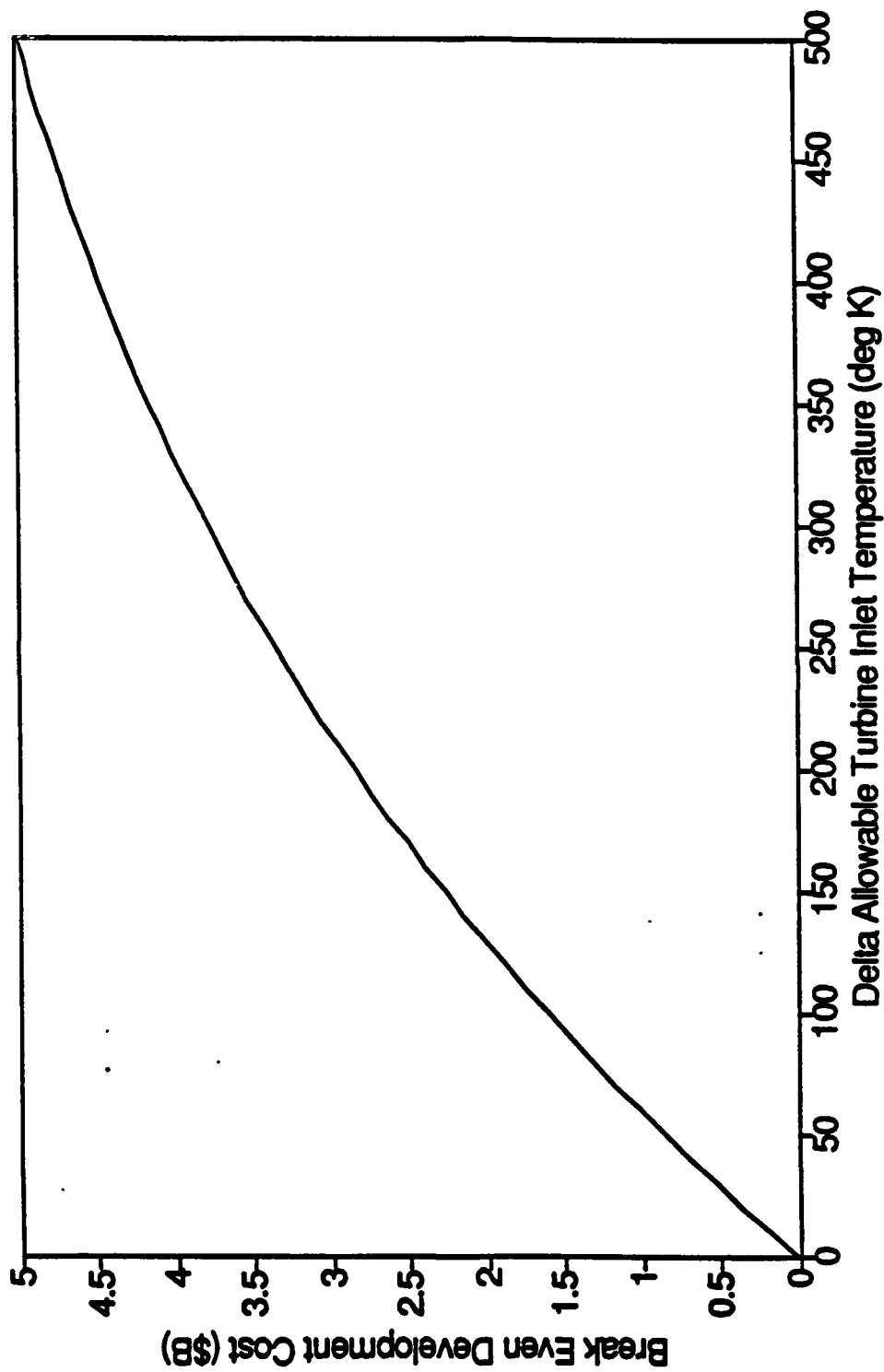
Slide Title: Break Even Development Cost vs Delta Allowable TIT

Text:

The goal of this effort is to demonstrate our ability to produce curves like this example, which shows the break even development cost required for materials which will allow the engine turbine inlet temperature of a new advanced fighter to be increased by various amounts. This information would be useful to someone trying to determine if an effort is worth funding.

We will now step through the process required to develop curves such as this.

Break Even Development Cost vs Delta Allowable TIT
Compared to More Aircraft Using Typical Life Cycle Cost



STR

Slide Title: Outline - Introduction

Text: The introduction will summarize the purpose of the analysis, with a brief description of the methodology. We will then step through each phase of performing the analysis, starting with the development of the base case, through the sensitivity analyses on advanced materials.

OUTLINE



Introduction

Scenario

Campaign Level Analysis

Engagement Level Analysis

Engineering Level Analysis

Campaign Outcomes vs. New Materials

STR

Slide Title: Analysis

Text: The purpose of this Phase I SBIR is to demonstrate our ability to estimate and compare the contributions of advanced materials and structures to campaign effectiveness, at the theater level.

We will use OME III and the Ground Battle Model to perform the analysis.

For demonstration purposes, and to keep the data unclassified, we will use a notional advanced fighter, which we postulate to have 25% more range than the F-16, the same payload capacity as an F-16, and is one-fourth of the way between an F-16 and an F-22 in air-to-air capability.

In order to demonstrate an example of other potential uses for the model, we are also going to do an out-of-scope excursion using changes in tank vulnerability.

ANALYSIS

- We will demonstrate the ability to perform effectiveness analyses on new materials and structures by assessing their impact on the probability of achieving campaign objectives at the theater level
 - .. OME III and the Ground Battle Model will be used to perform the theater level effectiveness analysis
 - .. A notional advanced fighter provides the example for the demonstration
 - .. We will also provide results for improved survivability of a tank, to demonstrate the flexibility of the model

Slide Title: How Advanced Materials Affect Campaign Outcomes

Text: The use of advanced materials in a weapons system can have a measurable effect on the lethality and/or survivability of that system in a battle. When a change in the characteristics of the system is applied to hundreds of vehicles or weapons in the theater, they can have an impact on the overall outcome of the campaign as more Blue forces survive or more Red forces are killed.

HOW ADVANCED MATERIALS AFFECT CAMPAIGN OUTCOMES

Advanced materials can impact the outcome of a campaign by affecting the characteristics of the weapon system or vehicle.

For example:

- Weight of an airplane**
- Survivability of a tank**
- Pk of a missile**
- etc.**

These changes are multiplied by all of the affected weapon systems in the theater, resulting in a measurable effect on the campaign outcome

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Slide Title: Effectiveness Evaluation Process

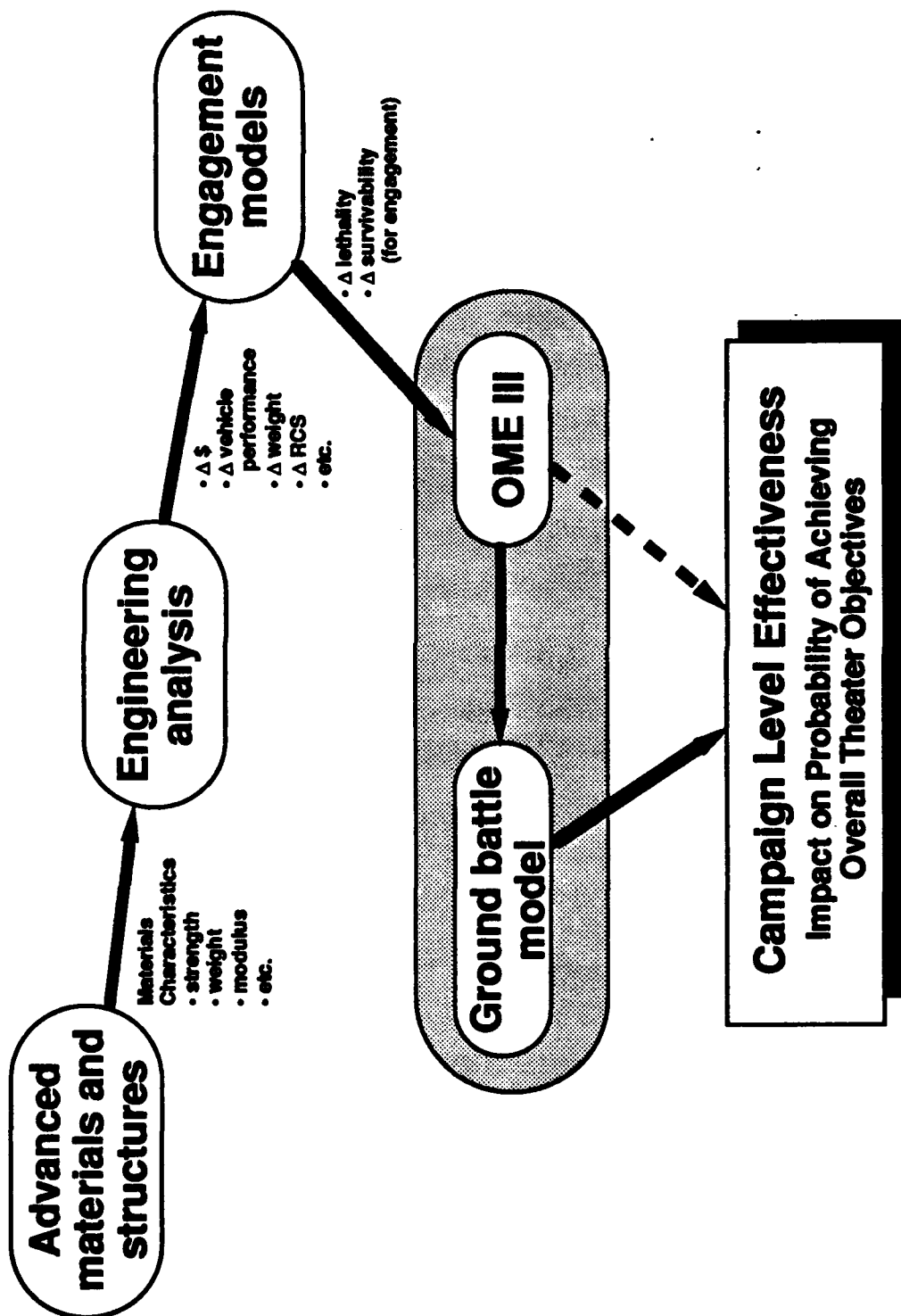
Text: Our methodology spans the engineering level through engagement and mission levels, to campaign outcomes.

The characteristics of the advanced materials are examined to determine how they differ from the baseline materials. The engineering analysis involves determining where and how the new materials will be used, and what impact they have on the performance, weight, etc., of the system.

The changes from the baseline determined in the engineering analysis are then used in engagement models. Most effectiveness analyses stop at this level, with the changes in lethality and survivability serving as the measures of effectiveness.

OME III and the GBM use Δ lethality and Δ survivability as inputs. As a theater-level model, the interaction of all air and ground forces are considered, not just the 1-v-1 type of engagement level interactions. Both models use game theory and dynamic programming to determine the best allocation of forces for both sides. The resulting measure of effectiveness is the probability of achieving overall campaign objectives.

EFFECTIVENESS EVALUATION PROCESS

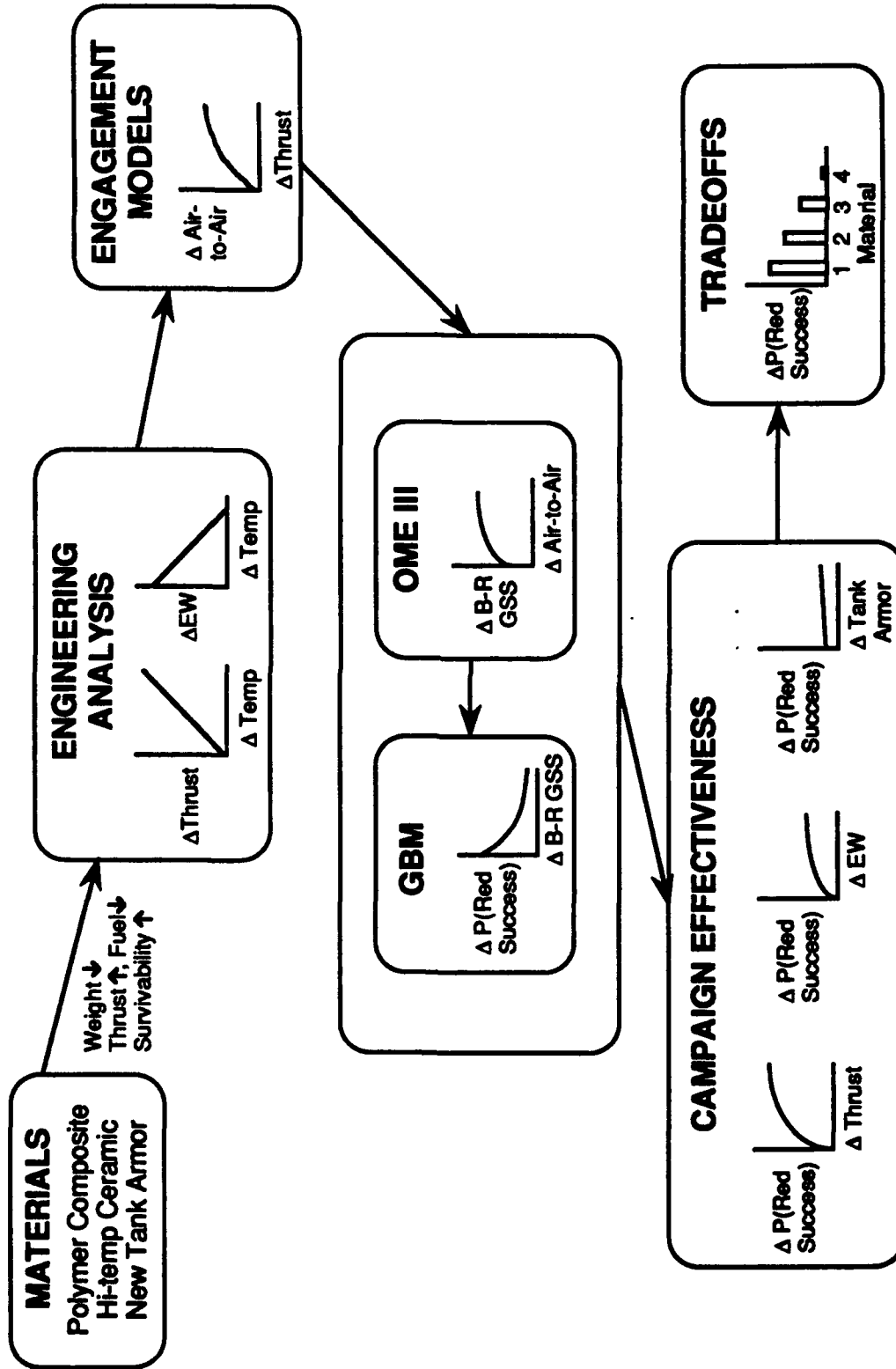


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Slide Title: Evaluation of New Materials

Text: This slide summarizes the steps of our analysis, and the types of figures we will be using.

EVALUATION OF NEW MATERIALS



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Slide Title: Analysis Outputs

Text: There are three types of outputs which can be provided.

- Parametric effectiveness curves showing changes in combat system performance characteristics vs. campaign effectiveness
- Graphs which describe the overall battle dynamics as a function of time, material, etc.
- When desired, a selected subset of options from within a set which maximize effectiveness within the desired constraints (such as manpower, money, etc.)

ANALYSIS OUTPUTS

- Theater level parametric effectiveness curves for those aircraft performance characteristics which are affected by the selected advanced materials
- Descriptive statistics (drawdowns, Blue and Red sorties flown by mission, ground battle kill losses, battle movement, etc.) sufficient to understand battle dynamics (with and without advanced materials)
- Set of options which maximize effectiveness within variable cost and other constraints

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Slide Title: Where We Are - Scenario

Text:

The first element of the FPAF is the scenario. A scenario consists of the campaign objectives for both sides, force compositions, munitions, and C3I. The scenarios we are currently using in our campaign analyses are similar to scenarios we are using on other projects for the Air Force.

WHERE WE ARE

Introduction



Scenario

Campaign Level Analysis

Engagement Level Analysis

Engineering Level Analysis

Campaign Outcomes vs. New Materials

STR

Slide Title: General Comments on Scenarios

Text: Five general comments, should be kept in mind while reviewing the scenario to be presented:

1. The future is in no way predictable.
2. This scenario is in no way a prediction of actual conflict or of the political crises which would precede a conflict.
3. Our planning scenarios must align with the national strategy in ensuring that our armed forces are structured to respond promptly and win unpredictable conflict situations.
4. Our force planning scenarios should, then, consider a full range of plausible situations in which our interests and our military capabilities are challenged.
5. Again, the scenario which is addressed in this briefing is predictive neither of a situation likely to lead to armed conflict nor of specific forces involved. It is illustrative of a plausible opponent, against whom our military capabilities must be able to succeed.

GENERAL COMMENTS ON SCENARIOS

- Very few wars are predictable 10 to 20 years (or even 6 months) in advance.
- Several powers with significant military capability and potential have world interests which potentially conflict with ours.
- Prudence dictates (and the National Security Strategy demands) that we plan our armed forces "to win quickly, decisively, and with few casualties" (National Security Strategy of the United States, The White House, March 1990) in such unpredictable conflict situations as may arise.
- Our planning should take into account the plausible range in military strength and capabilities of our potential opponents, as well as the potential conflict in our interests.
- The following scenario is therefore not to be taken as predictive regarding either the political situations leading to potential conflict, or of the specific military forces involved. Rather, it should be considered illustrative of a plausible opponent, geography, and military capabilities with which we must be able "to win quickly, decisively, and with few casualties."

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Slide Title: Scenario: Iran Invasion of Persian Gulf Region

Text: The scenario is set in the Middle East, where Iran and a Saudi Arabian coalition are protagonists. In this scenario, Iran invades the Persian Gulf region.

This briefing covers the significant features of the regional geography; the objectives of Iran, the coalition forces, and the United States; the campaign concept for both sides; some ground rules to define the nature of the conflict; and the forces arrayed in the theater.

We will show the regional force comparison of significant ground, artillery, and air units; detailed counts of opposing fighter assets; and the baseline fighter force.

SCENARIO: IRAN INVASION OF PERSIAN GULF REGION

- **Geography**
- **Objectives**
- **General Campaign Concept**
- **Ground Rules**
- **Force Comparisons**

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Slide Title: Geography - Theater Of Operations

Text: The geographical scale of this scenario is impressive, particularly considering the relatively small number of forces involved.

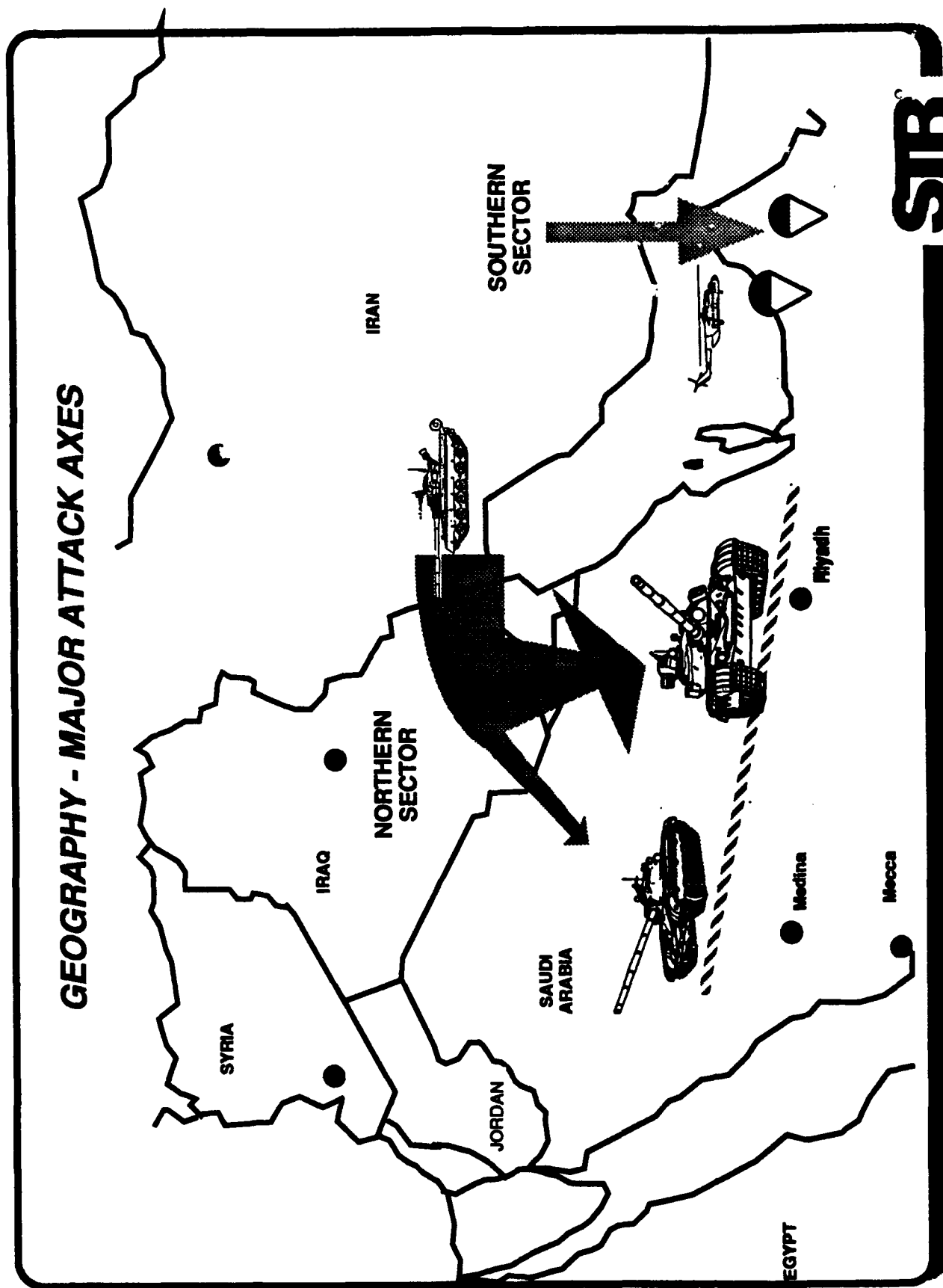
The population of the Arabian Gulf states is low in contrast to Iran.

Iran aligns its attack in two sectors. In the North, the main force sweeps around Kuwait, through southeast Iraq across the neutral zone, on a line toward Riyadh. A smaller force initially sweeps toward Medina to give credence to the holy war deception, but quickly aligns with the larger force to push the battle area down the Arabian peninsula.

Airborne troops seize key lines of communication within the UAE and Oman and engage forces of the two states, as well as some Saudi forces. This action pins down coalition forces which would otherwise impede the main attack.

Control of the Straits of Hormuz and UAE ports would effectively prevent major US reinforcements from entering on the flanks of the main Iranian attack axis.

GEOGRAPHY - MAJOR ATTACK AXES



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Slide Title: Objectives

Text: Iran declares a jihad, but is actually motivated by territorial expansion goals.

The coalition forces cannot, on their own, prevent the invasion, but will try to slow or halt the Iranian advance until reinforcements can be brought into the area within 20 days.

The U.S. Assists the coalition and guarantees the security of POMCUS stores in Saudi Arabia.

OBJECTIVES

Iran

- **Declared:** Place the holy centers of Mecca and Medina in the hands of true believers
- **Actual:** Seize control of the Persian Gulf areas including Riyadh, Dahrn, and Al Jubayl

Coalition Forces

- Slow or stop the invasion until reinforcements arrive (20 day criterion)

United States

- Assist Coalition Forces in attaining their objective
- Assure security of POMCUS stores

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Slide Title: General Campaign Concept

Text: Iranian forces plan to advance quickly through southern Iraq in a blitzkrieg movement to seize the oil fields of the Persian Gulf. They also move to control the Straits of Hormuz.

The allied coalition must ensure that the available forces can slow or halt the enemy advance until reinforced at about 20 days. Two methods are used:

1. A force oriented mobile defense comprises a series of hasty ambushes, followed by rapid disengagement, and air strikes on confused and disorganized enemy ground forces. It acts to slow and attrit the lead elements of the enemy advance.
2. Metering is the use of interdiction to attrit and delay the follow-on echelons from joining the battle in strength.

GENERAL CAMPAIGN CONCEPT

Iran

- Massive, swift invasion
- Forces echeloned -- provide great shock
- Seize Persian Gulf and its oil fields before the coalition can bring enough forces to bear to block Iran maneuver objectives

Allied Coalition

- Force Oriented Mobile Defense -- slow the advance of the Iranian Forces, delay, harass -- but give up territory to survive.
- Meter the quantity of heavy firepower (armor) arriving at the forward area in both sectors
- Sustain until reinforced -- (~20 day criterion)

STR

Slide Title: Overall Ground Rules

Text: This slide establishes the basic scenario ground rules (self explanatory)

OVERALL GROUND RULES

- 2010 timeframe
- 21 wing USAF force available
- Nuclear weapons are not used by either side but nuclear capabilities will be subject to targeting
- High chemical and biological alert status but weapons not used
- Good, current information on ground force disposition and activities is assumed (availability of J-Stars and AWACS)
- Combat Coded Aircraft in Squadrons of 24 aircraft will be used

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Slide Title: MidEast Scenario Ground Rules

Text: A basic framework is required to ensure that force mix analyses are benchmarked to a set of consistent rules which govern the play. Shown are the basic rules.

Note that friendly naval surface forces are precluded initially from entering the Persian Gulf, and that U.S. reinforcements do not arrive for 20 days after the outbreak of hostilities.

MIDEAST SCENARIO GROUND RULES

- Iran has significantly modernized its air and ground forces
- Tanker support capability is available to Iran
- No Outside Arab intervention
- Two Naval Carrier Battle Groups available when hostilities begin
- Straits of Hormuz are closed by Iranian military activities in the UAE
- 250 Naval Cruise missiles available and used by U.S. Forces
- European member forces arrive 20 days after start of conflict
- Saudi forces will be employed "2/3 up, 1/3 back"

STR

Slide Title: Fighter Assets In Mideast Scenario

Text: For the purpose of this effort, we will postulate that no USAF fighter aircraft are permanently based in the Middle East during peacetime, but the US is able to reinforce with 588 fighter A/C to the theater.

Notional Advanced Fighter aircraft account for nearly 32% of the total friendly fighter force.

We postulate that all Iranian fighter A/C are committed to the attack. While they initially enjoy about a 2:1 numerical advantage over the Saudi fighters, enough coalition fighters are ultimately added to outnumber Iranian fighters.

FIGHTER ASSETS IN MIDEAST SCENARIO

Allied		Total US		Total
In-Place	Reinforcements			Iranian
Adv. Ftr.		288	Flanker	105
F-22		84	Fulcrum	150
F-15E		72	M. 2000	60
F-117		48	Fencer	135
F/A-18 (Navy)		60	Flogger	180
F-14 (Navy)		36		
Tornado	70			
F-15C	120			
F-16	100			
F/A-18	24			
Subtotal	314	588		630
TOTAL		902		630

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Slide Title: Projected Regional Forces Comparison

Text: Saudi and coalition armored/mechanized forces are outnumbered by a ratio of about 5:1.

PROJECTED REGIONAL FORCES COMPARISON

	<u>Blue</u>	<u>Red</u>
Tanks	931	4,859
APCs	1,598	5,668
SpArty	324	2,790
T-Arty	126	954
Trucks	13,606	69,215
Personnel	87,276	428,706

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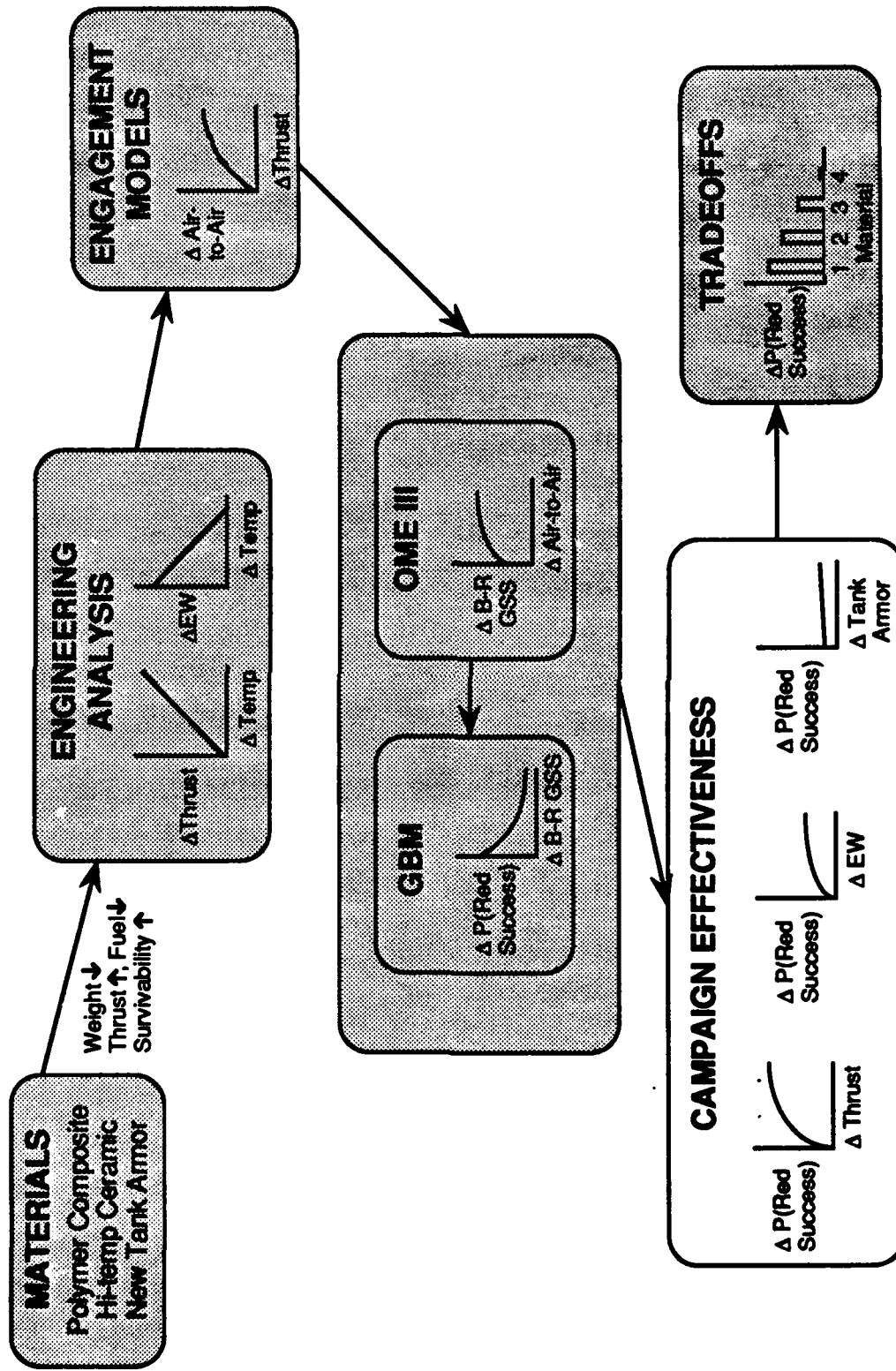
Slide Title: Where We Are - Campaign Level Analysis

Text: This section of the brief describes the concepts behind our methodology, and the OME III and GBM models.

The methodology and models are unique in that they are the only ones available to government and industry which fill the requirements of DODI 5000.2 and the Kent "Strategy to Task" framework for force planning analysis. The difficult requirement of these two prime directives is that the forces of both sides must be demonstrated to be used to best effect toward achieving conflicting objectives. This is an extremely difficult analytical challenge not met by other methodologies and models. OME III and the associated GBM employ sophisticated mathematical search algorithms to assure that these demanding requirements are met.

First, two slides on why this is so important.

EVALUATION OF NEW MATERIALS



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Slide Title: Air Battle Frame Of Reference

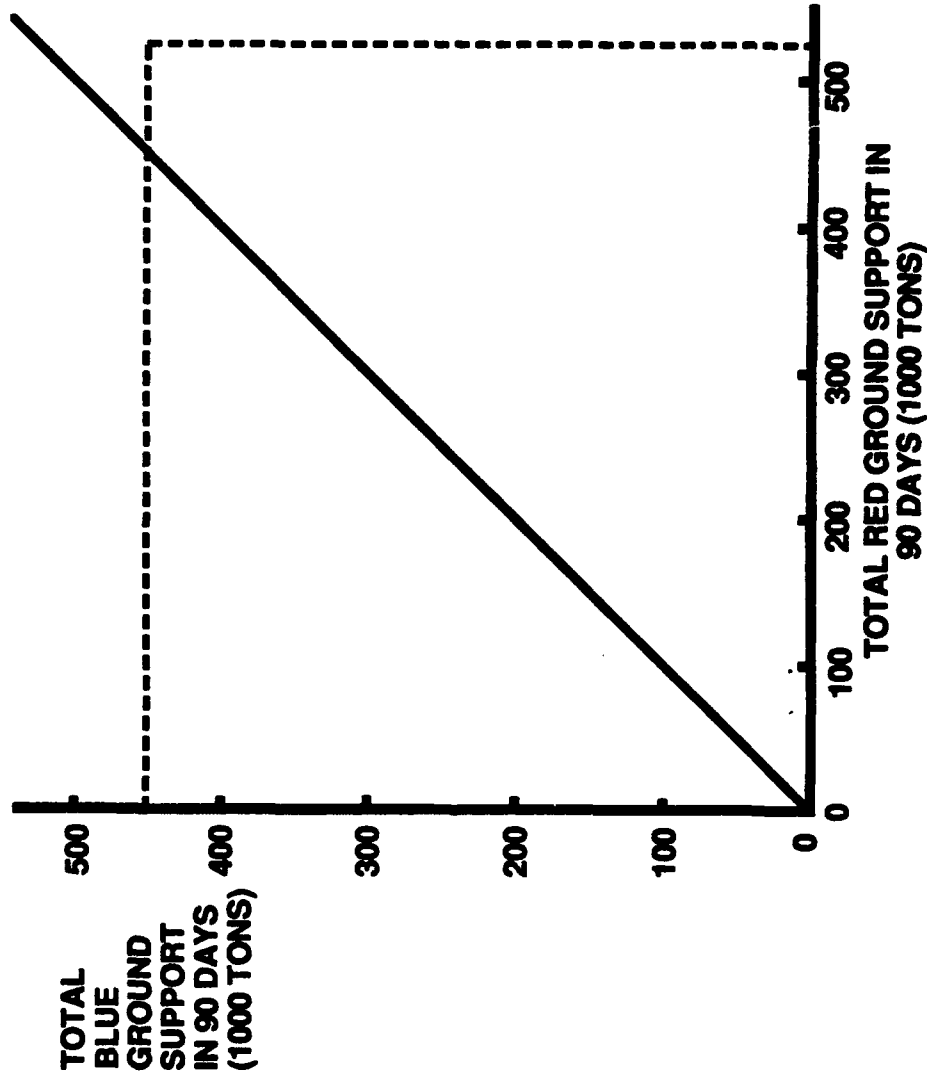
Text:

Force allocation strategy and tactics are used as inputs to most campaign analyses, rather than as an integral part of the analysis. The strategy is usually derived from the opinions of experts. However, this approach is notorious for producing inconsistent and conflicting results.

Consider an experiment run in the early 1970s. A small model was developed to determine the range in outcomes which could be expected due to differences in opinion among the experts in how the forces might be used.

The overall measure of merit was the amount of ground support that could be put at the disposal of the ground forces over a 90 day campaign -- Blue minus Red. Experts were polled for strategies for both Blue and Red, and each expert opinion was played against the opposing opinions in the campaign model. It was expected that the outputs would cluster in some small area of the feasible region.

AIR BATTLE FRAME OF REFERENCE



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Slide Title: Range of Expert Opinion

Text:

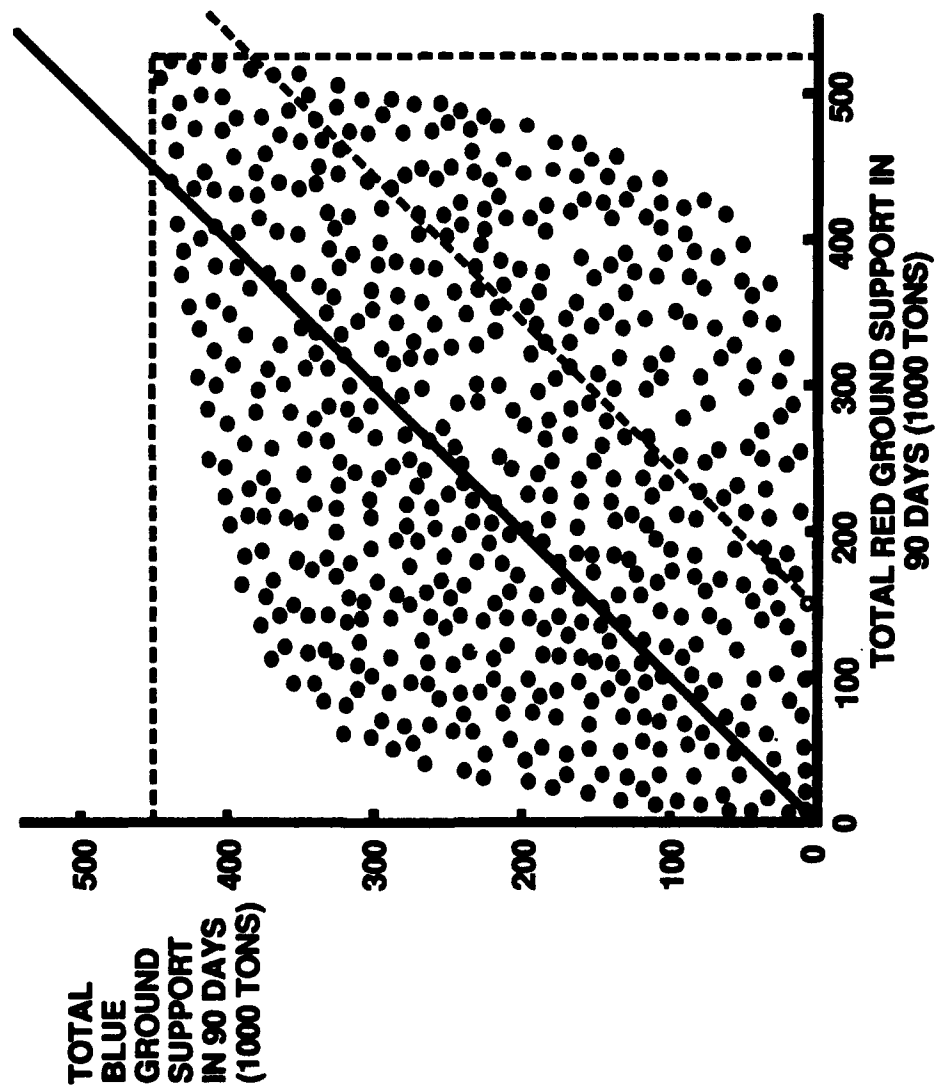
The results did not cluster in a small area on the chart. They filled almost the entire feasible region as depicted in the chart -- a disaster for analysis.

Application of OME III produces the result shown by the open circle on the chart. OME III employs sophisticated search algorithms, game theory, and dynamic programming to solve simultaneously for the best use of the forces by both sides over a campaign to achieve conflicting objectives.

This single solution has the characteristic that it is mutually enforceable. If Blue uses his forces as determined by the model through the campaign, he is assured of a solution which lies to the upper left side of the diagonal dashed line through the open circle. Conversely, if Red uses his forces as determined, he is assured of solution which lies to the lower right side of the line. Either side will do worse if he deviates from the solution and his opponent does not.

Such experiments as this can and have been repeated in many forms yielding similar startling results. It is the recognition of this very large variation in outcomes within the range of expert opinion (you can have any answer you like!) which has led to the demanding requirements of DODI 5000.2 and the "Strategy to Task" framework.

RANGE OF EXPERT OPINION



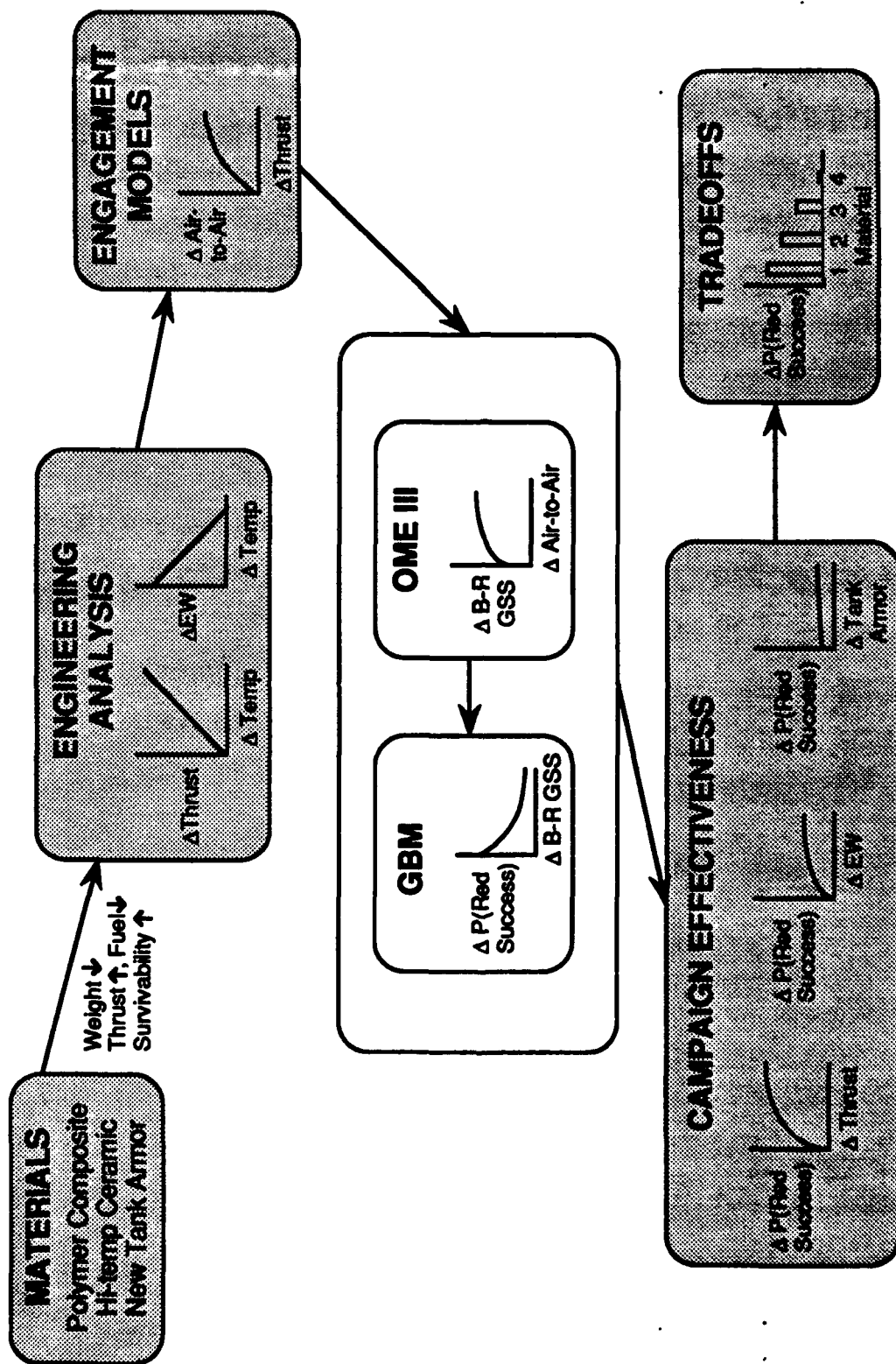
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Slide Title:

Text: The following slides describe OME III and the Ground Battle Model.



EVALUATION OF NEW MATERIALS



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Slide Title: OME III Structure

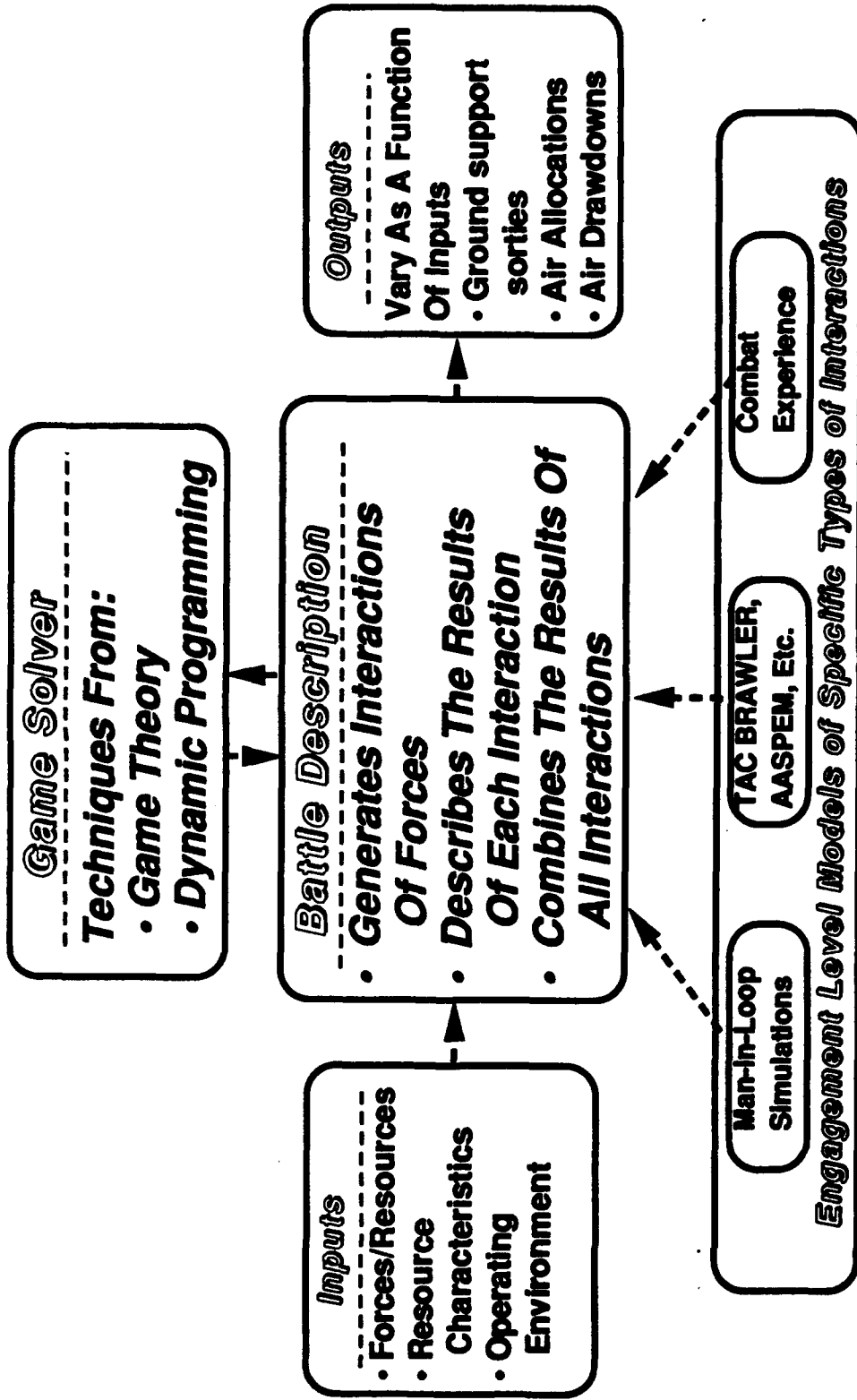
Text: OME III is a proprietary model developed by STR. Its use in USAF-related work has increased significantly in the last two years; in fact, the Commanders of TAC, SAC, and AFSC/ASD have directed its use in USAF analyses of B-2 and Multi-Role Fighter (MRF) combat effectiveness.

OME III is an analytical model, not a Monte-Carlo simulation. Since the best allocation of forces is determined by the model, it is insensitive to an analyst's views on force employment strategies. As a consequence, the results of OME III are consistent and repeatable.

OME III uses game theory and dynamic programming to determine the best use of air forces on both sides. Note that OME III uses air-to-air lethality and survivability data generated by engagement-level models such as TAC BRAWLER as inputs. Inputs to OME III include such factors as the number and type of aircraft in the theater, expected kills on various target types, terminal attritions, size of the theater, numbers of airfields, and surface-to-air missile (SAM) data. The data used in the base case analysis are provided in the backup slides.

The primary outputs of OME III are the daily ground support sortie schedule, net ground support sorties at the end of the campaign (Blue - Red), and force drawdowns during the course of the campaign. The daily ground support sortie schedule is then used as an input to the GBM.

OME III STRUCTURE



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Slide Title: Ground Battle Model

Text:

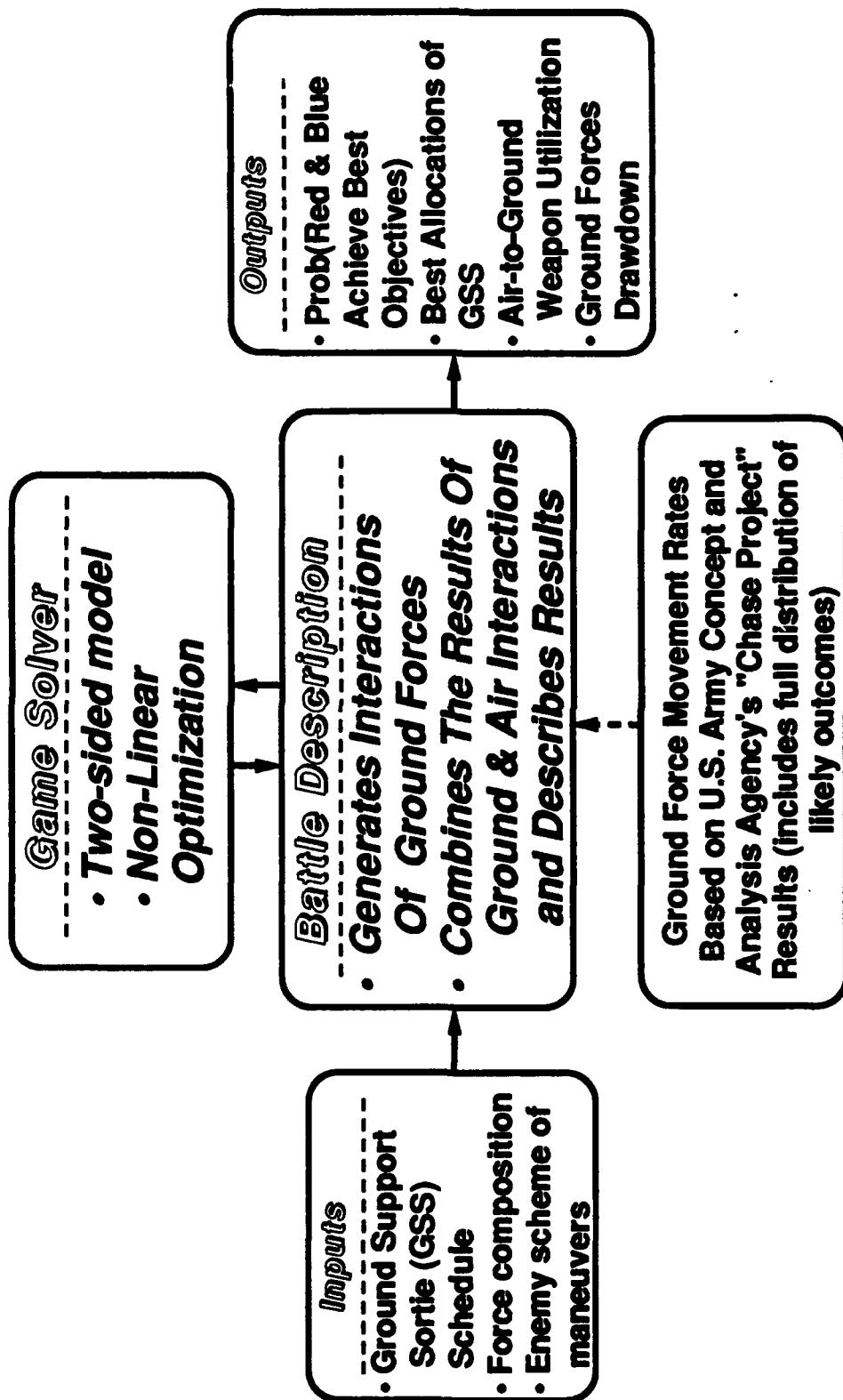
The GBM is also a proprietary model developed by STR. It is used in conjunction with OME III to model the ground portion of a campaign.

The GBM, like OME III, is an analytical model, which uses game theory and a non-linear search algorithm to determine the best use of ground support sorties against the opposing ground forces.

In addition to the daily ground support sortie schedule generated by OME III, other GBM inputs include the numbers of targets, expected kill against each type of target with various weapons, number of echelons and rates of movement, campaign objectives for both sides, and the Red attack plan. These inputs are provided in the backup slides.

The outputs of the GBM include the probability of enemy success in achieving his ground campaign objectives, forces killed, reconstituted and remaining by day during the campaign, by target type, drawdowns of the various targets types over time, and the probability distribution of the FLOT trace.

GROUND BATTLE MODEL



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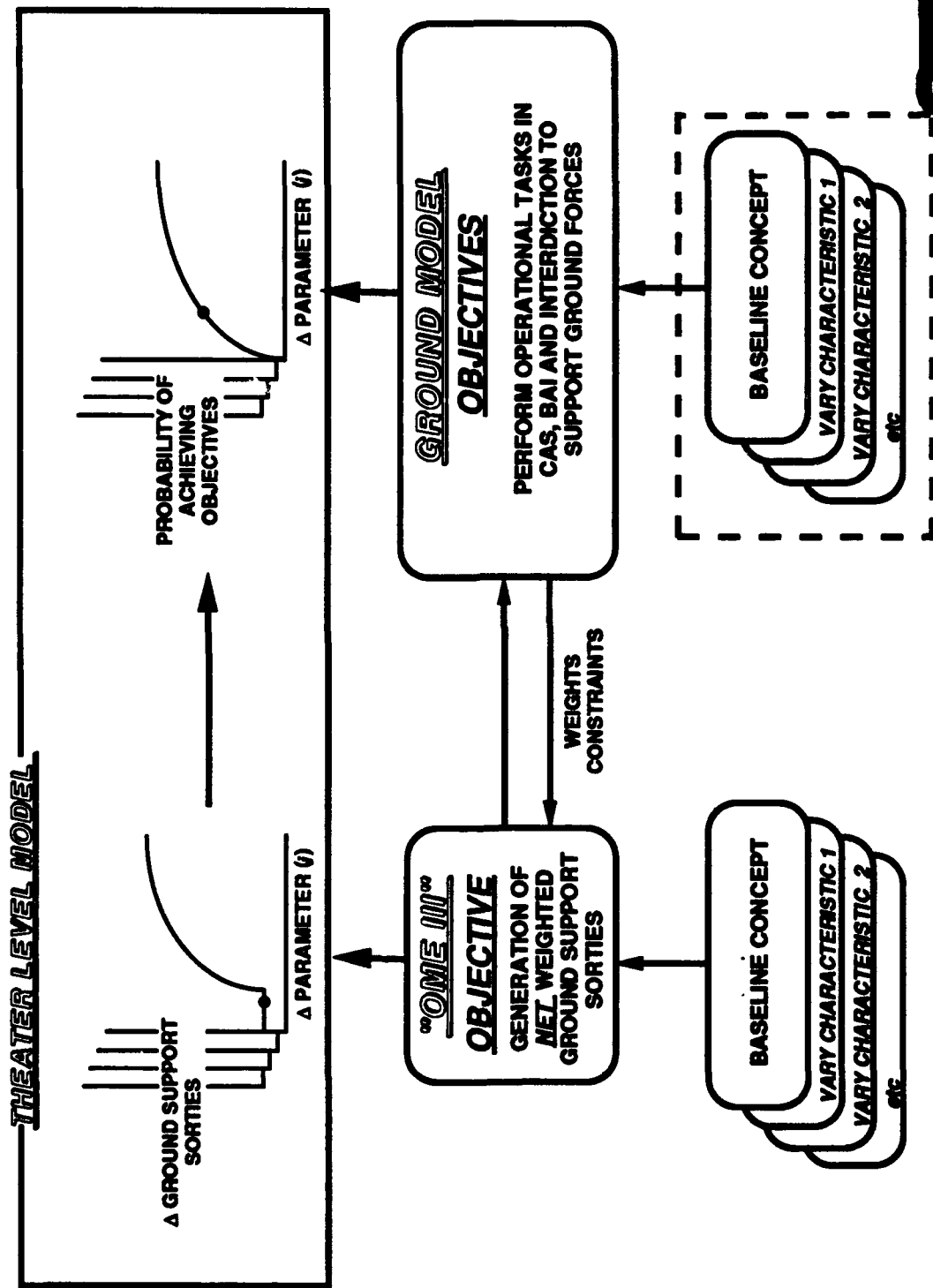
Slide Title: Development of Parametric Curves

Text:

If only changes in aircraft characteristics are being made, the net ground support sorties can be used as the measure of effectiveness for comparison. In general, however, the probability that the enemy achieves his stated objectives ($P(\text{enemy success})$) is used as the overall measure of effectiveness for the theater. This allows comparisons of disparate options, such as changes to aircraft, tanks or numbers of forces.

The models are run several times with the characteristics of interest varied each time. Parametric curves are then developed to represent changes in characteristic vs. effectiveness.

DEVELOPMENT OF PARAMETRIC CURVES



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Slide Title: Base Case Results

Text: This section of the brief contains the results for the base case run in the Middle East Scenario.

BASE CASE RESULTS

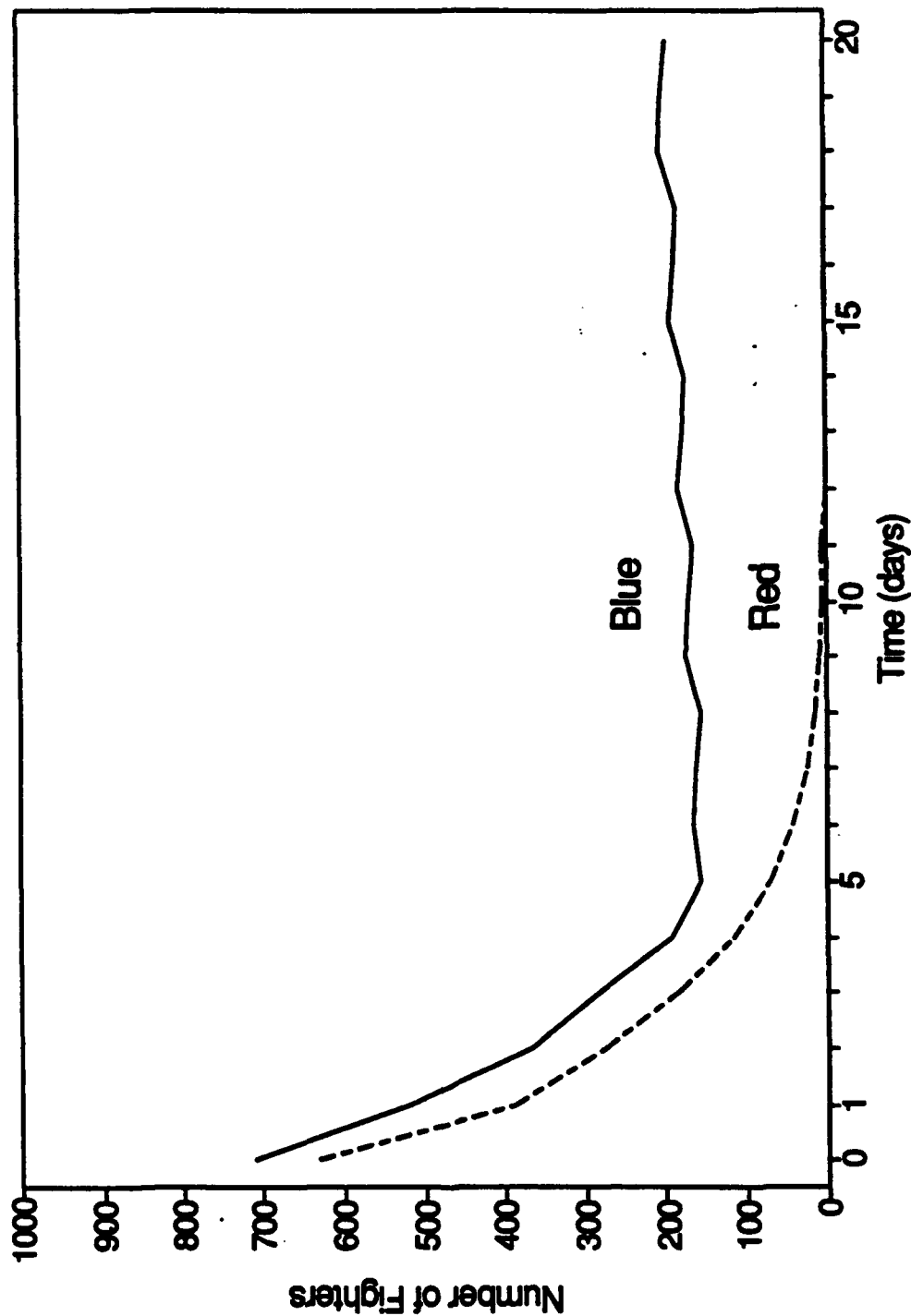
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Slide Title: Number of Fighters vs. Time

Text:

This graph shows the drawdowns of blue and red aircraft over time. The slight increase evident in the number of Blue aircraft is caused by the continuing arrival of Blue reinforcements later in the campaign. Once there are less than 100 Red aircraft left, Blue does not lose aircraft as rapidly.

Number of Fighters Vs Time
Mid-East -- Blue min GSS 100, Red min GSS 50 -- Base Case



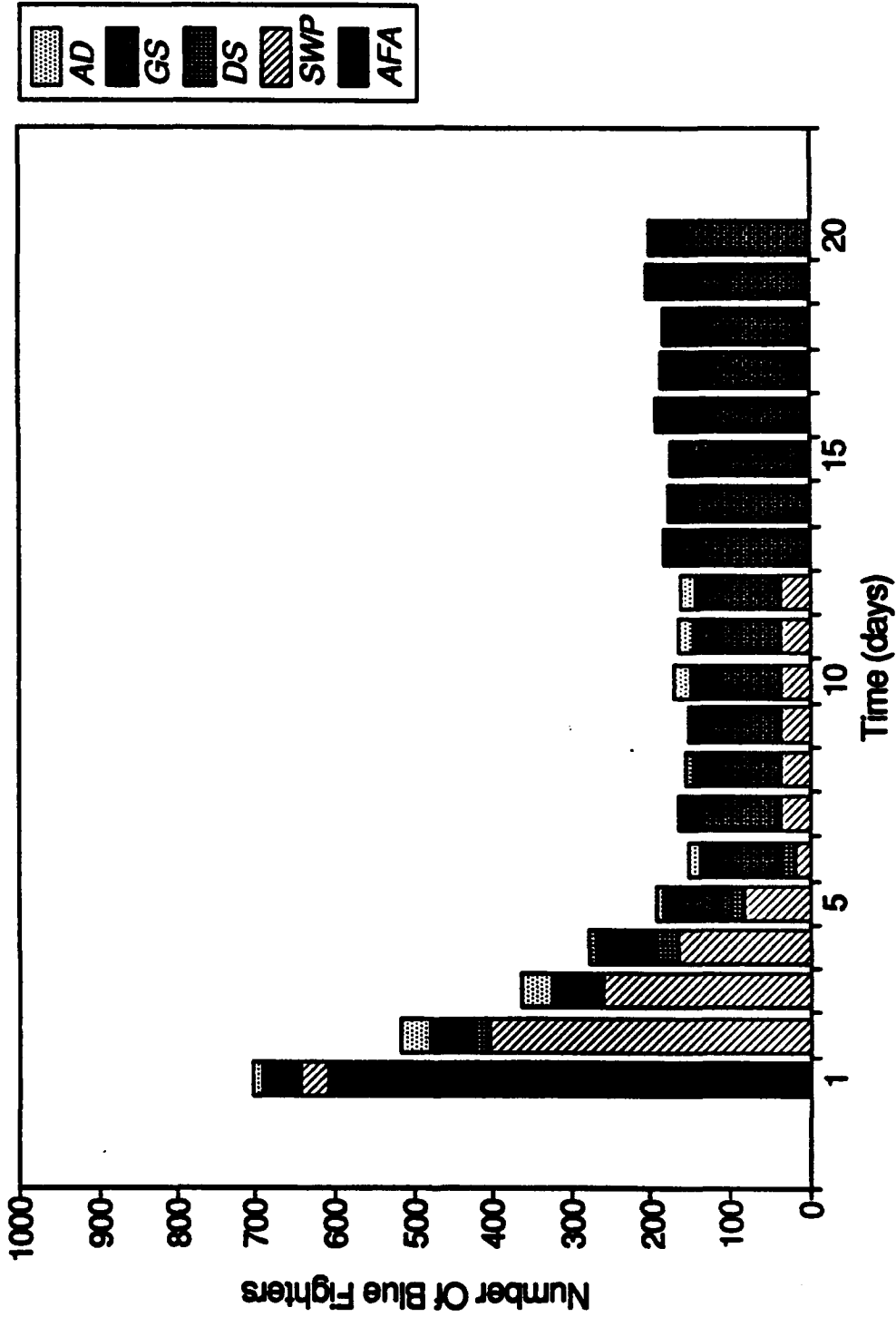
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Slide Title: Number of Blue Fighters vs. Time

Text: This slide shows the ground support sortie allocations for Blue aircraft on each day of the campaign. The minimum required ground support sorties per day for Blue aircraft is 100, for Red is 50. These values were determined through search algorithms in OME III.

The OME III methodology determines the best allocation of both blue and red fighter aircraft based on the characteristics of both forces.

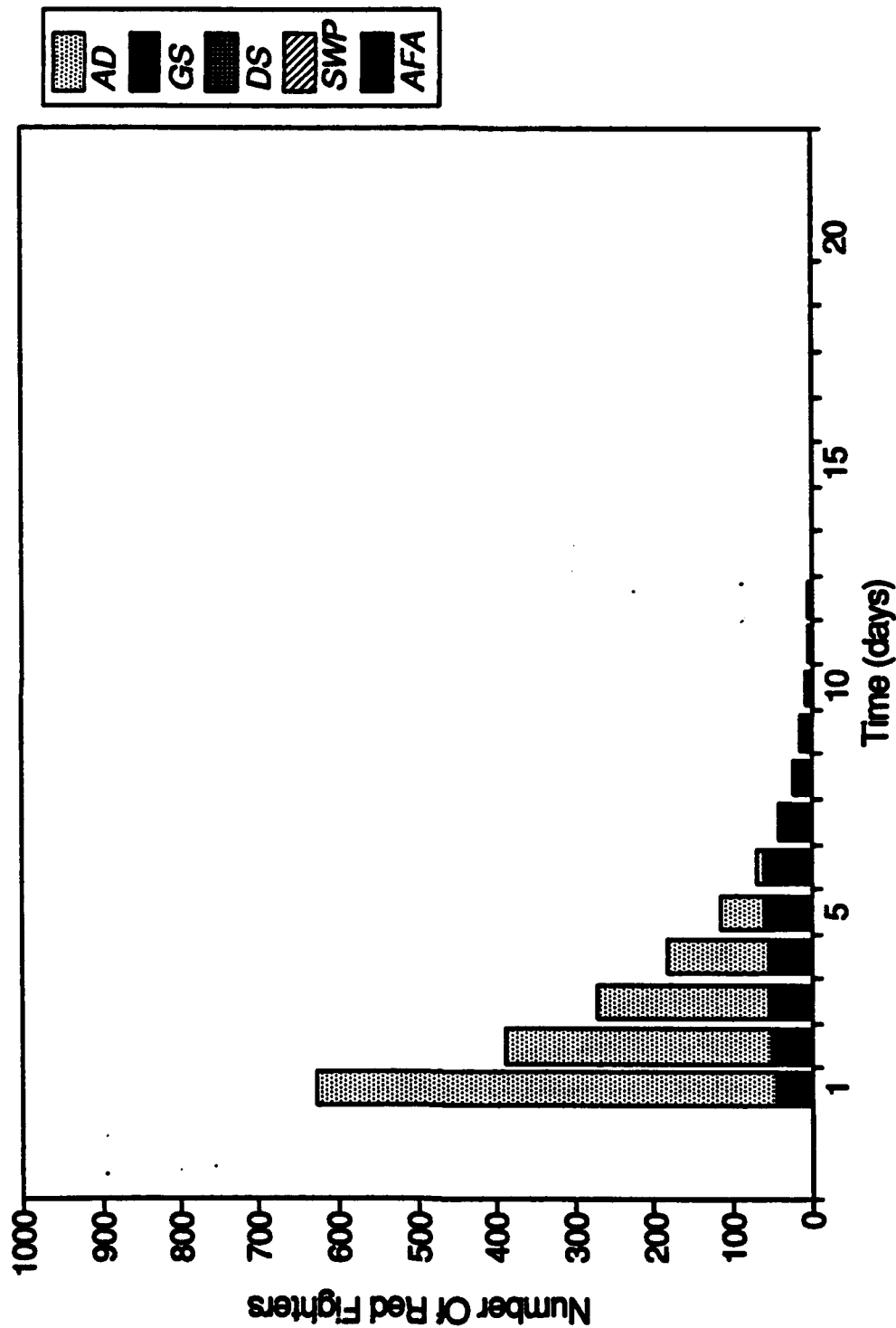
Number Of Blue Fighters Vs Time
 Mid-East -- Blue min GSS 100, Red min GSS 50 -- Base Case



Slide Title: Number of Red Fighters vs. Time

Text: This graph show the allocation of red fighter aircraft

Number Of Red Fighters Vs Time
Mid-East -- Blue min GSS 100, Red min GSS 50 -- Base Case



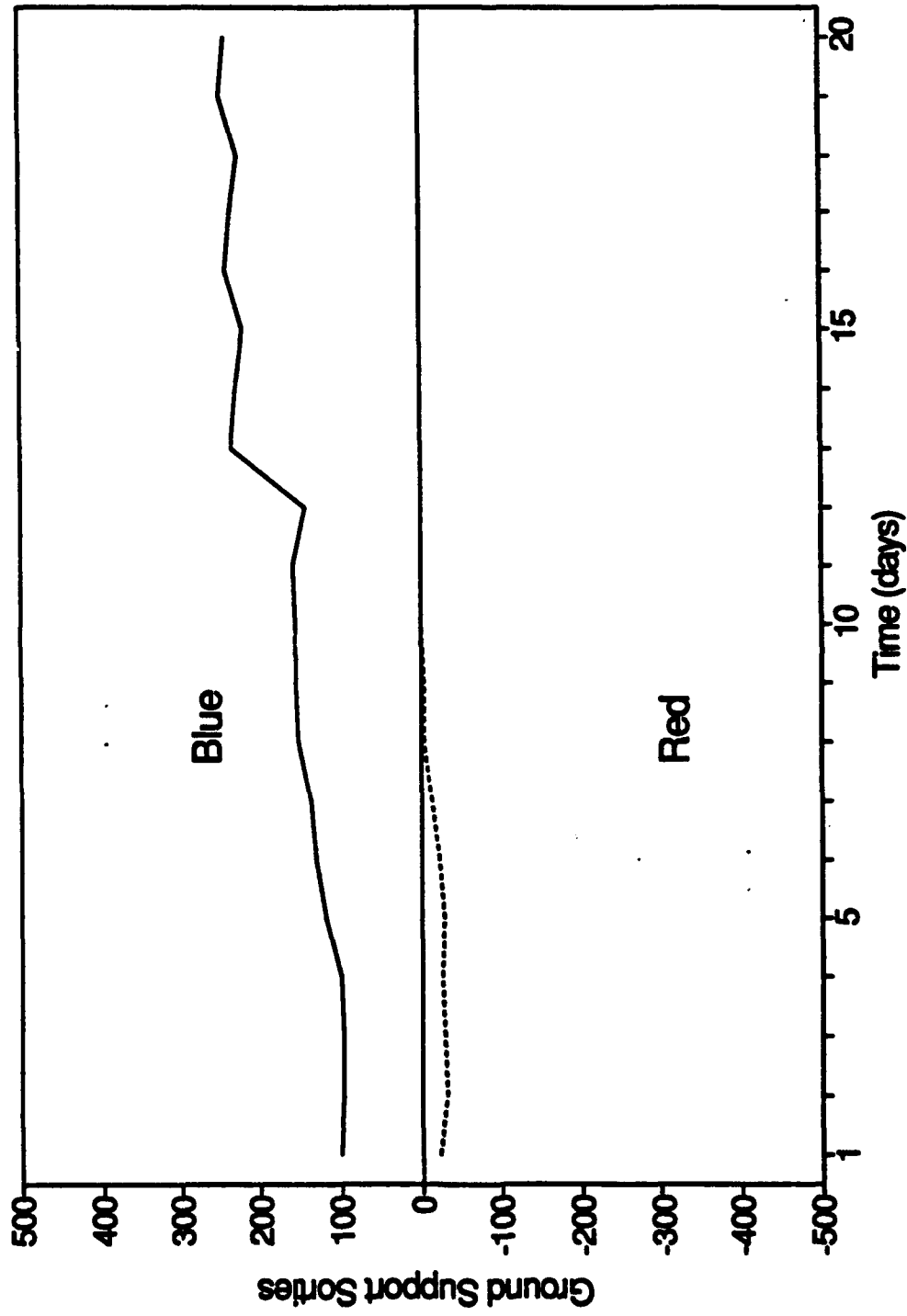
Slide Title: Ground Support Sorties vs. Time

Text:

For this base case, Blue is able to deliver at least 100 ground support sorties per day through about day 13, at which time he can commit all of his aircraft to support of the ground forces.

Red is unable to deliver the minimum desired 50 GSS per day, and loses all aircraft by day 12.

Ground Support Sorties Vs Time
Mid-East -- Blue min GSS 100, Red min GSS 50 -- Base Case



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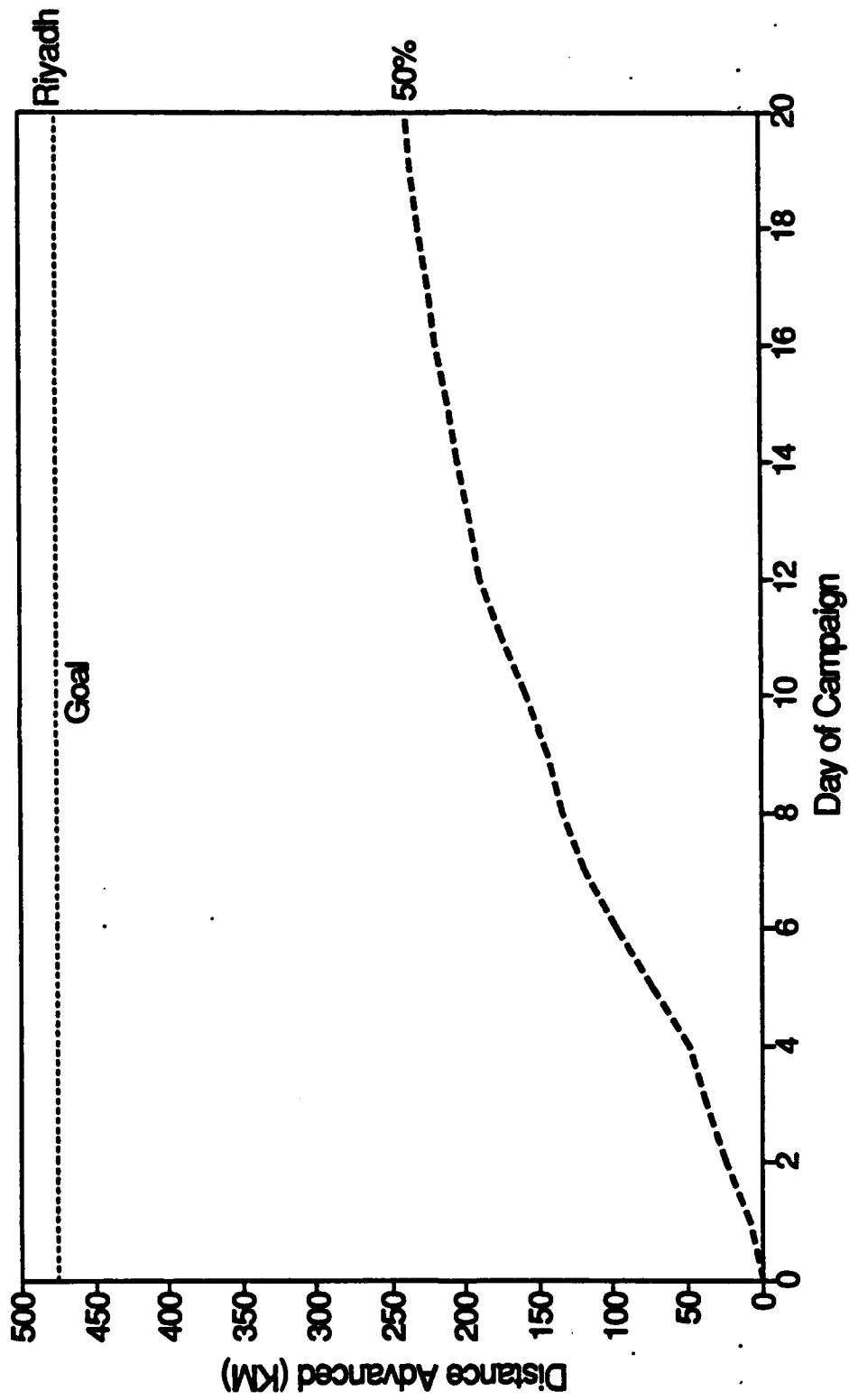
Slide Title: Cumulative Advance vs. Day of Campaign (single line)

Text: We will show several descriptive measures which facilitate understanding of the dynamics of the ground campaign.

The first of these descriptive measures is ground movement. Traditionally, ground movement rates are expressed as some sort of expected value, perhaps corresponding to the 50th percentile. Our methodology (based on the US Army Concepts and Analysis Agency's recently completed "Chase" study), enables the full distribution of advance rates to be estimated. Here we plot the estimate for the 50th percentile, using the convention that red will do as well or better 50% of the time. Higher percentiles therefore lie to the lower right, and lower percentiles to the upper left of this plot.

Said another way, in 50% of the cases, Red won't quite make it half way there. But there is a finite probability (<50%) that he will make it all the way to Riyadh in 20 days. That probability turns out to be 37% in this scenario.

Cumulative Advance (50% Probability) vs. Day of Campaign
Mid East: Base Case Probability of Reaching Distance = 37%



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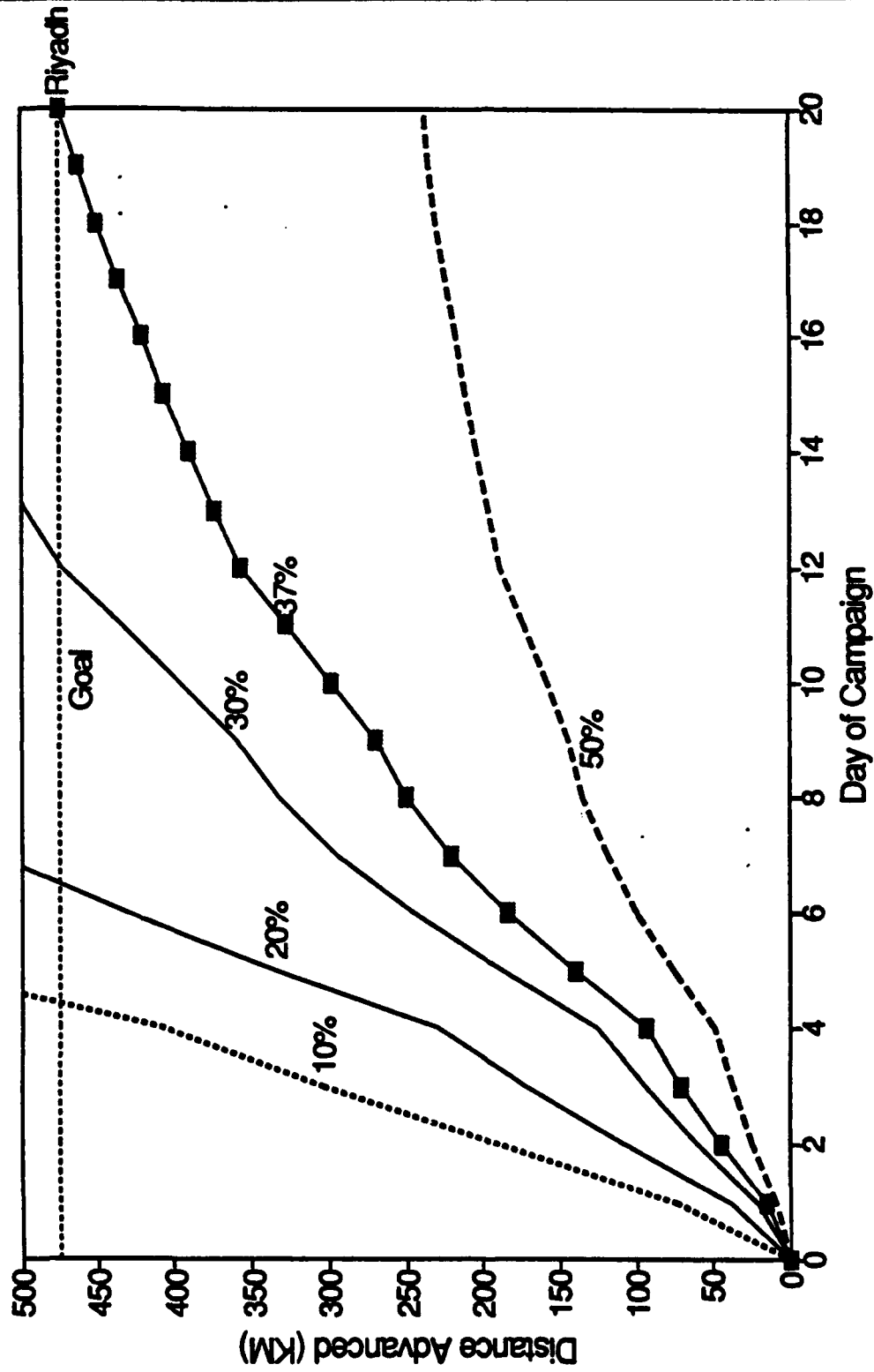
Slide Title: Cumulative Advance vs. Day of Campaign (multiple lines)

Text:

A range of percentiles is shown here, with the 37% line running through Riyadh on day 20, the stated campaign objective.

The interpretation is that in the base case, Red will reach Riyadh with 37% probability in 20 days or less.

Cumulative Advance vs. Day of Campaign
Mid East: Base Case Probability of Reaching Distance = 37%



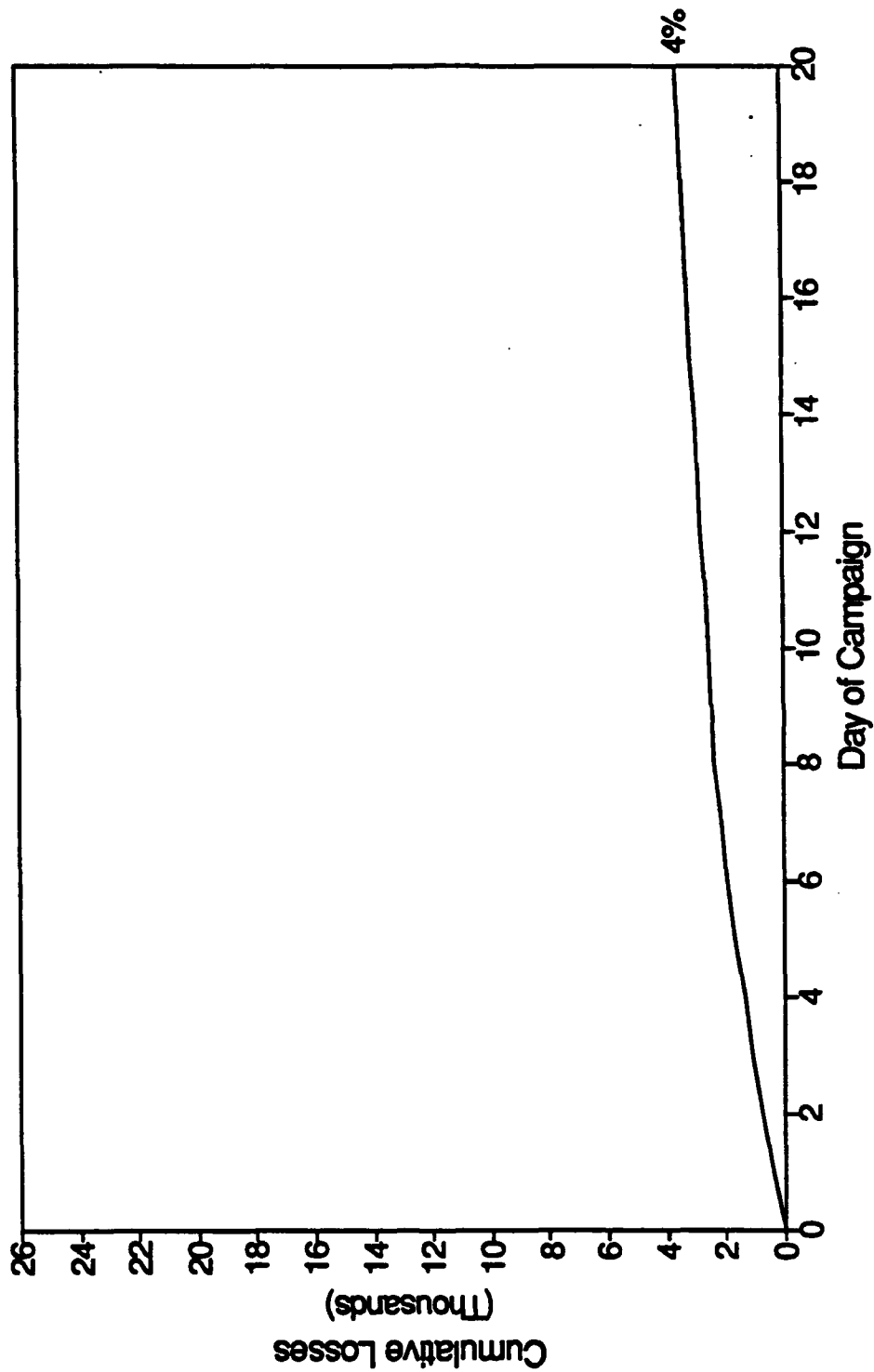
Slide Title: Cumulative Blue Casualties vs. Day of Campaign

Text: This slide depicts the losses of Blue personnel over the course of the campaign



Cumulative Blue Casualties vs. Day of Campaign

Mid East: Base Case



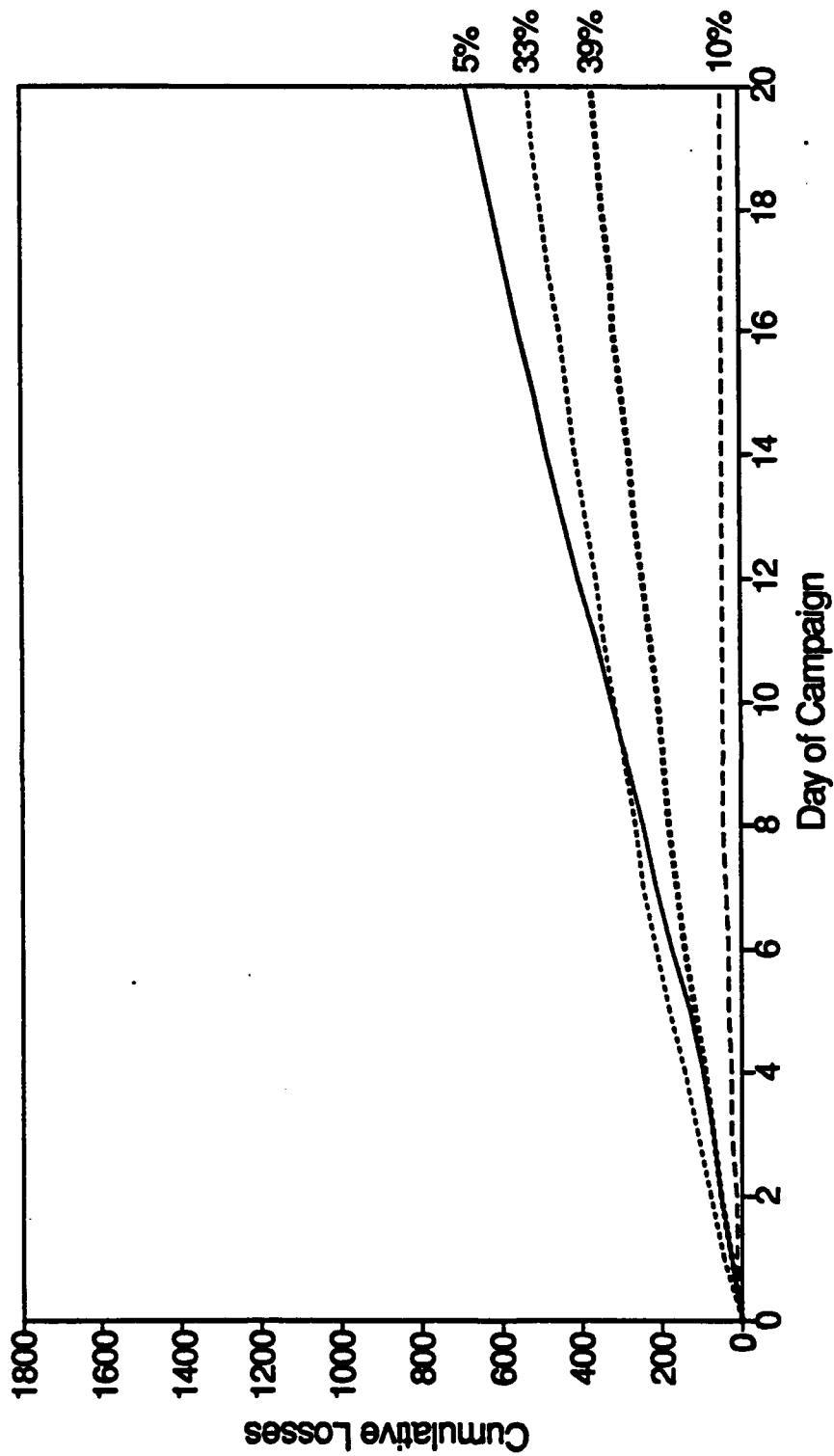
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Slide Title: Cumulative Blue Losses vs. Day of Campaign

Text: Here we plot losses for a few Blue ground force elements.



Cumulative Blue Losses vs. Day of Campaign
Mid East: Base Case



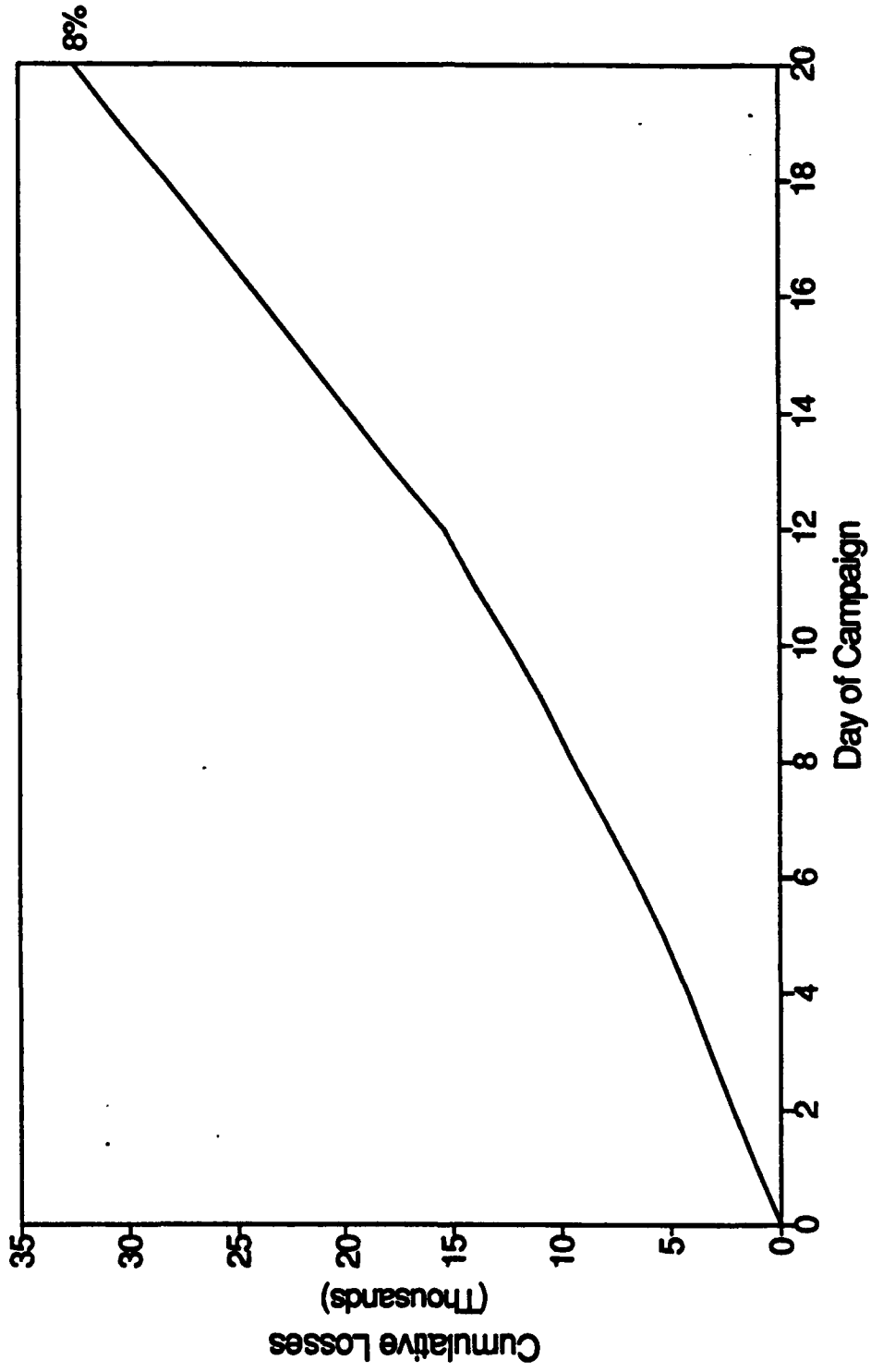
..... Tanks APC/IFV -.-.- Art --- Trucks

STR

Slide Title: Cumulative Red Casualties vs. Day of Campaign

Text: This slide depicts the losses of Red personnel over the course of the campaign

Cumulative Red Casualties vs. Day of Campaign
Mid East: Base Case

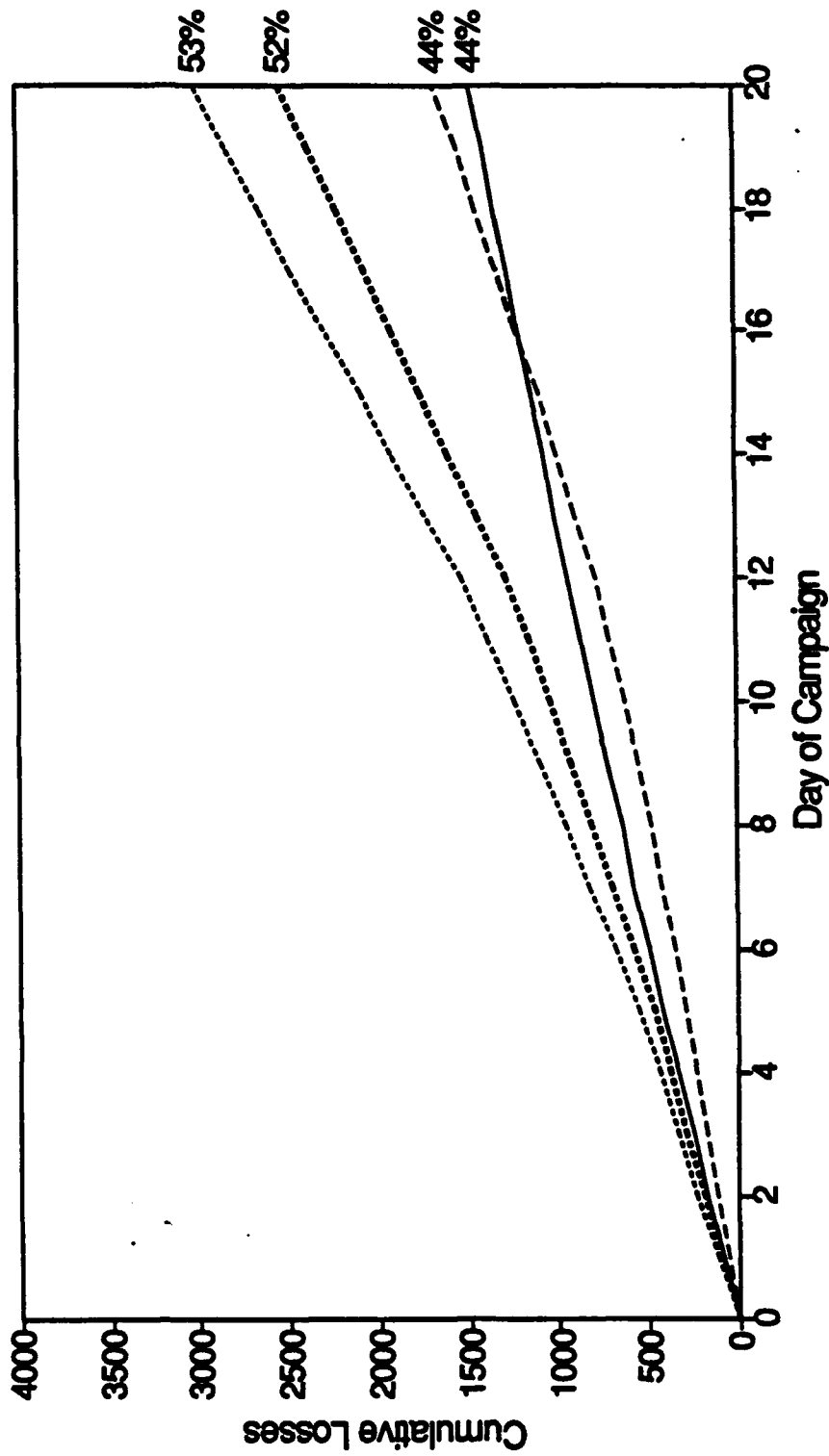


STR

Slide Title: Cumulative Red Losses vs. Day of Campaign

Text: ...and the losses of Red equipment.

Cumulative Red Losses vs. Day of Campaign Mid East: Base Case



..... Tanks APC/IFV ---- Artillery — Trucks

STR

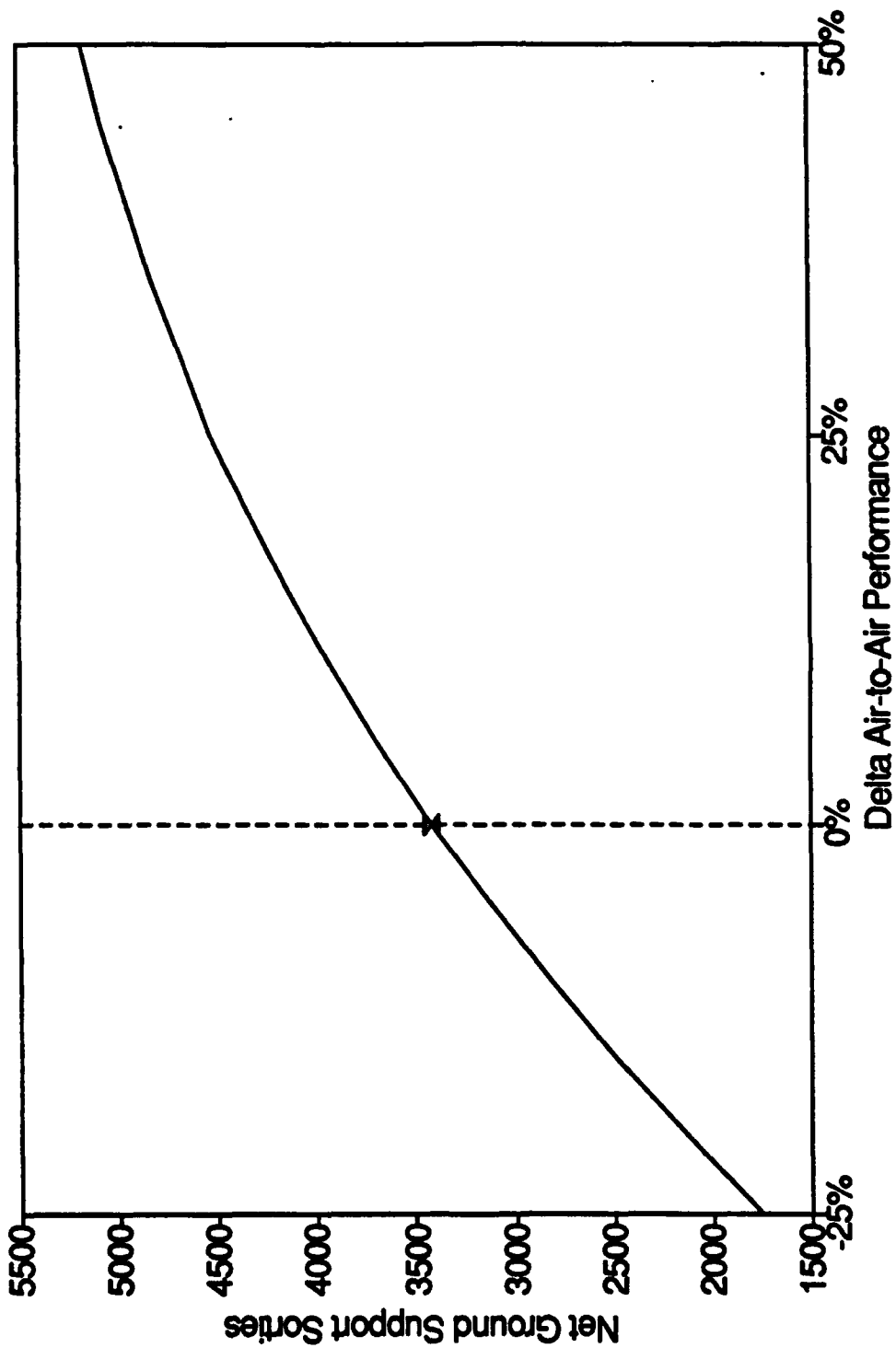
***Slide Title:* Net Ground Support Sorties vs. Air to Air Performance**

Text:

We have seen how the output of the air campaign is net ground support sorties (Blue minus Red -- in accordance with a prescribed schedule over time, unambiguously determined through "best use of force" algorithms in OME III). We have also seen how the ground battle model (GBM) translates these sortie schedules into probability of enemy success. To provide an interface to the next lower (engagement) level, it is necessary only to vary the OME III input parameters corresponding to those particular aircraft performance characteristics which will change as a function of the characteristics of the material -- in this case, the air-to-air characteristics of the aircraft.

This graph shows the relationship between air-to-air performance of our notional fighter and the total net ground support sorties (Blue minus Red) available.

Net Ground Support Sorties vs Air-to-Air Performance Mid-East -- Baseline Advanced Aircraft



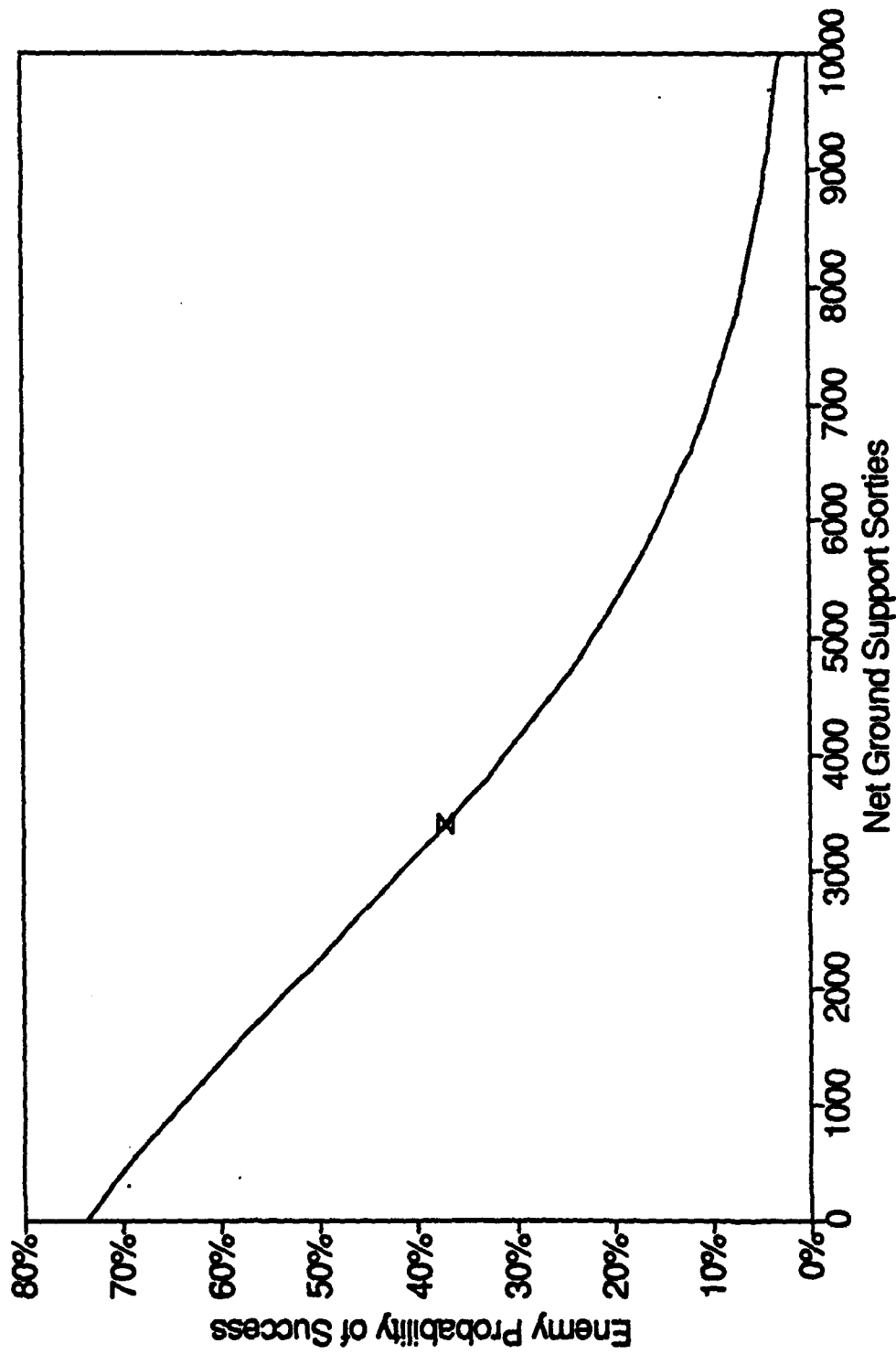
STR

Slide Title: Enemy Probability of Success vs. Net Ground Support Sorties

Text: This slide shows the relationship of Net Ground Support Sorties vs. P(Red Success). This base case is shown by the mark on the curve.



Enemy Probability of Success vs Net Ground Support Sorties
Mid-East -- Baseline Advanced Aircraft

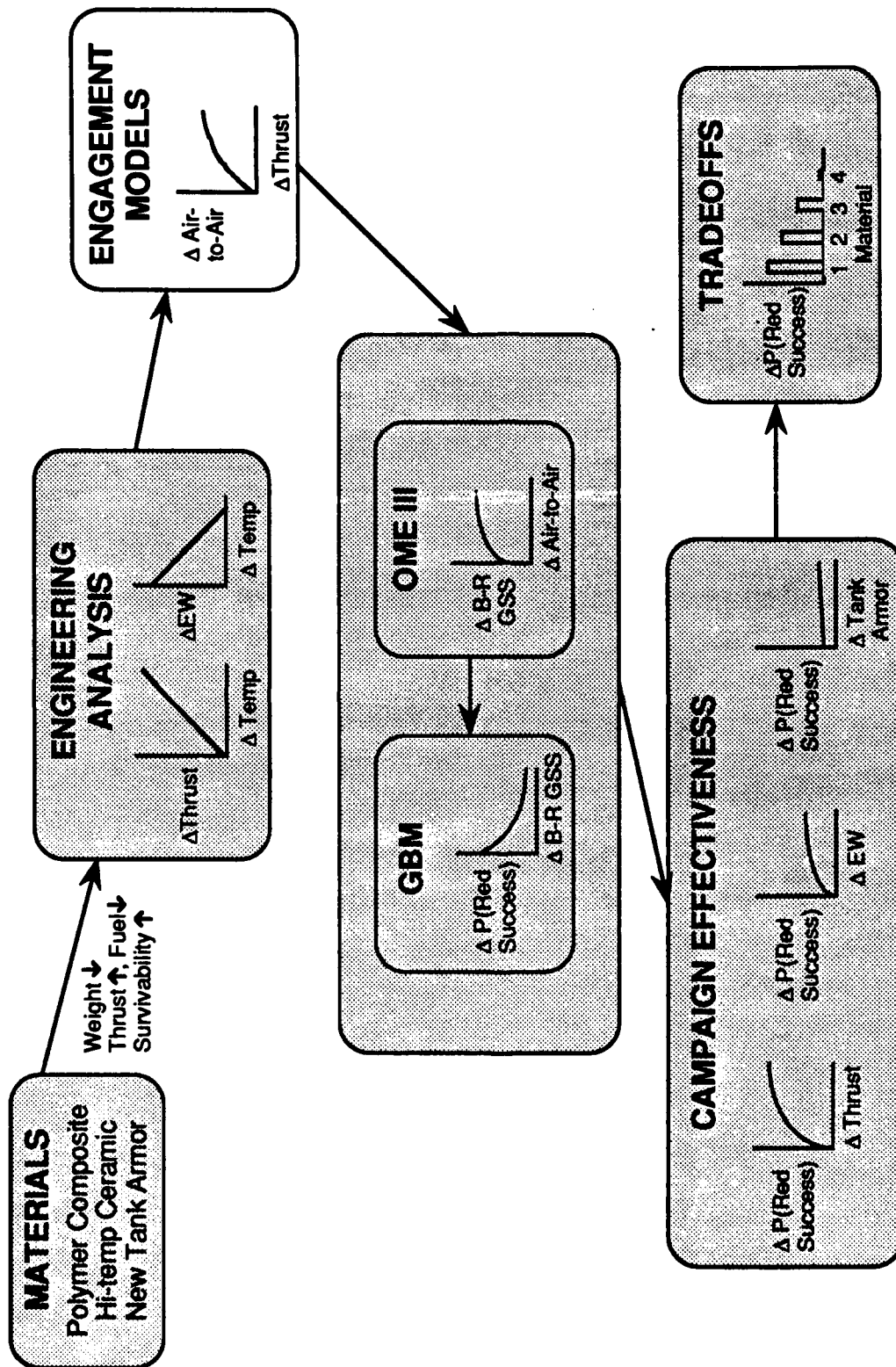


STR

Slide Title: Where We Are - Engagement Level Analysis

Text: Now that the base case has been established, along with parametric variations to determine the variation in campaign outcome as a function of critical campaign inputs from the engagement level (such as was illustrated by the air-to-air capability example), we step down to the engagement level to look at how aircraft characteristics affect the lethality and survivability inputs for the fighter .

EVALUATION OF NEW MATERIALS

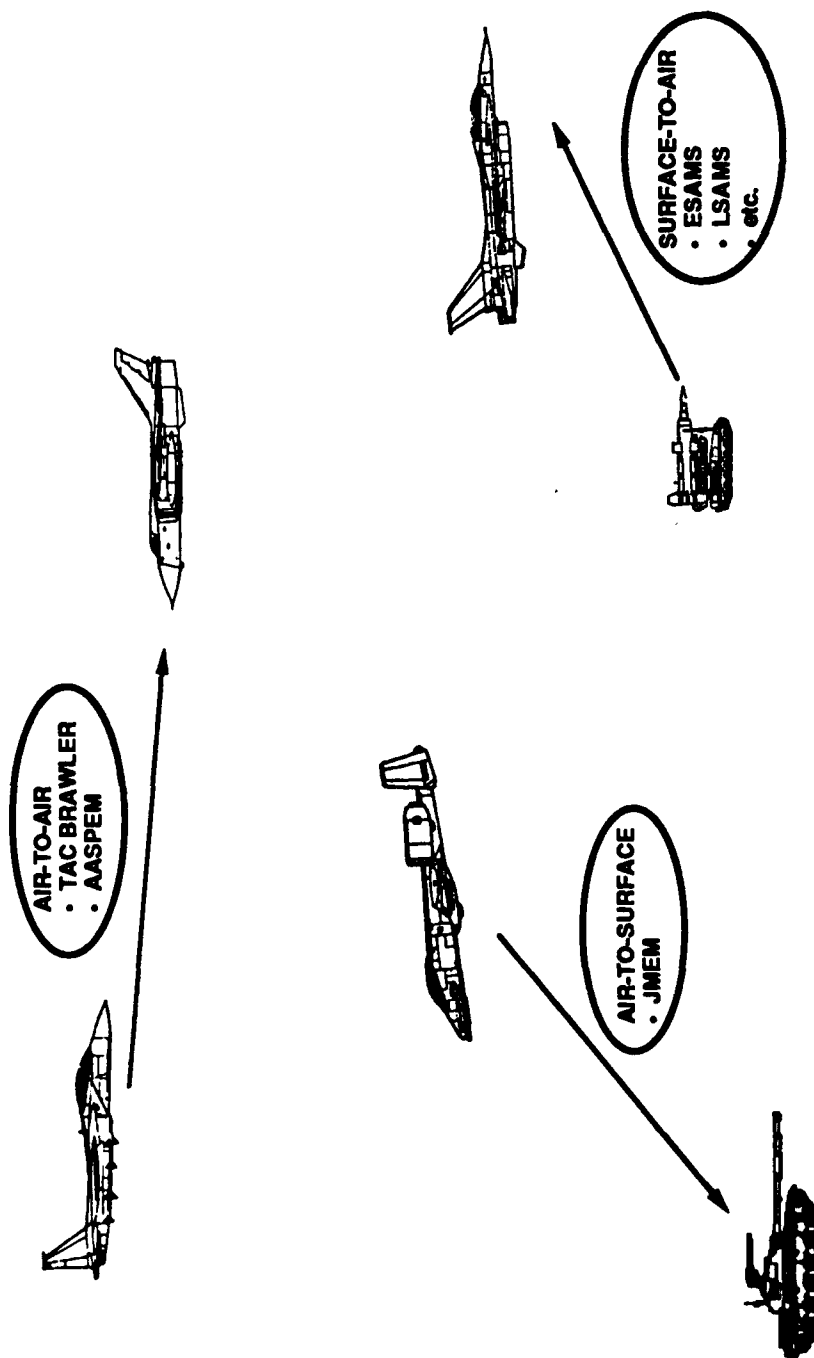


STR

Slide Title: Data From Engagement Models

Text: Data was collected from the engagement model TAC BRAWLER, which was used to develop delta air-to-air lethality and survivability curves as a function of changes in thrust and changes in empty weight. These curves are shown in the following slides. When the impact on thrust and empty weight caused by the use of new materials is known, the changes in lethality and survivability are read off of the curve and are the entering arguments for the parametric curves already generated which now extend all the way to theater outcomes.

DATA FROM ENGAGEMENT MODELS

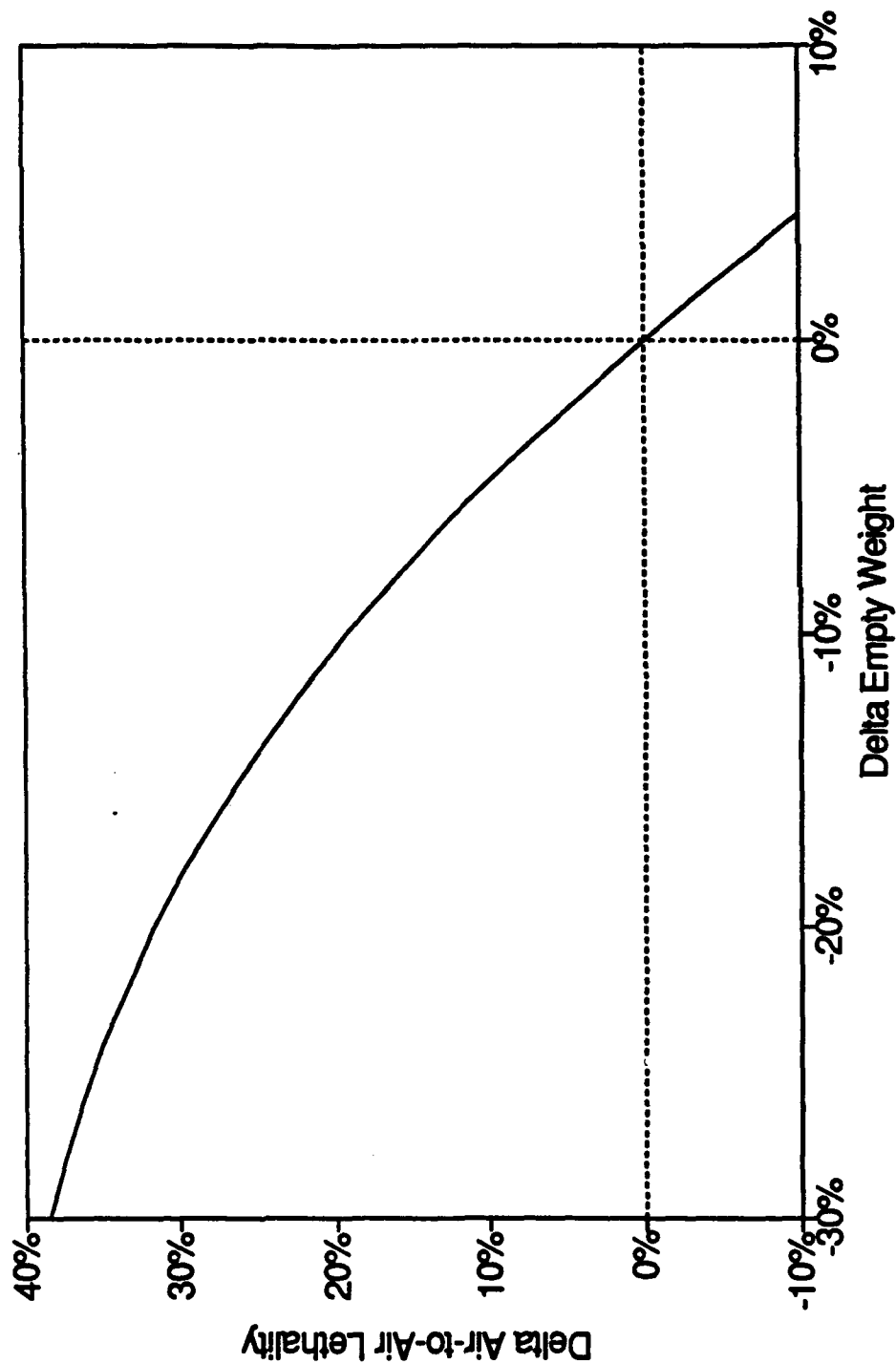


STR

Slide Title: Delta Air-to-Air Lethality vs. Delta Empty Weight

Text: This graph shows how air-to-air lethality for the notional fighter varies as a function of empty weight for the types of air-to-air engagements encountered within OME III. As empty weight decreases, air-to-air lethality increases.

Delta Air-to-Air Lethality vs Delta Empty Weight
Data From Engagement Level Outcomes

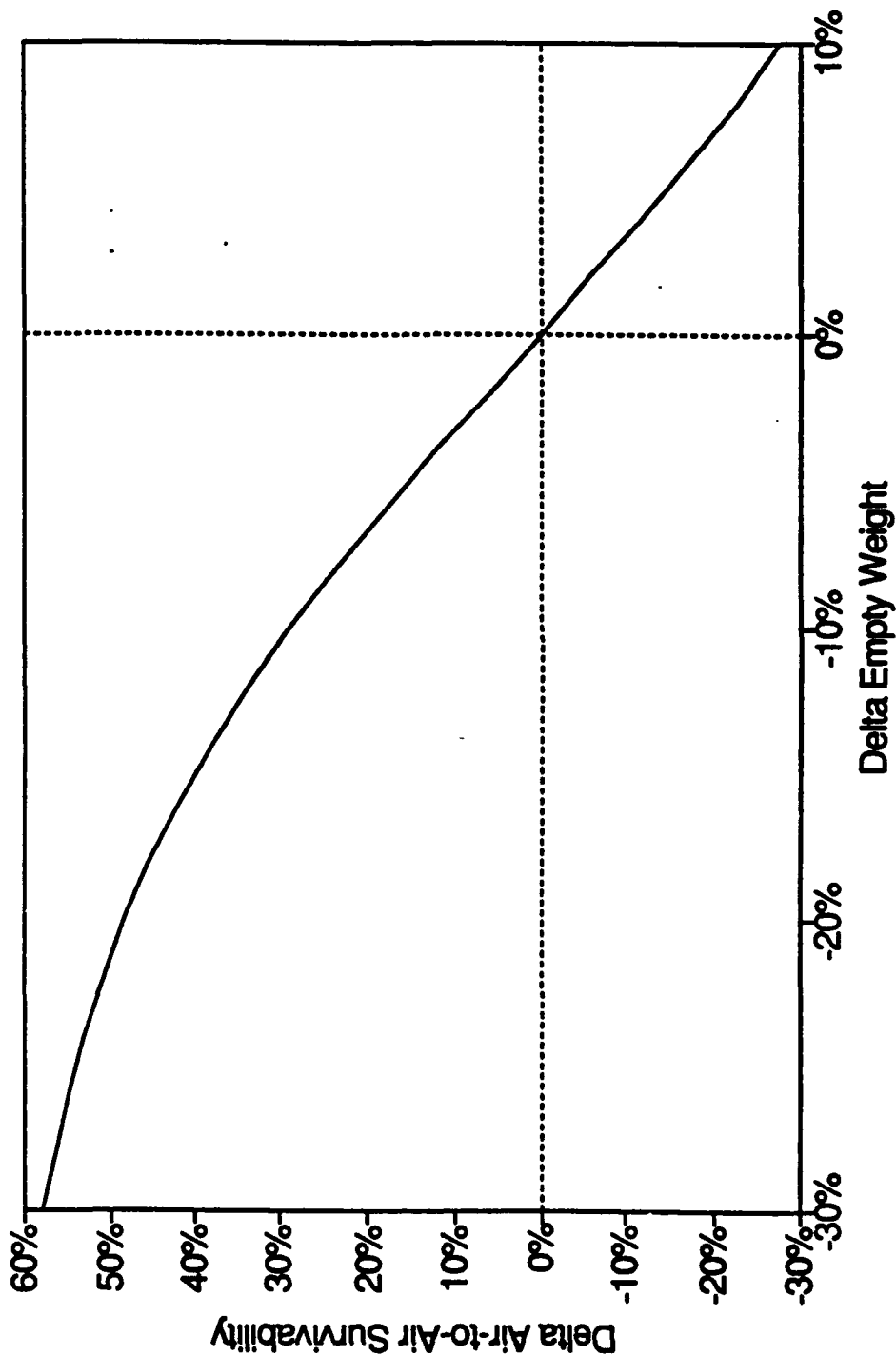


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Slide Title: Delta Air-to-Air Survivability vs. Delta Empty Weight

Text: This graph shows how air-to-air survivability for the notional fighter varies as a function of empty weight. As empty weight decreases, air-to-air survivability increases.

Delta Air-to-Air Survivability vs Delta Empty Weight
Data From Engagement Level Outcomes

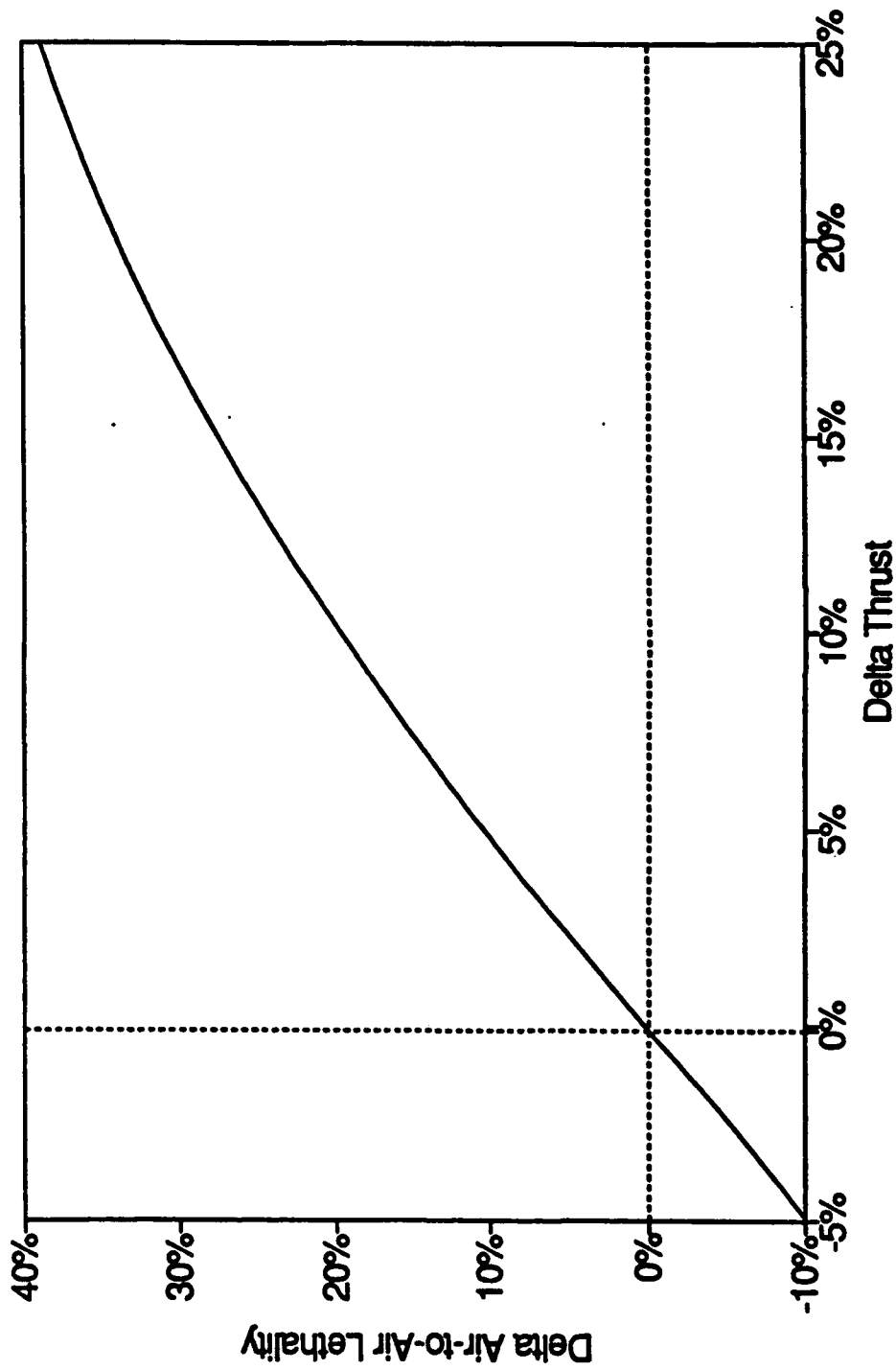


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Slide Title: Delta Air-to-Air Lethality vs. Delta Thrust

Text: This graph shows how air-to-air lethality for the notional fighter varies as a function of thrust. As maximum thrust increases, air-to-air lethality increases.

Delta Air-to-Air Lethality vs Delta Thrust
Data From Engagement Level Outcomes



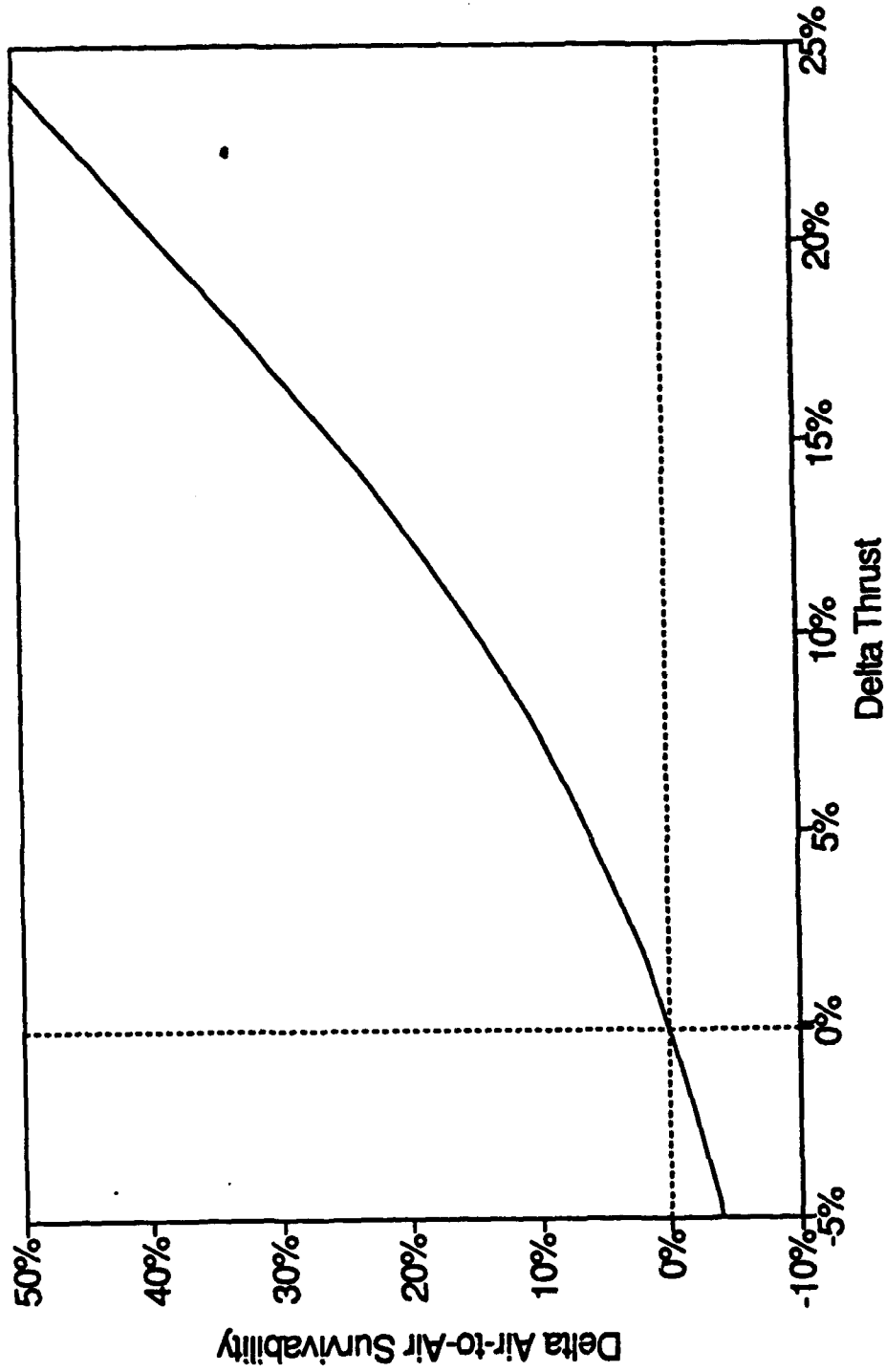
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Slide Title: Delta Air-to-Air Survivability vs. Delta Thrust

Text: This graph shows how air-to-air survivability for the notional fighter varies as a function of thrust. As thrust increases, air-to-air survivability increases.

The lethalties and survivabilities of the notional advanced fighter combine to form the overall parameter which we have used to describe the overall air-to-air capability -- the entering argument on the parametrics generated at the theater level.

Delta Air-to-Air Survivability vs Delta Thrust
Data From Engagement Level Outcomes



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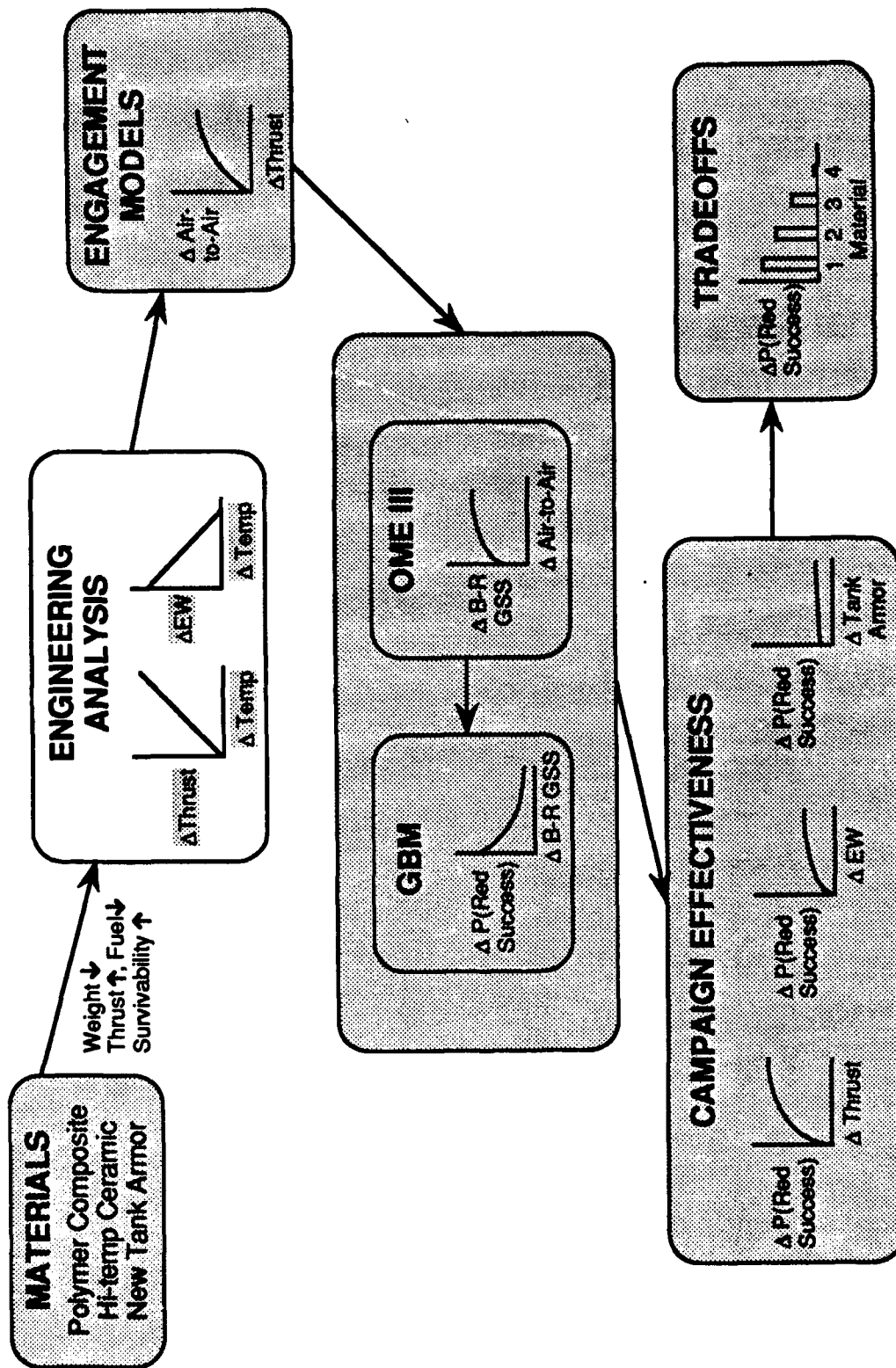
Slide Title: Where We Are - Engineering Level Analysis

Text:

Now that we know how changes in aircraft characteristics will affect theater-level effectiveness, we are ready to determine how our hypothetical materials affect the aircraft characteristics.



EVALUATION OF NEW MATERIALS



STR

Slide Title: Advanced Materials to Assess

Text: The hypothetical materials we will examine consist of two materials for use on the advanced fighter, and one on the tank. The materials for the fighter affect empty weight and maximum thrust. The tank advanced armor affects tank survivability.

ADVANCED MATERIALS TO ASSESS

We will assess three hypothetical advanced materials, two on the notional fighter, as proposed, and an additional material on a tank.

Fighter

- Conventional polymer-based composite used on load-bearing structure - reduces empty weight
- Hi-temperature ceramic used in engine hot section- increases allowable turbine inlet temperature, producing increases in thrust and fuel efficiency

TANK

- Improved armor material

STR

Slide Title: Empty Weight Reduced By Fighter Materials

Text:

The first material to be examined is one which could impact the structural components of a fighter aircraft, such as a polymer composite. The impact of a structural composite type material is its effect on the empty weight of the aircraft. This slide shows basic weight distribution of the typical fighter aircraft constructed of current materials (aluminum). If an alternative material such as a conventional polymer based composite is used in the construction of the wings, fuselage and empanage a weight savings of the load bearing component results.

To estimate this savings the material density ratio of the new material and the proportion of the current material which could be replaced by the new material is estimated.

EMPTY WEIGHT REDUCED BY FIGHTER MATERIALS

Material: Current design (Aluminum)

Weight Summary:

<u>Non-load</u>	<u>Weight</u>	<u>Fraction</u>	<u>Load</u>	<u>Weight</u>	<u>Fraction</u>
Engine	4216	0.16	Fuselage	7449	0.29
Avionics	3514	0.14	Wings	5059	0.19
Internal	2108	0.08	Empennage	1405	0.05
Gear	2249	0.09			
Subtotal	12086	0.46	Subtotal	13914	0.54

Total Weight 26000 lbs

Material: Polymer based composite

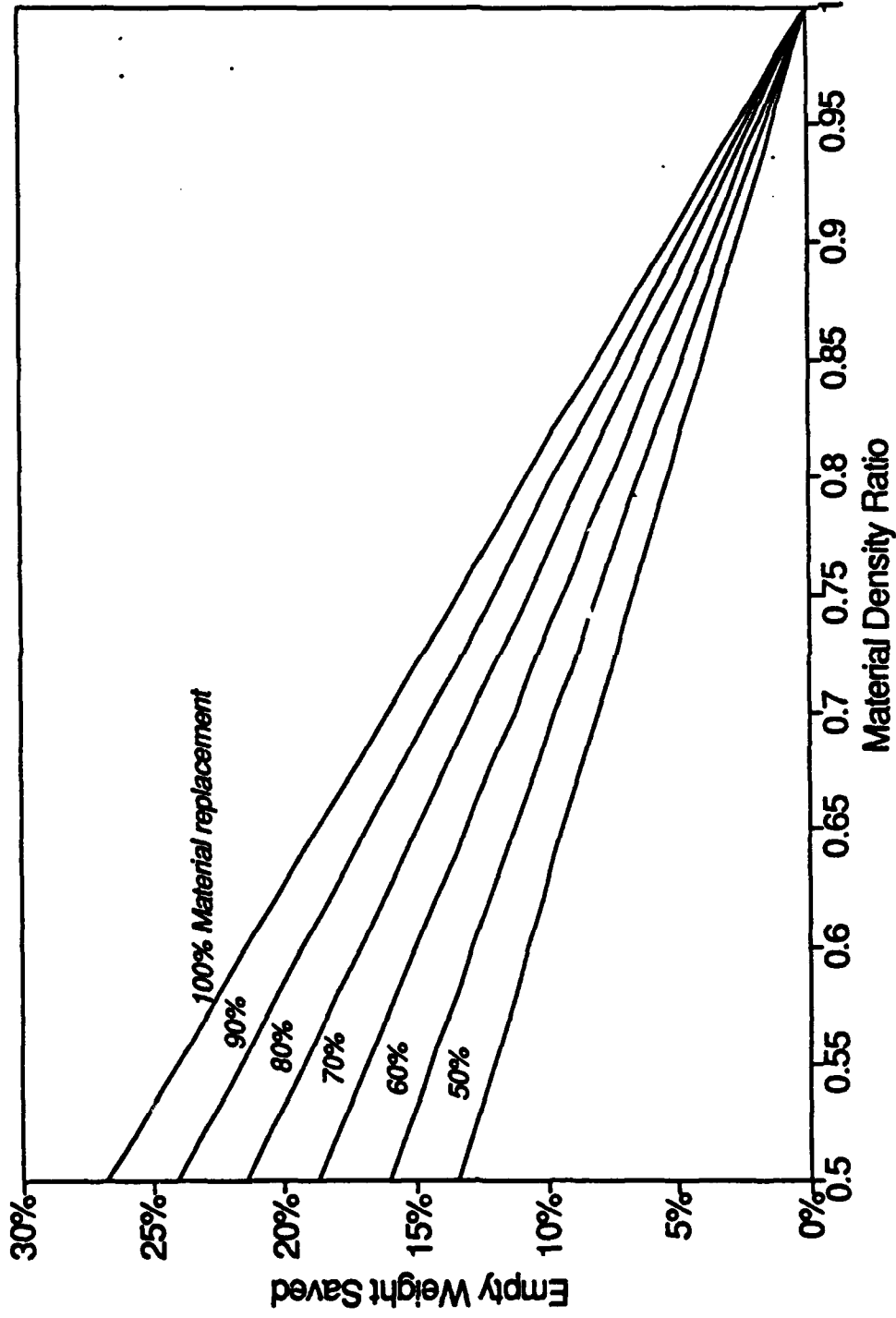
Material Density: .6 that of aluminum
Fraction replaced: 90%

STR

Slide Title: Empty Weight Saved Vs. Material Density Ratio

Text: The chart shows the relationship between Material Density Ratio, percent of material replacement and empty weight saved. The chart is based on the empty weight characteristics outlined in the previous slide. It is used to estimate empty weight saved once engineering analysis defines the Material Density function and the percentage of original material that could be replaced by the advanced material.

Empty Weight Saved vs. Material Density Ratio
Wings, Fuselage and Empennage Materials



STR

Slide Title: Effect Of Ceramics On Aircraft Performance

Text: The next material to be examined is a hi-temperature ceramic, which can be used in engine hot sections. As the next two slides will demonstrate, permitting turbine engines to operate at higher temperatures increases both performance and fuel efficiency. In this case the increased efficiency is reflected as decreasing the fuel requirement to maintain constant range/payload and is reflected as a decrease in empty weight.

EFFECT OF CERAMICS ON AIRCRAFT PERFORMANCE

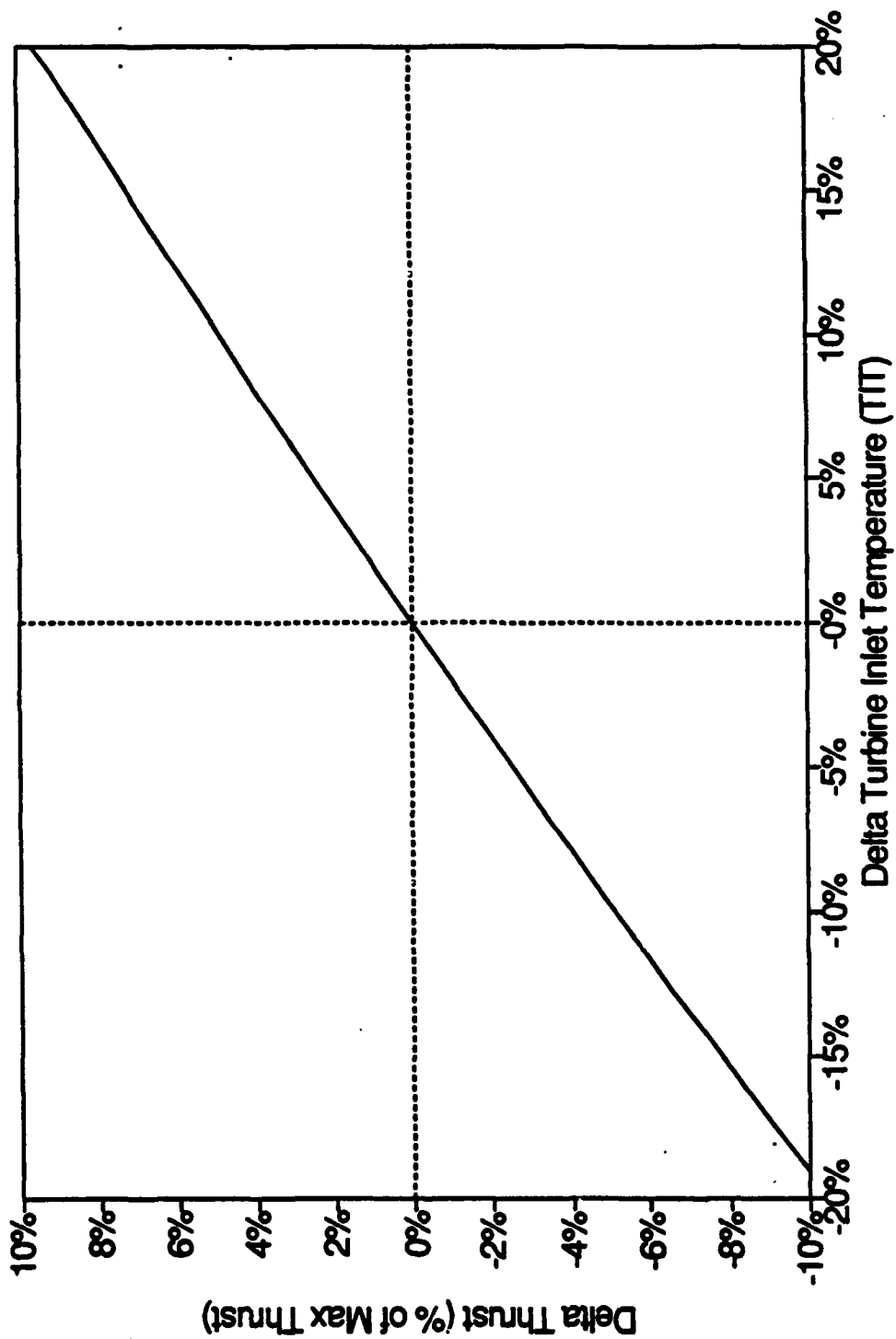
- Use of ceramics in engine hot sections permits engine operation at higher turbine inlet temperatures
 - Higher operating temperatures provide increased maximum thrust
 - Higher operating temperatures also increase fuel efficiency, providing the ability to maintain range payload/performance with less fuel (shown as a function of empty weight)
- Baseline turbine inlet temperature was assumed to be 1260 degrees K

STR

Slide Title: Delta Thrust Vs. Delta Turbine Inlet Temperature

Text: The slide shows the relationship between changes in turbine inlet temperature and thrust. Use of the data permits converting engineering estimates of material performance in turbine hot sections to performance of the engine measured in terms of increased or decreased thrust.

Delta Thrust vs. Delta Turbine Inlet Temperature (TIT)
Baseline TIT = 1260 deg K

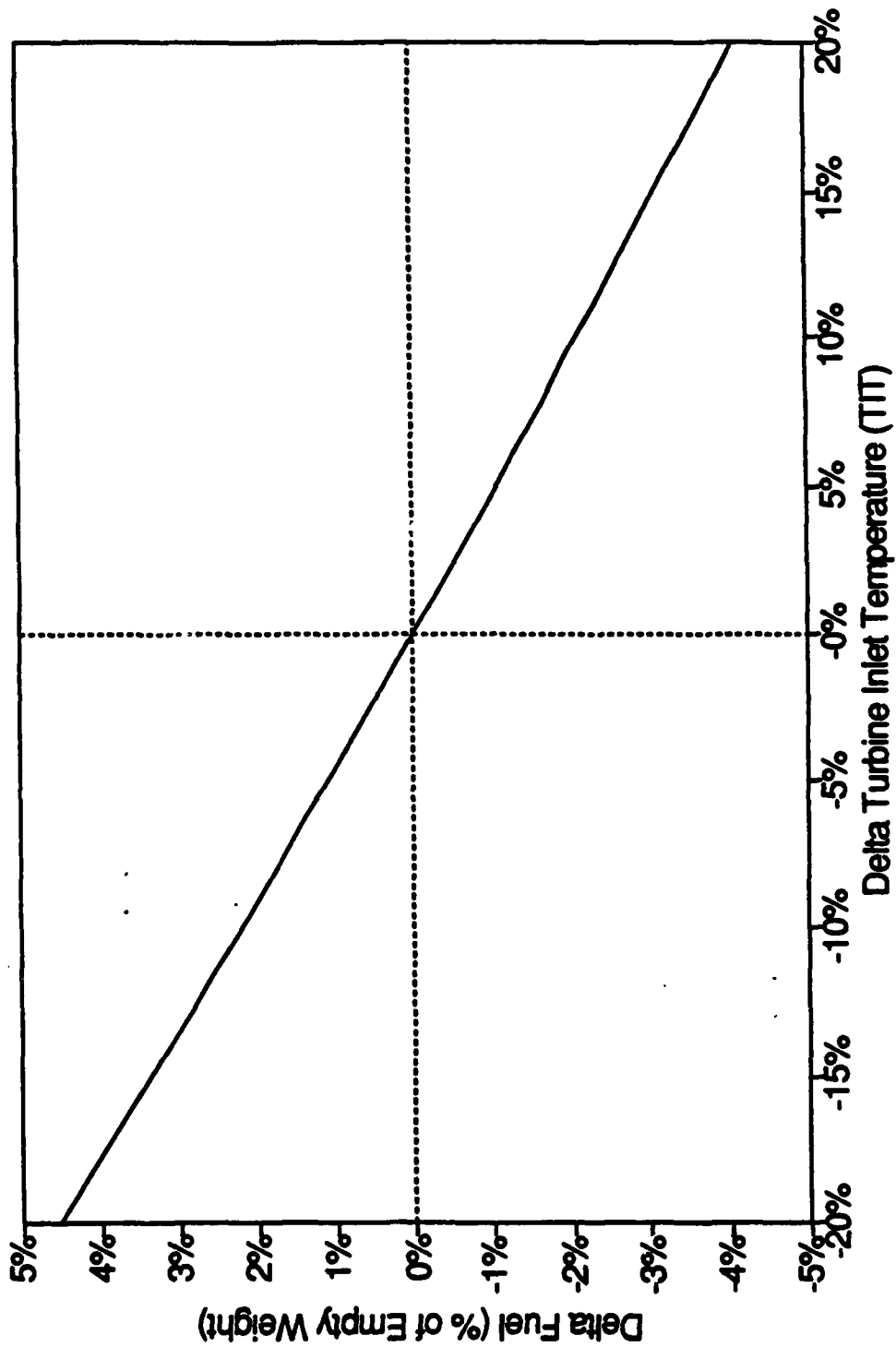


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Slide Title: Delta Fuel Weight Vs. Delta Turbine Inlet Temperature

Text: The slide shows the relationship between changes to maximum turbine inlet temperature and changes to fuel required to maintain constant range/payload, expressed as percent of empty weight.

Delta Fuel Weight vs. Delta Turbine Inlet Temperature (TIT)
Constant Range Performance -- Baseline TIT = 1260 deg K

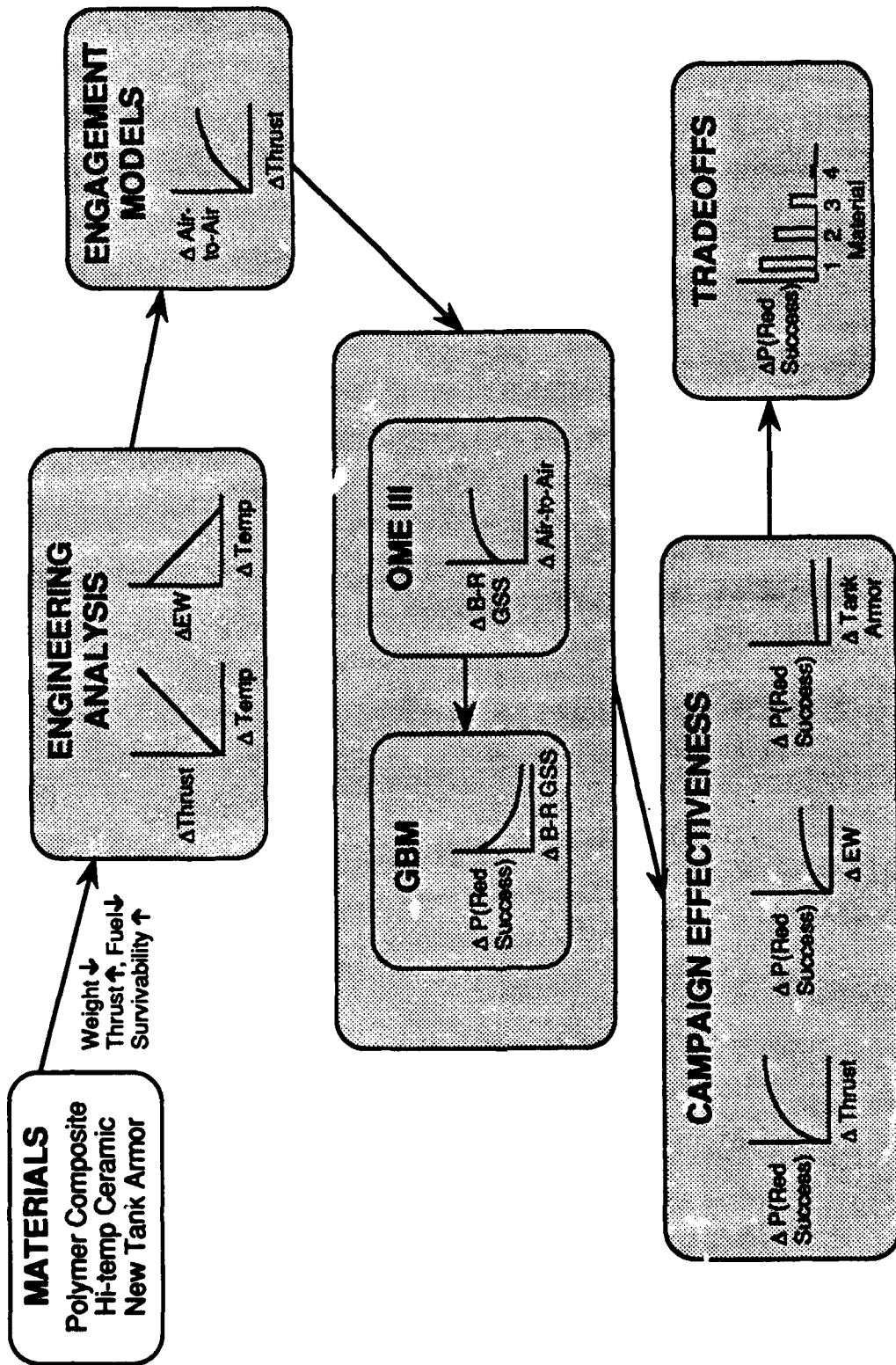


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Slide Title: Where We Are - Campaign Outcomes vs. New Materials

Text: This section shows the changes in campaign effectiveness as a result of using the various materials. With estimated costs, we also show the best mix of material vs. cost.

EVALUATION OF NEW MATERIALS



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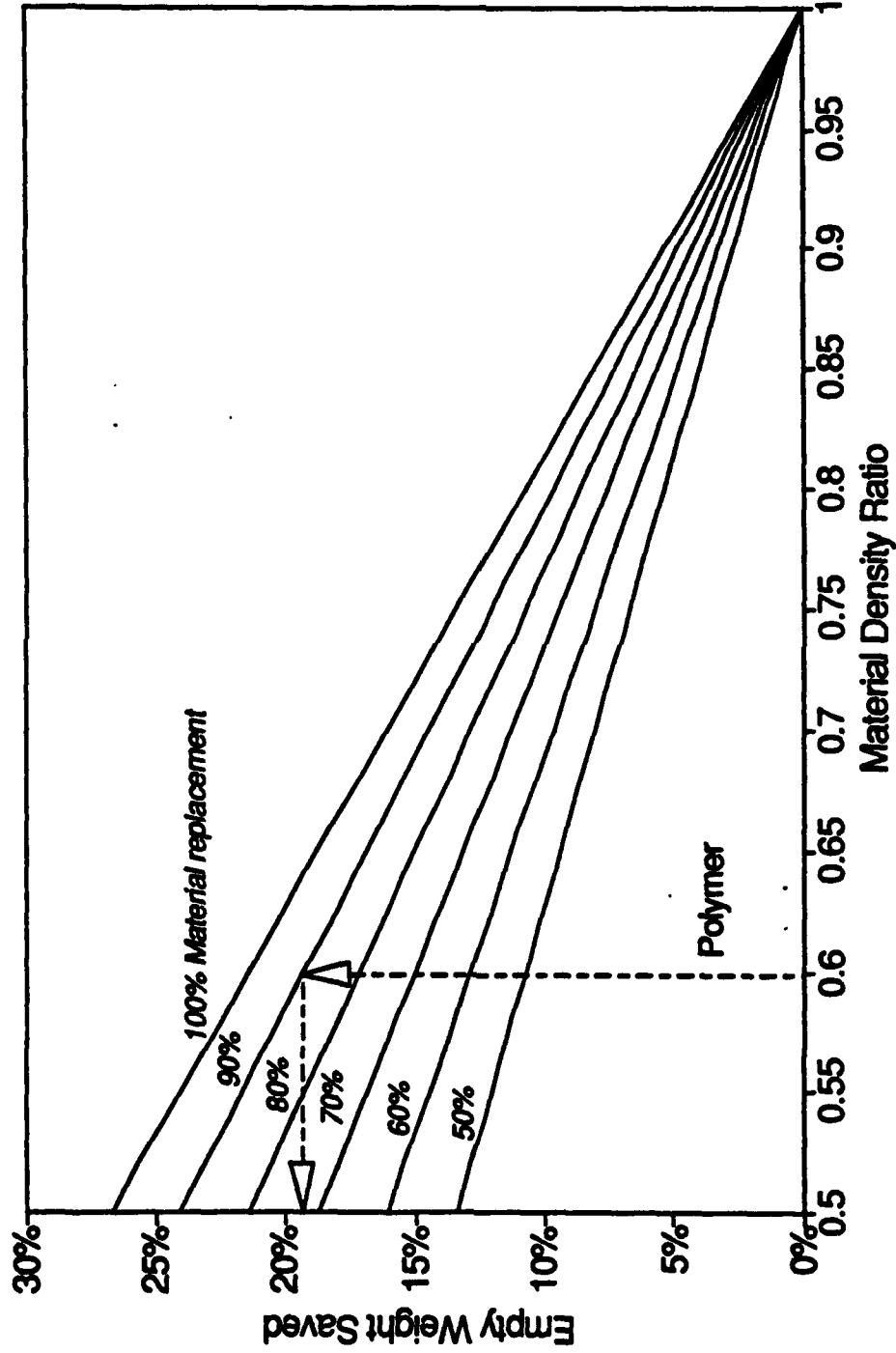
Slide Title: The Impact Of The Polymer Based Composite

Text:

The next series of slides will demonstrate the methodology by applying it to the first sample advanced material. Recall the first advanced material is a structural polymer based composite with the potential to replace structural components of an illustrative advanced fighter aircraft. To begin the process, engineering estimates of the density of the advanced composite are made and the fraction of the current material that could be replaced by the composite are determined. We assumed the new material would have density of 0.60 that of the current material and that it could replace 90 percent of the current material.

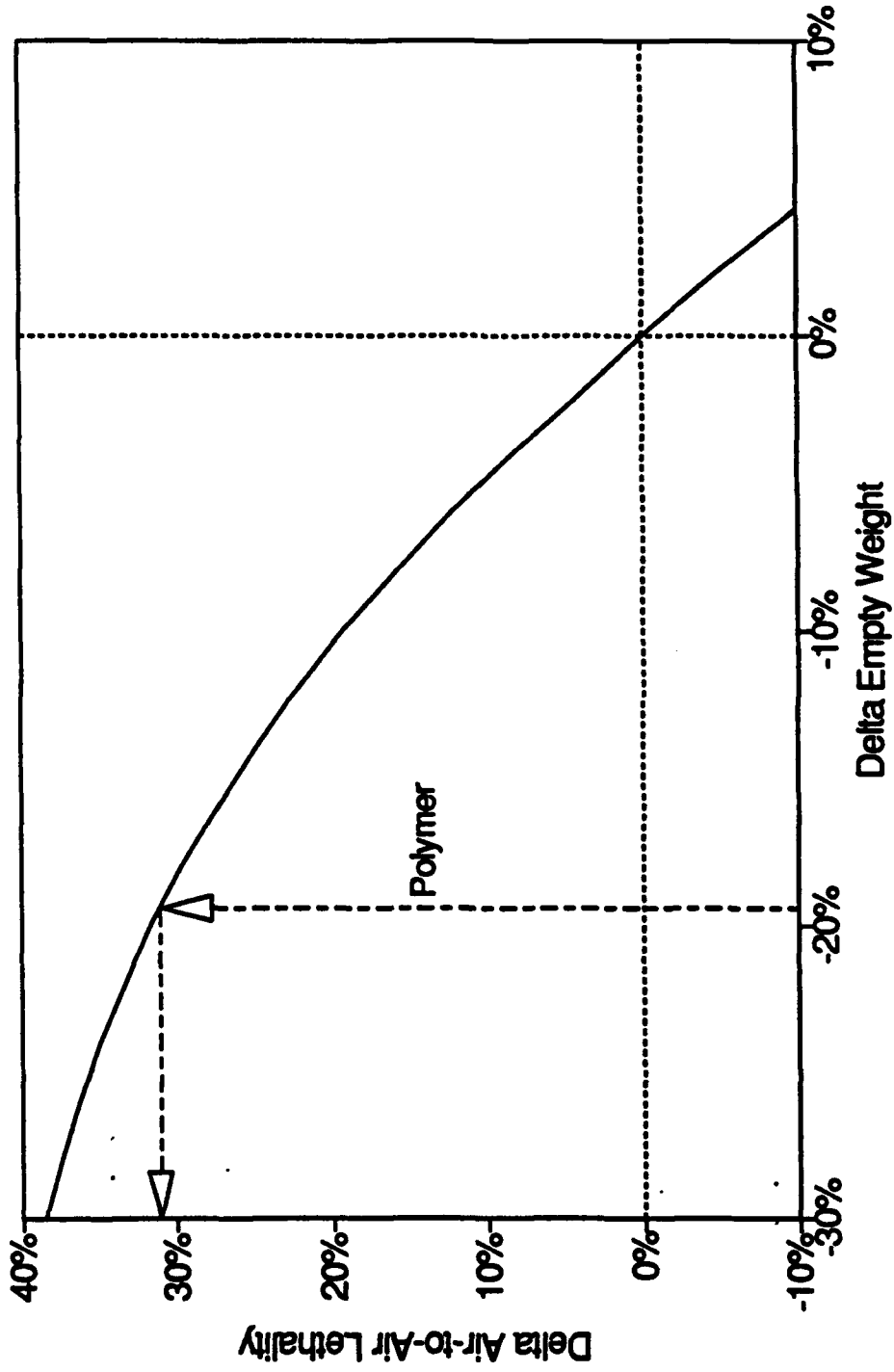
Entering the first chart with these values provides the delta in empty weight necessary to enter the air-to-air lethality and survivability graphs. These are combined to identify the overall delta in air-to-air capability, changes in Blue minus Red ground support sorties and finally, the new Probability of Enemy Success.

Empty Weight Saved vs. Material Density Ratio Wings, Fuselage and Empennage Materials



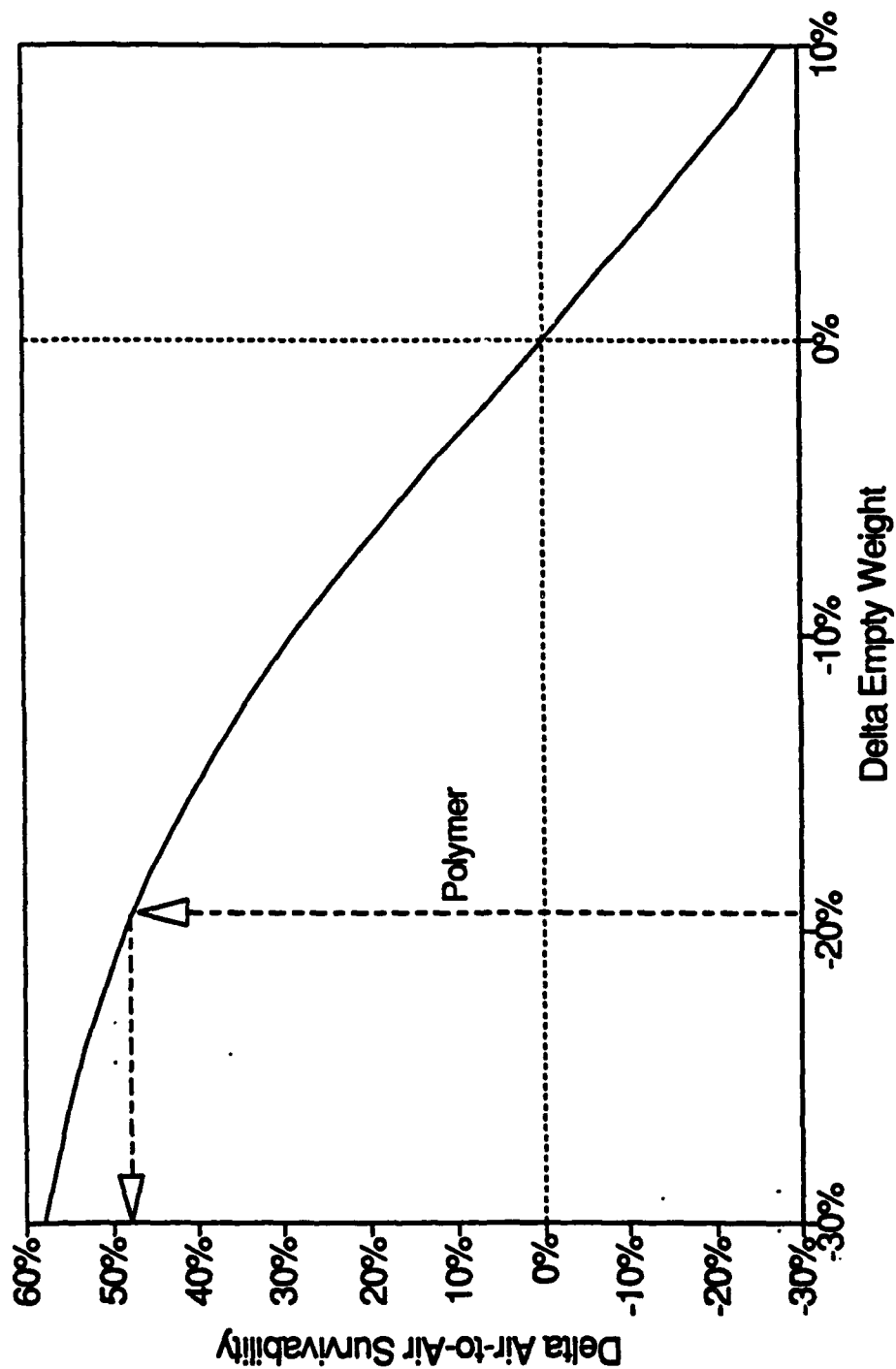
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Delta Air-to-Air Lethality vs Delta Empty Weight
Data From Engagement Level Outcomes



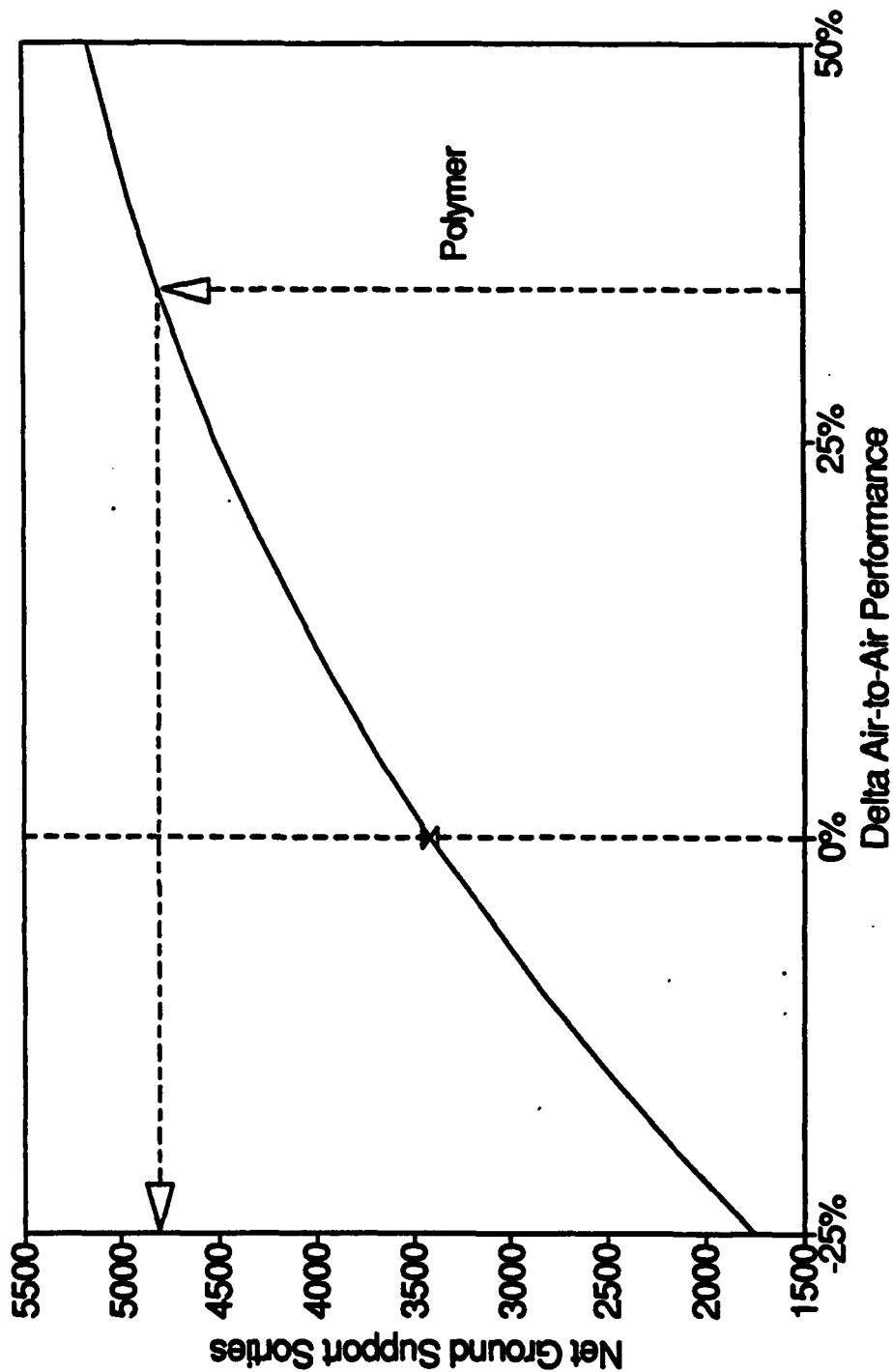
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Delta Air-to-Air Survivability vs Delta Empty Weight
Data From Engagement Level Outcomes



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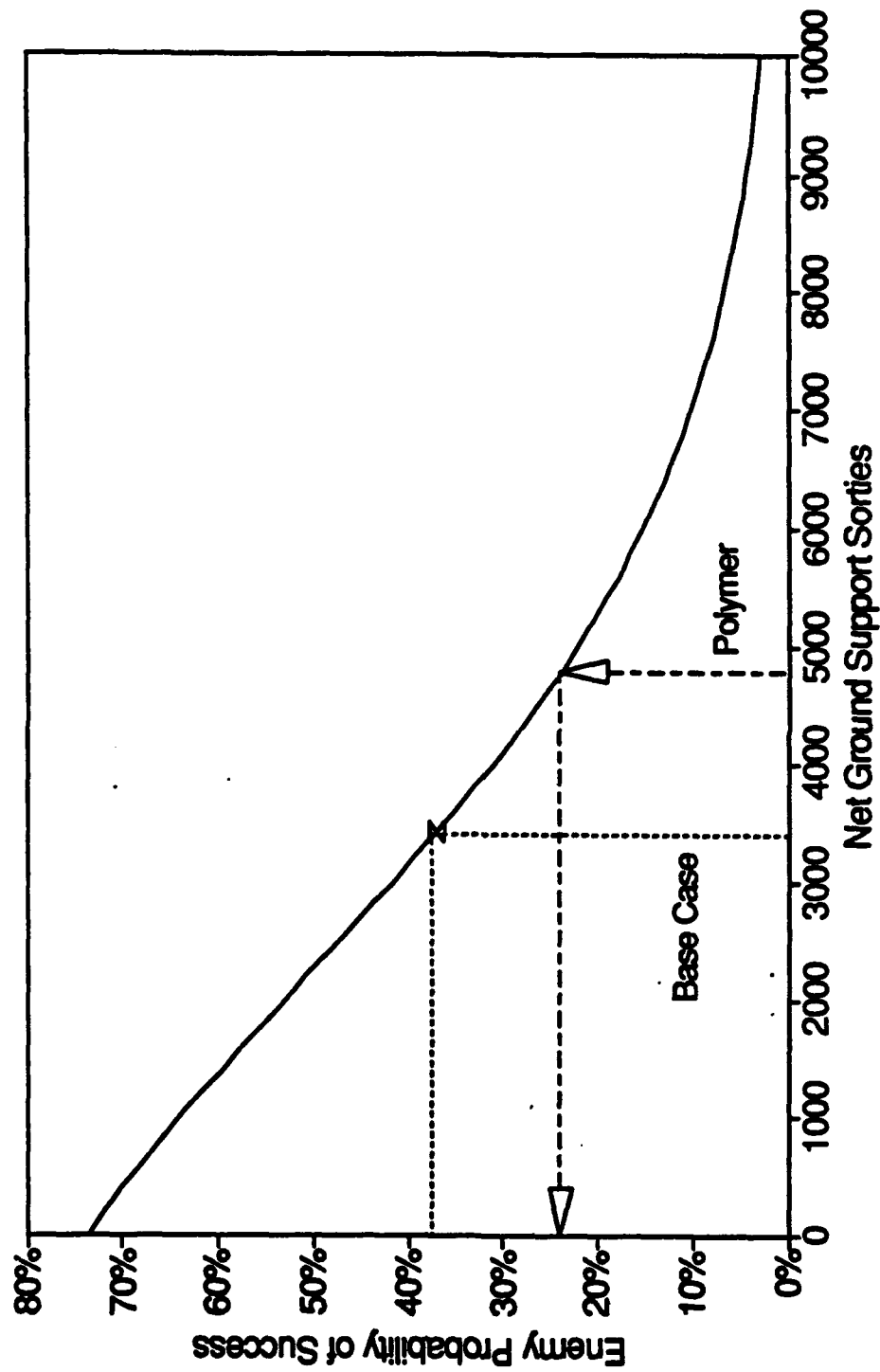
Net Ground Support Sorties vs Air-to-Air Performance Mid-East - Baseline Advanced Aircraft



$$(0.8 \times \text{delta Lethality} + 0.2 \times \text{delta Survivability})$$

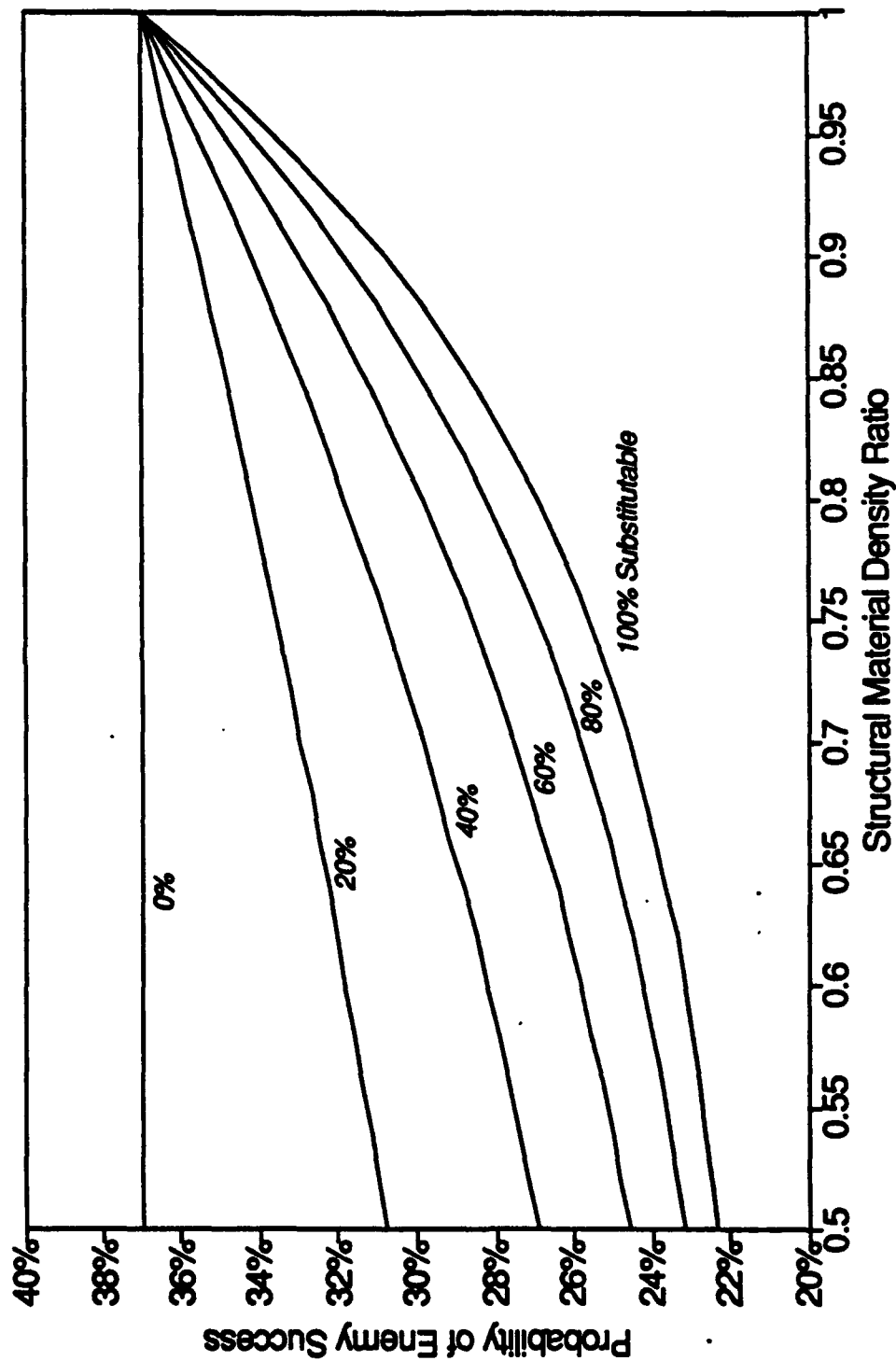
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Enemy Probability of Success vs Net Ground Support Sorties *Mid-East -- Baseline Advanced Aircraft*



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Probability of Enemy Success vs Structural Material Density Ratio
Mid-East Scenario -- Various Levels of Material Substitutability



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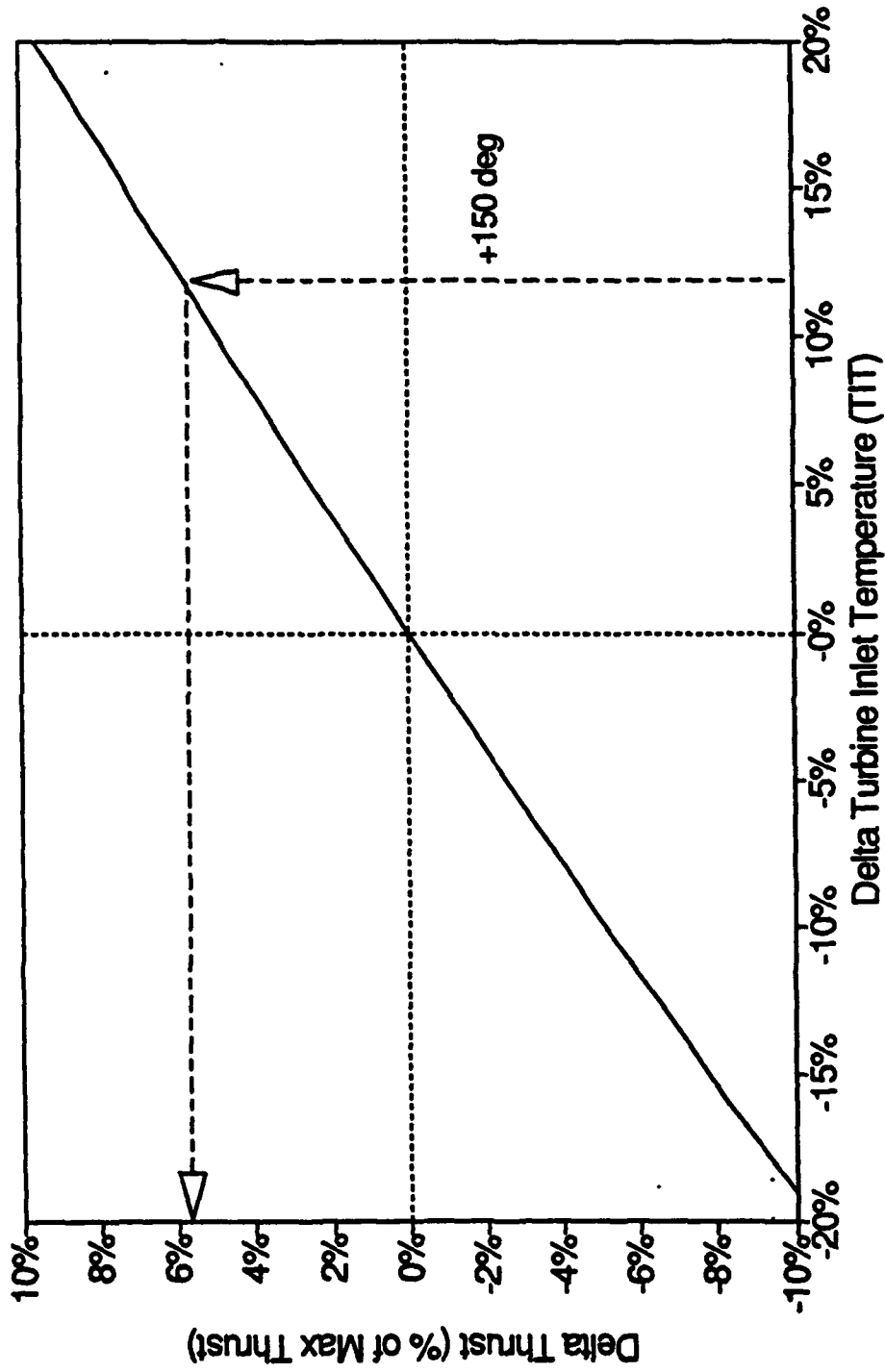
Slide Title: The Impact Of The High Temperature Ceramic Material

Text:

This series of slides illustrates the impact of a high temperature ceramic that could replace components of jet engine hot sections. The major advantage of the new material is that it will allow engines to operate at higher turbine inlet temperatures (TIT). We assumed the new material would permit a 150 degree centigrade increase in maximum turbine inlet temperature of the engine of the illustrative advanced fighter aircraft.

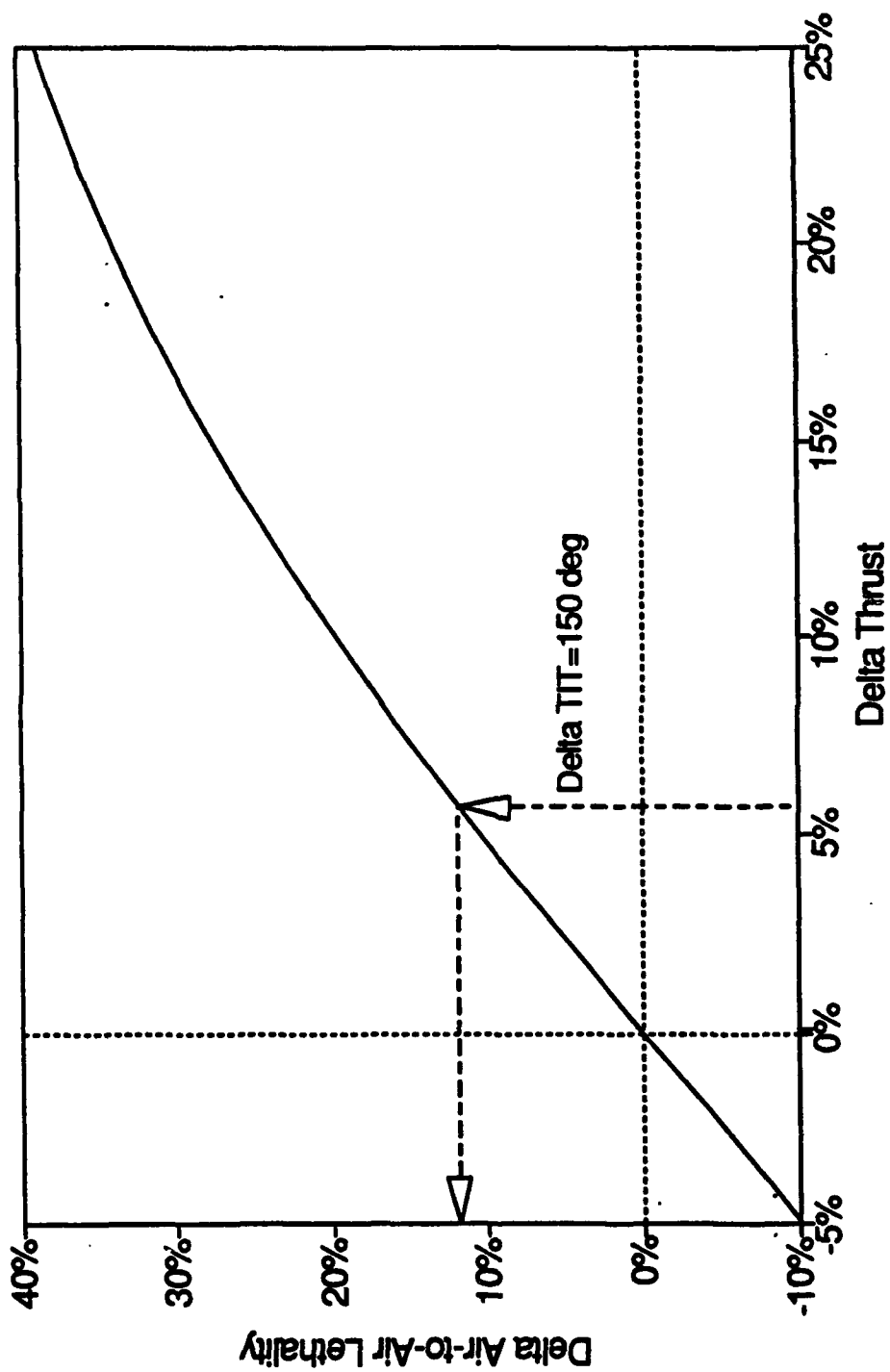
Recall that the higher TIT produces increased performance (thrust), as well as increased efficiency, (fuel saved reflected as a percentage of empty weight). Entering these two charts with the delta TIT provides estimated changes to thrust and weight. These in turn are used to determine variations in air-to-air lethality and survivability which, when combined, produce a new Blue minus Red Net ground support sortie schedule and finally the new Probability of Red Success.

Delta Thrust vs. Delta Turbine Inlet Temperature (TIT)
Baseline TIT = 1260 deg K



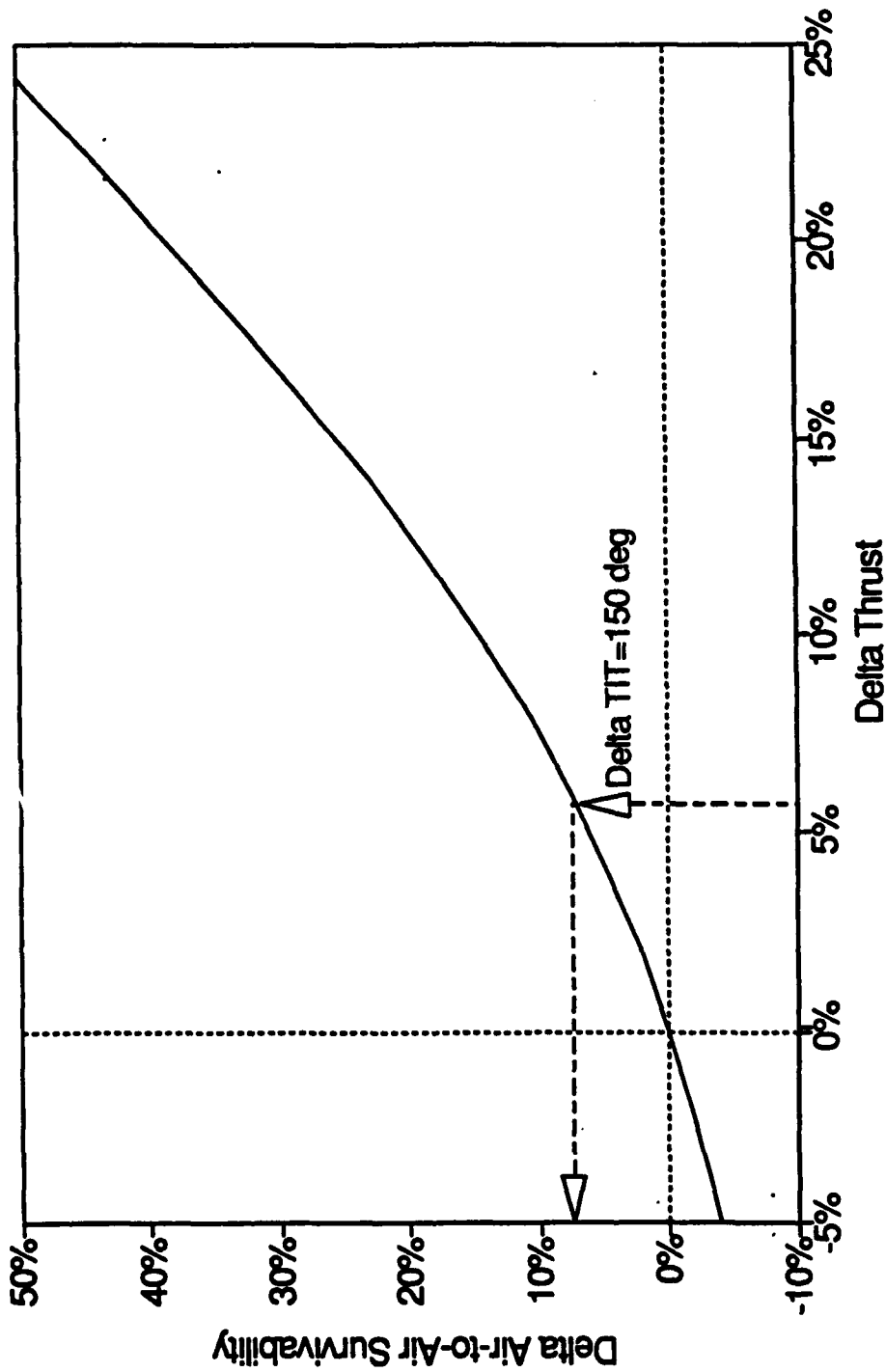
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Delta Air-to-Air Lethality vs Delta Thrust
Data From Engagement Level Outcomes



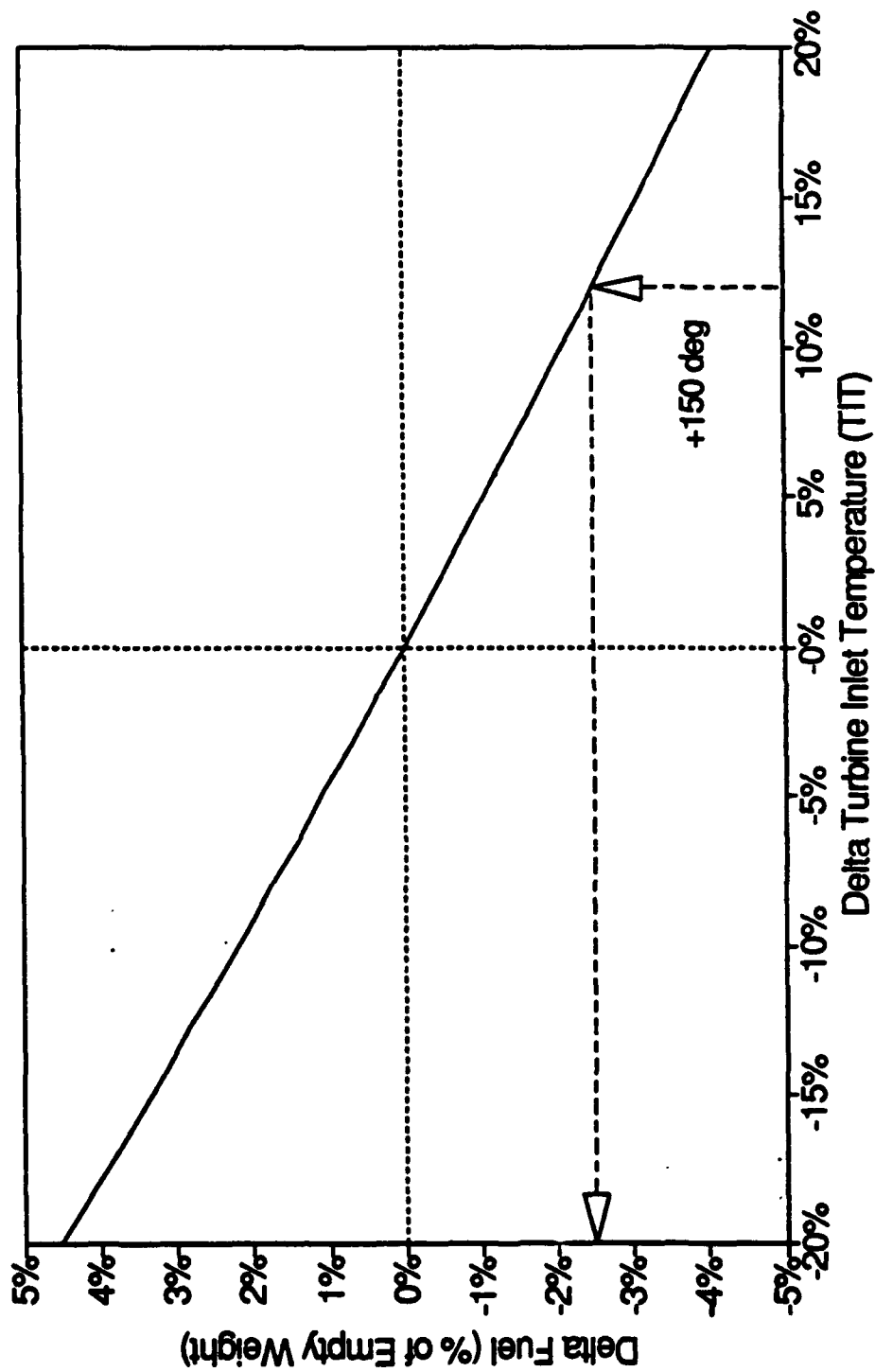
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Delta Air-to-Air Survivability vs Delta Thrust
Data From Engagement Level Outcomes



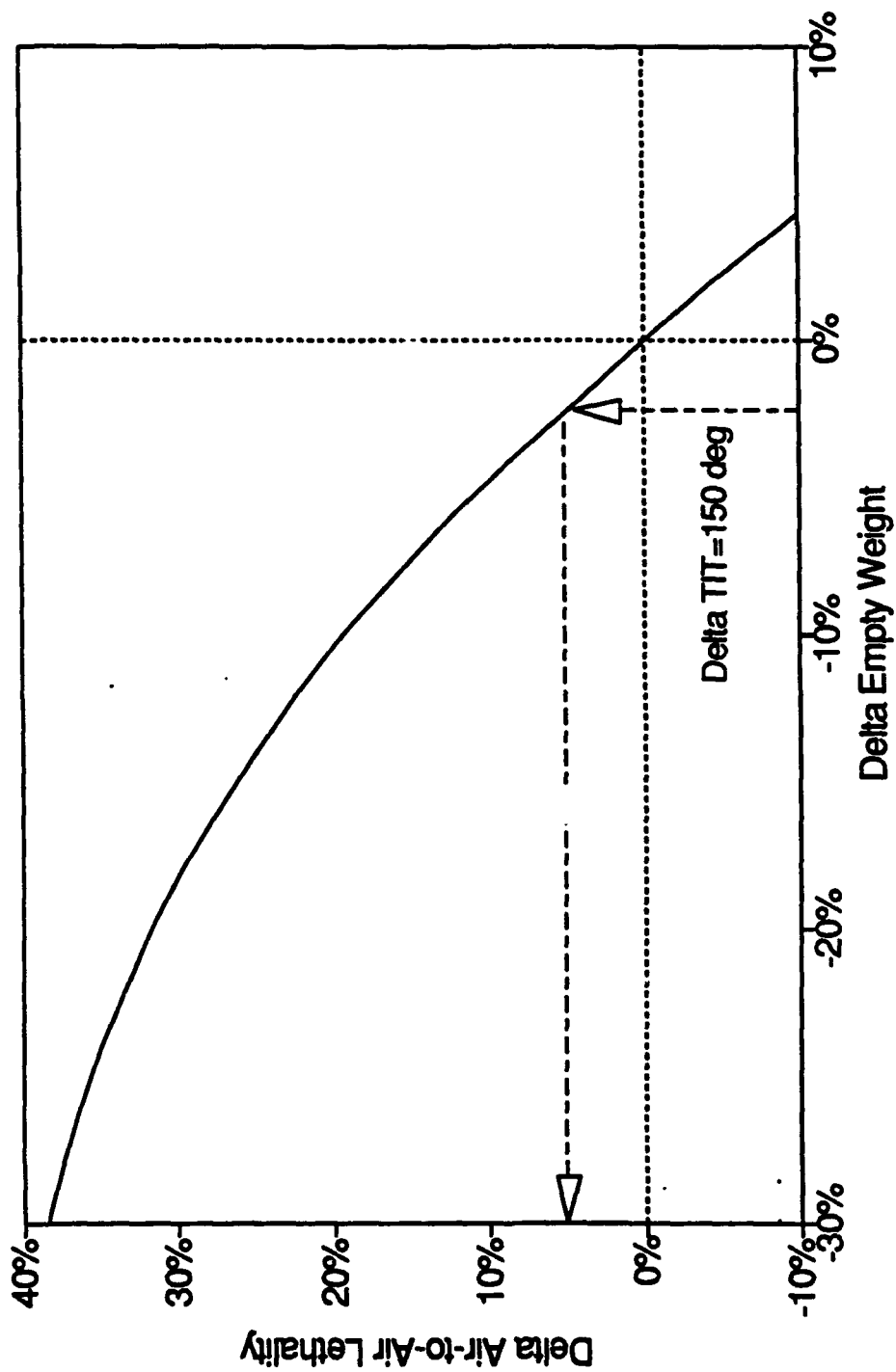
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Delta Fuel Weight vs. Delta Turbine Inlet Temperature (TIT)
Constant Range Performance -- Baseline TIT = 1260 deg K



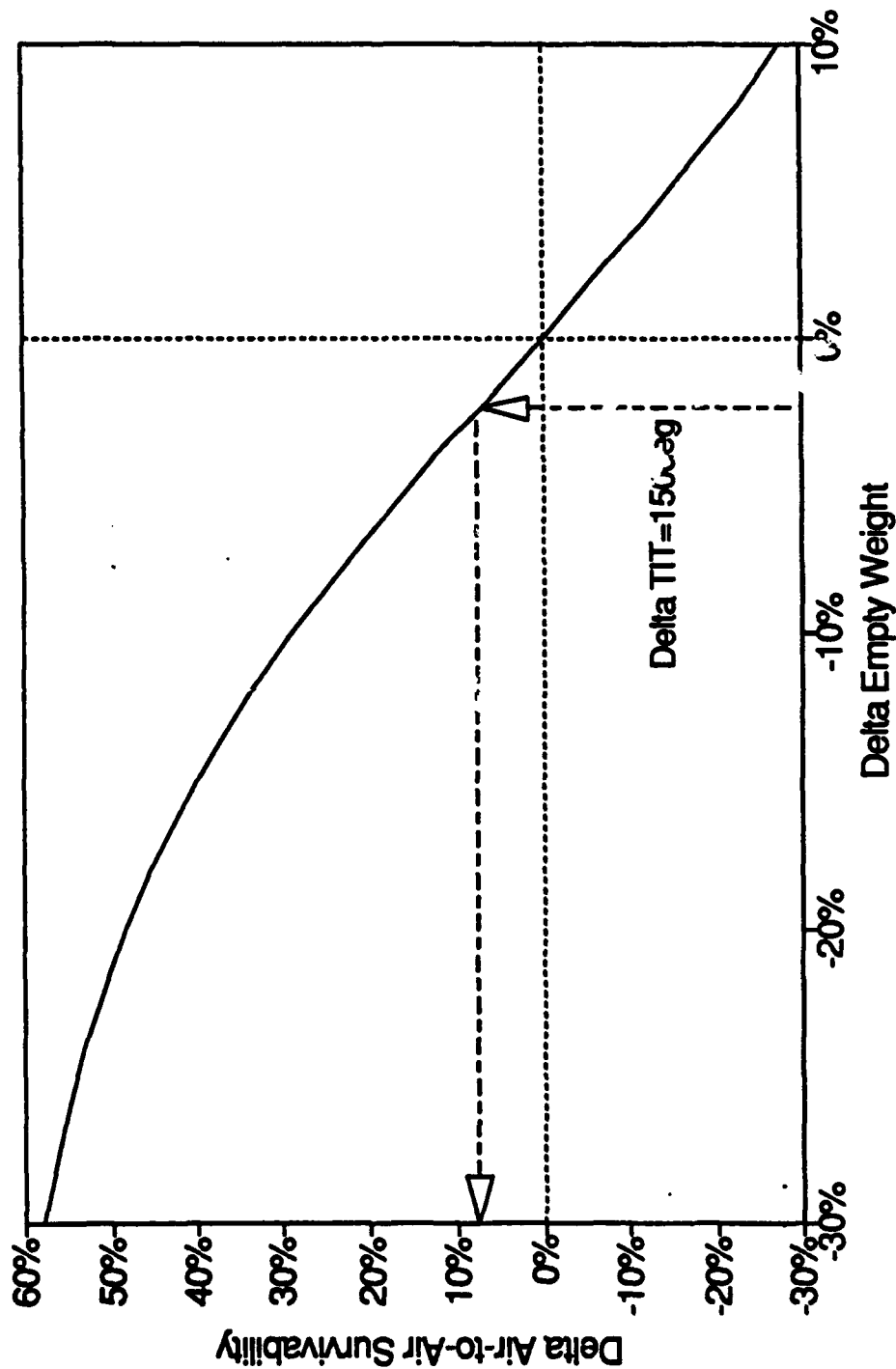
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Delta Air-to-Air Lethality vs Delta Empty Weight
Data From Engagement Level Outcomes



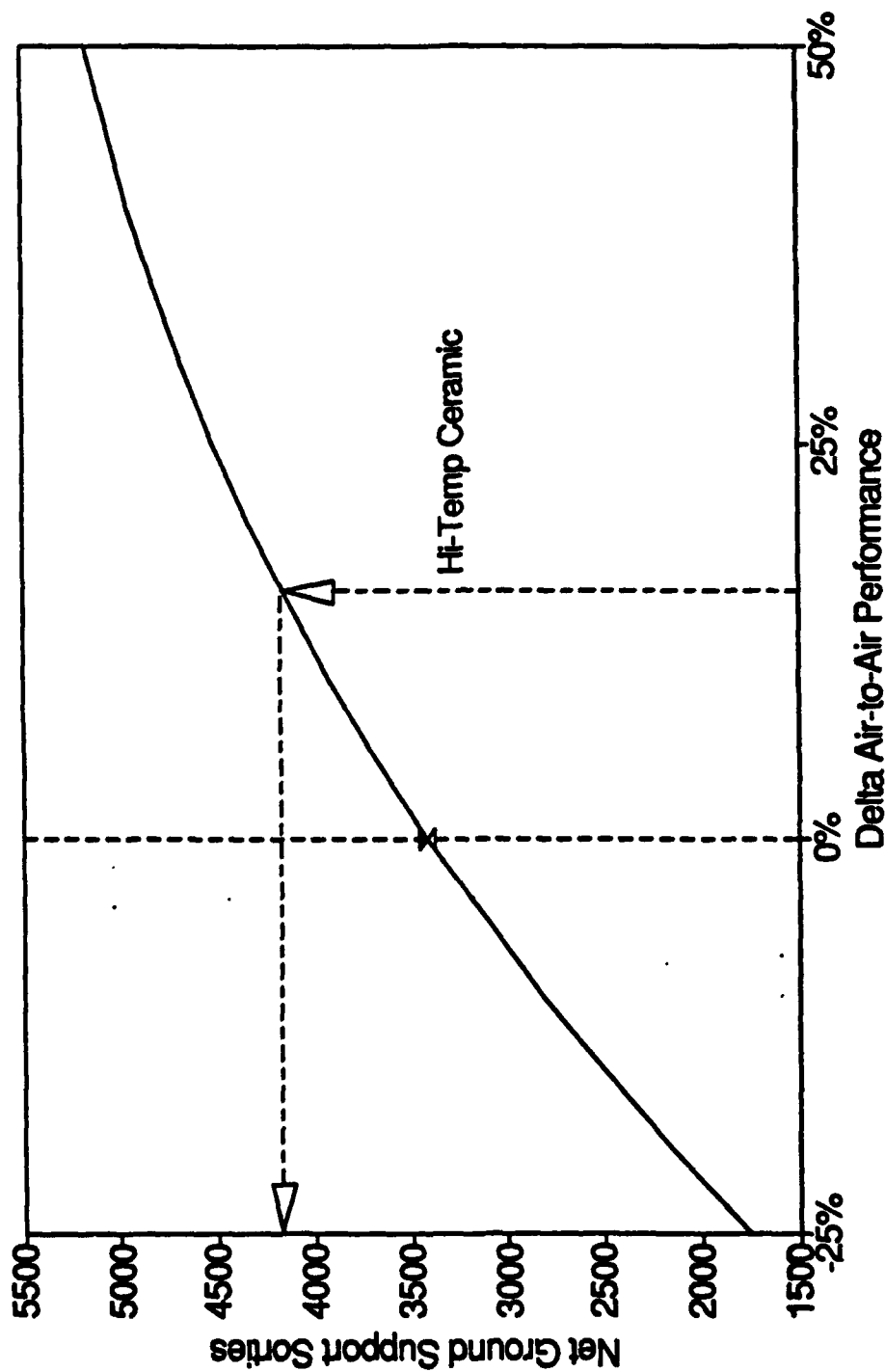
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Delta Air - Air Survivability vs Delta Empty Weight
 Data From Engagement Level Outcomes



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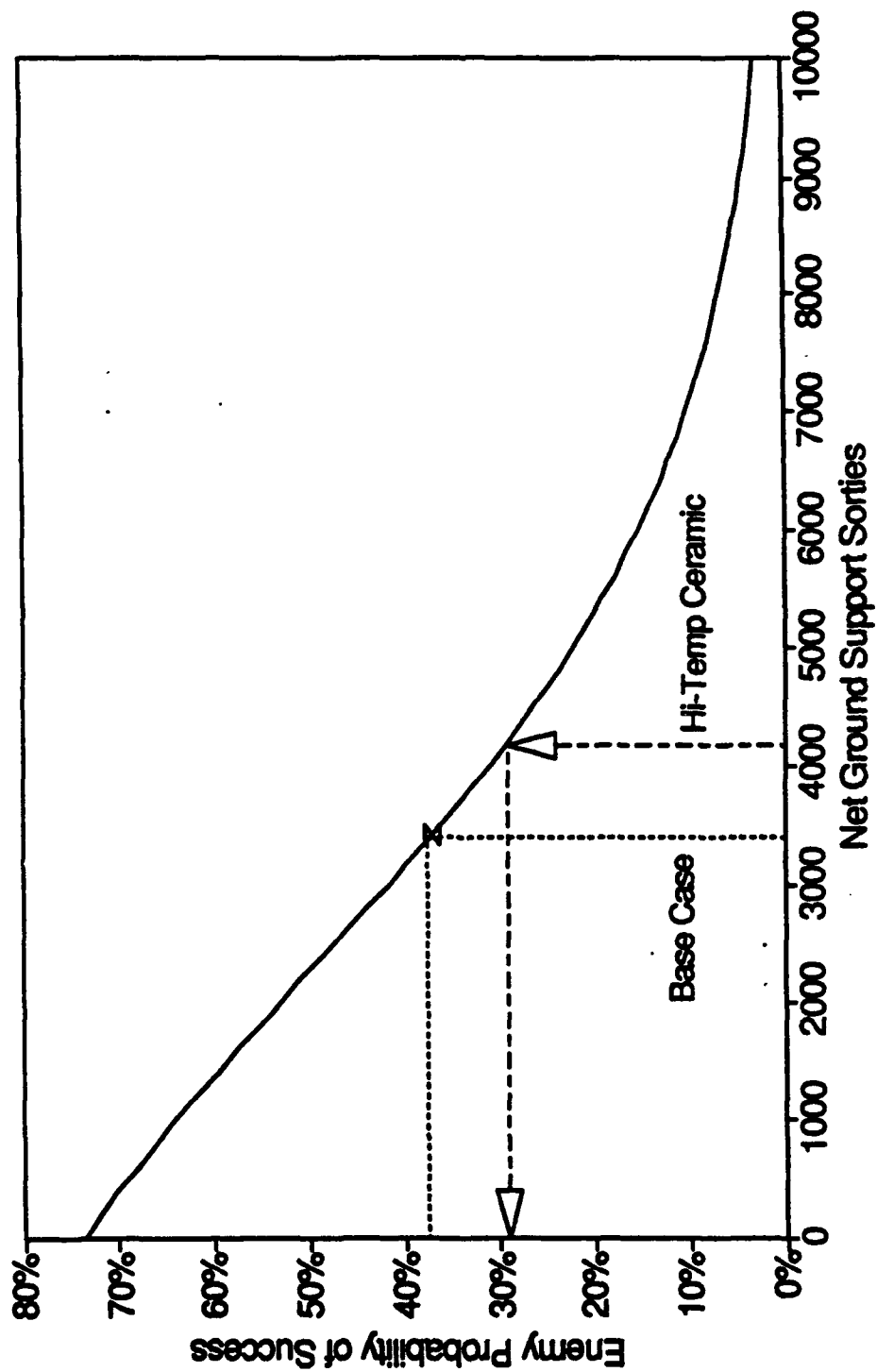
Net Ground Support Sorties vs Air-to-Air Performance Mid-East - Baseline Advanced Aircraft



(0.8 x delta Lethality + 0.2 x delta Survivability)

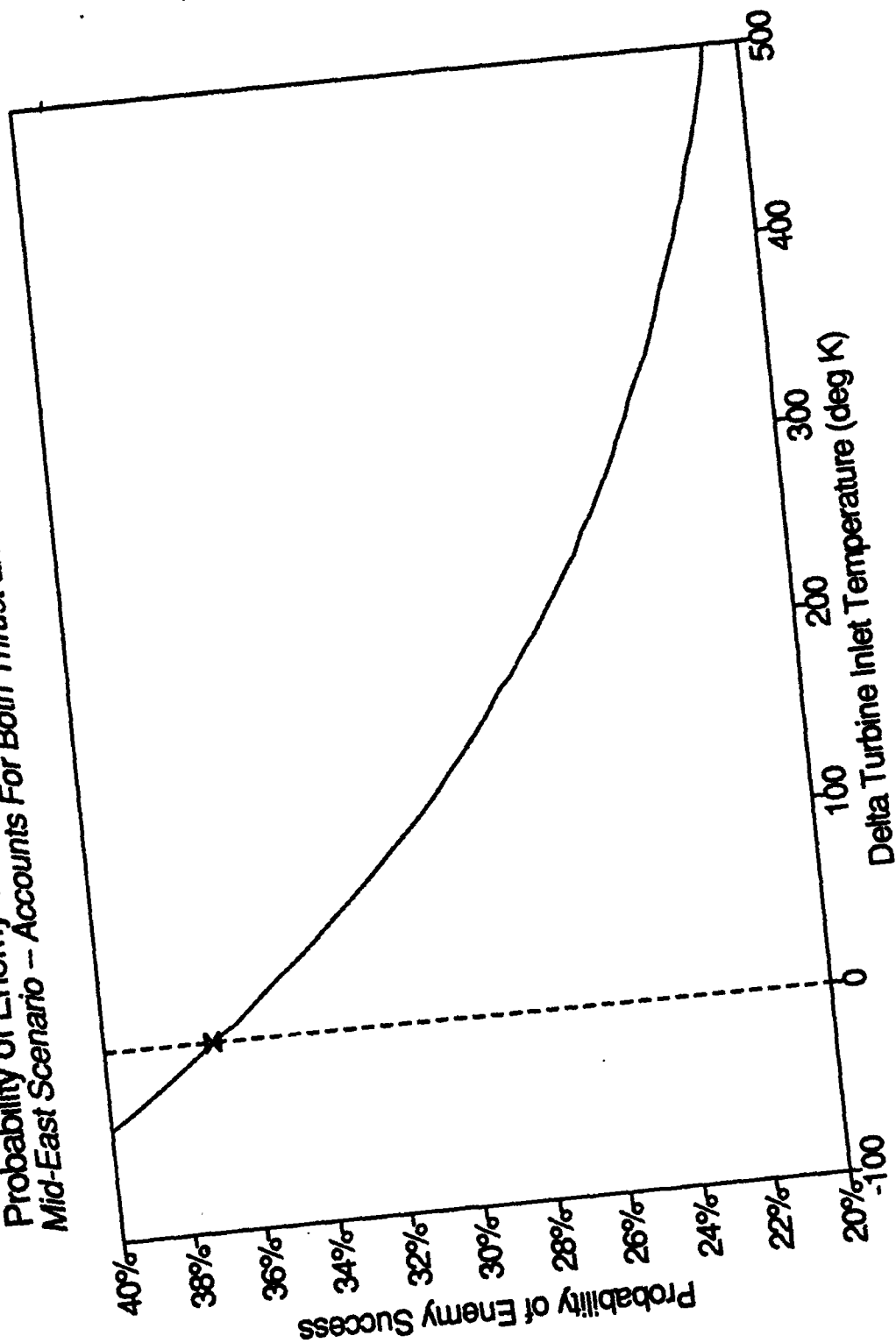
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Enemy Probability of Success vs Net Ground Support Sorties Mid-East -- Baseline Advanced Aircraft



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Probability of Enemy Success vs Delta Turbine Inlet Temperature
Mid-East Scenario - Accounts For Both Thrust and Weight Improvements



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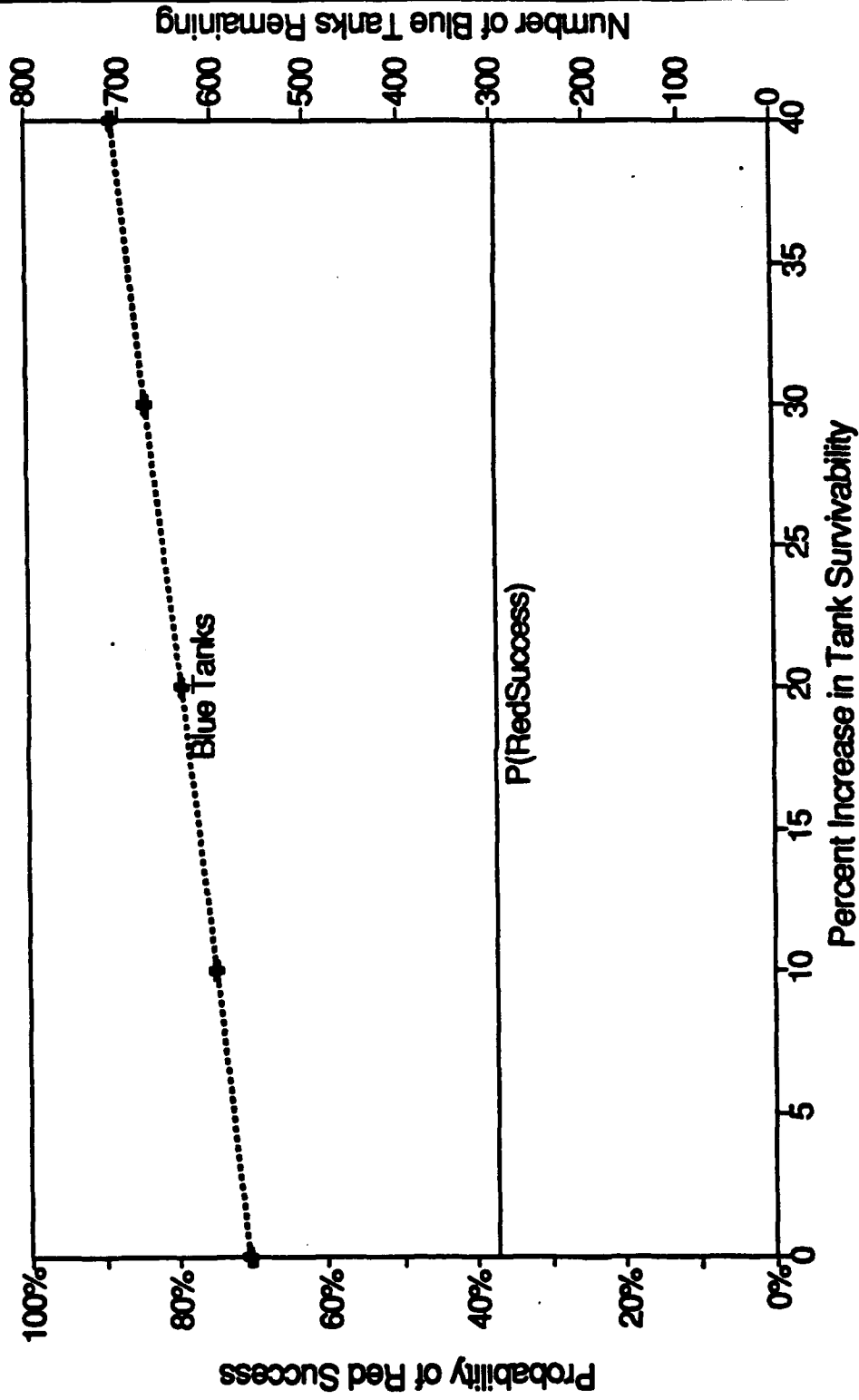
Slide Title: Probability Red Success vs. Increased Tank Survivability

Text: This graph shows the impact of increased tank survivability on the campaign.

The right axis shows the impact on the number of tanks remaining at the end of the 20-day period, as a function of increased tank survivability.

The left axis shows the impact of tank survivability on $P(\text{Red success})$. Little impact is evident in this scenario, in which Blue tries not to engage ground forces. In a European scenario, which entails more ground conflict, the contribution of tanks to $P(\text{Red success})$ would be greater.

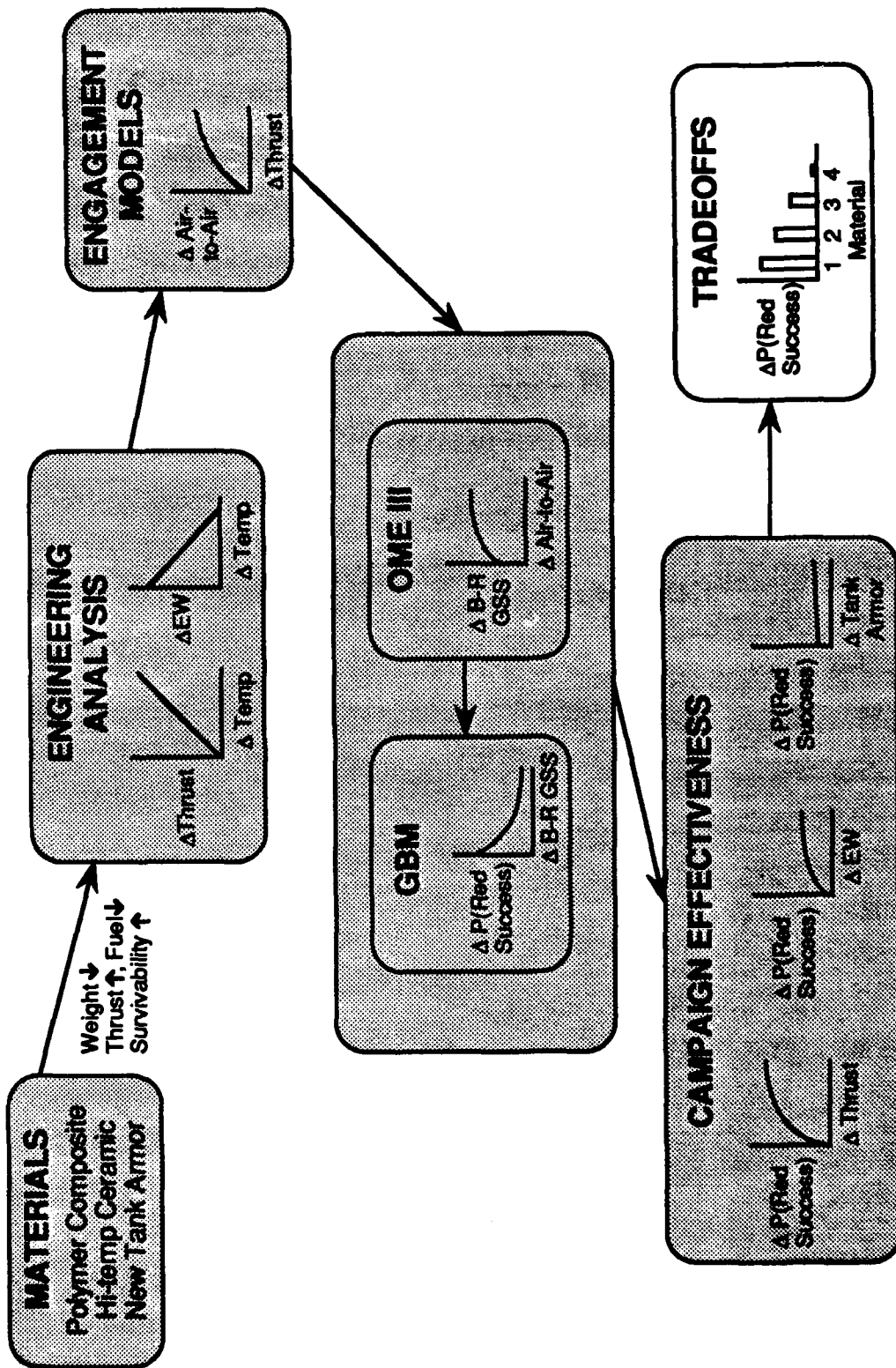
Probability Red Success vs. Increased Tank Survivability Mid East Scenario



Slide Title: Where we are - Tradeoffs

Text: This last series of slides compare the development costs of these new technologies to the cost of buying more advanced fighters.

EVALUATION OF NEW MATERIALS



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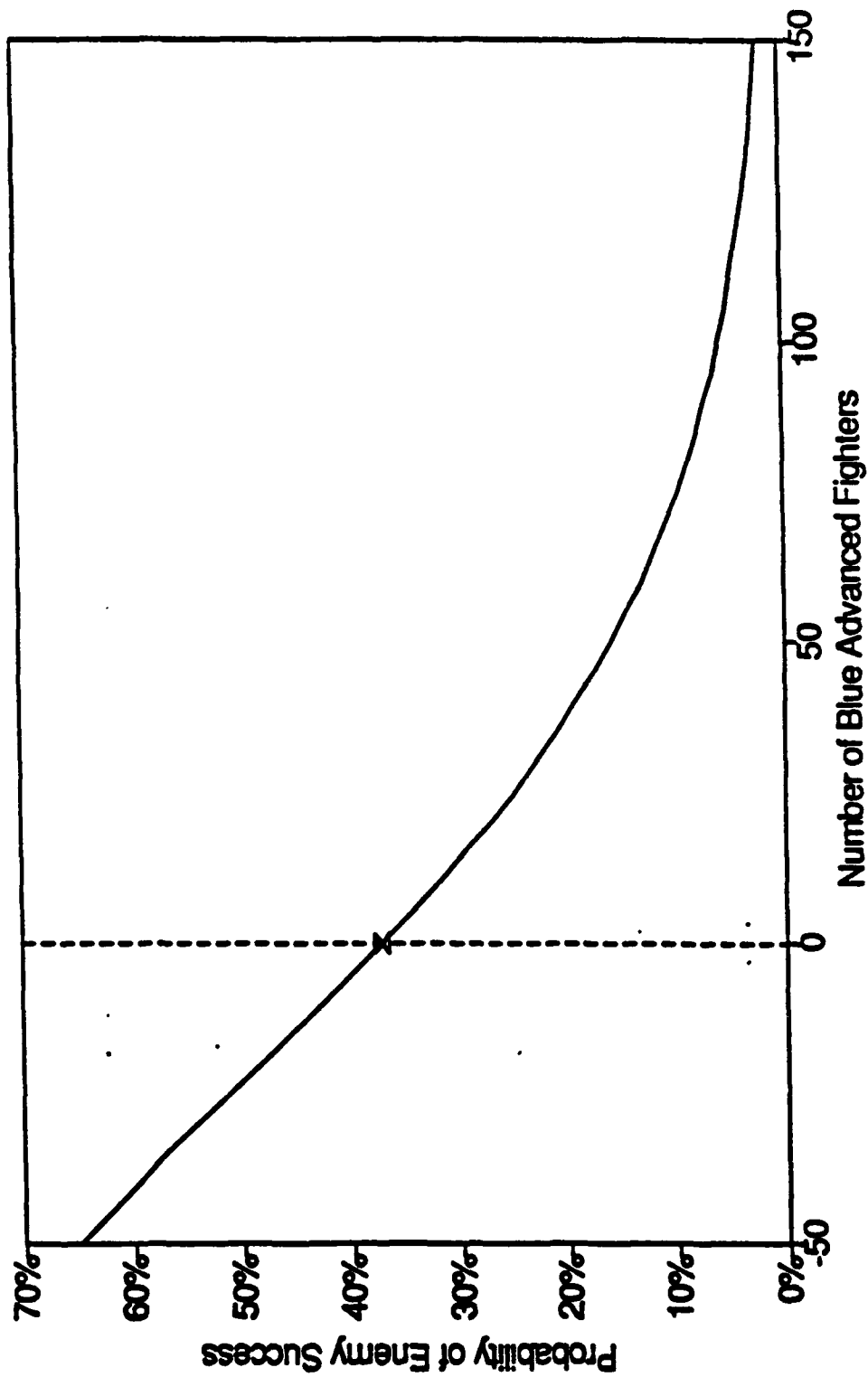
Slide Title: Probability of Enemy Success vs Number of Blue Advanced Fighters

Text:

Cost effectiveness analyses are performed to compare various options. These analyses should be performed at the theater level. A baseline can then be chosen for comparisons -- comparing the cost of development of new technologies to the cost of buying more advanced fighters. What we ultimately want to determine is the break-even cost of research compared to the cost of simply buying more aircraft.

For comparison, we therefore need the curve of probability of enemy success as a function of the number of advanced fighter available to the conflict.

Probability of Enemy Success vs Number of Blue Advanced Fighters
Mid-East Scenario -- Fighters in Theater and Available From Start



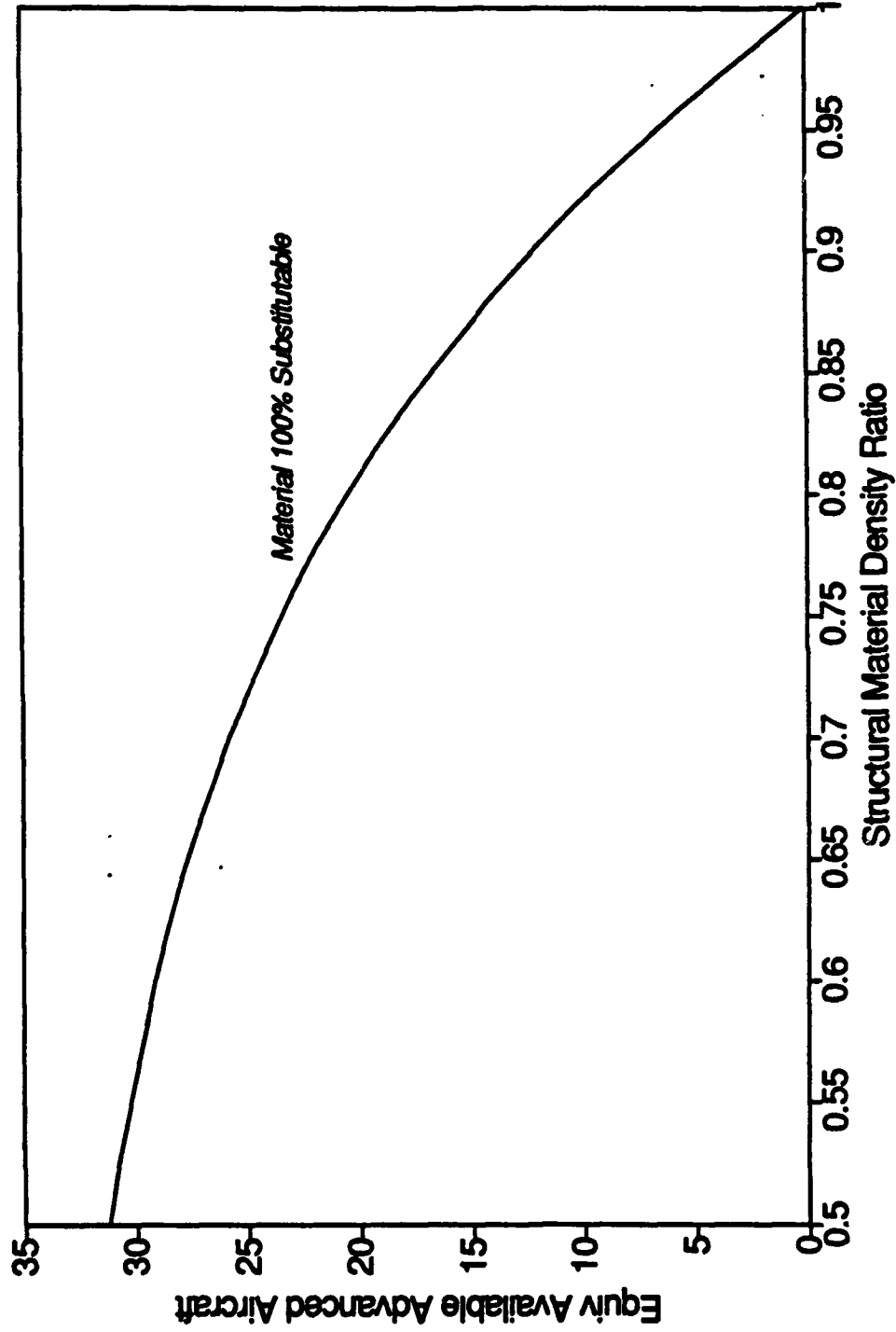
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Slide Title: Equivalent Available Aircraft vs Delta Material Density Ratio

Text:

This slide shows the equivalent number of additional advanced fighter aircraft required to achieve the same delta P (red success) produced by using an advanced material to reduce aircraft empty weight.

Equiv Available Advanced Aircraft vs Material Density Ratio
"Available" = In Place At Beginning Of Conflict

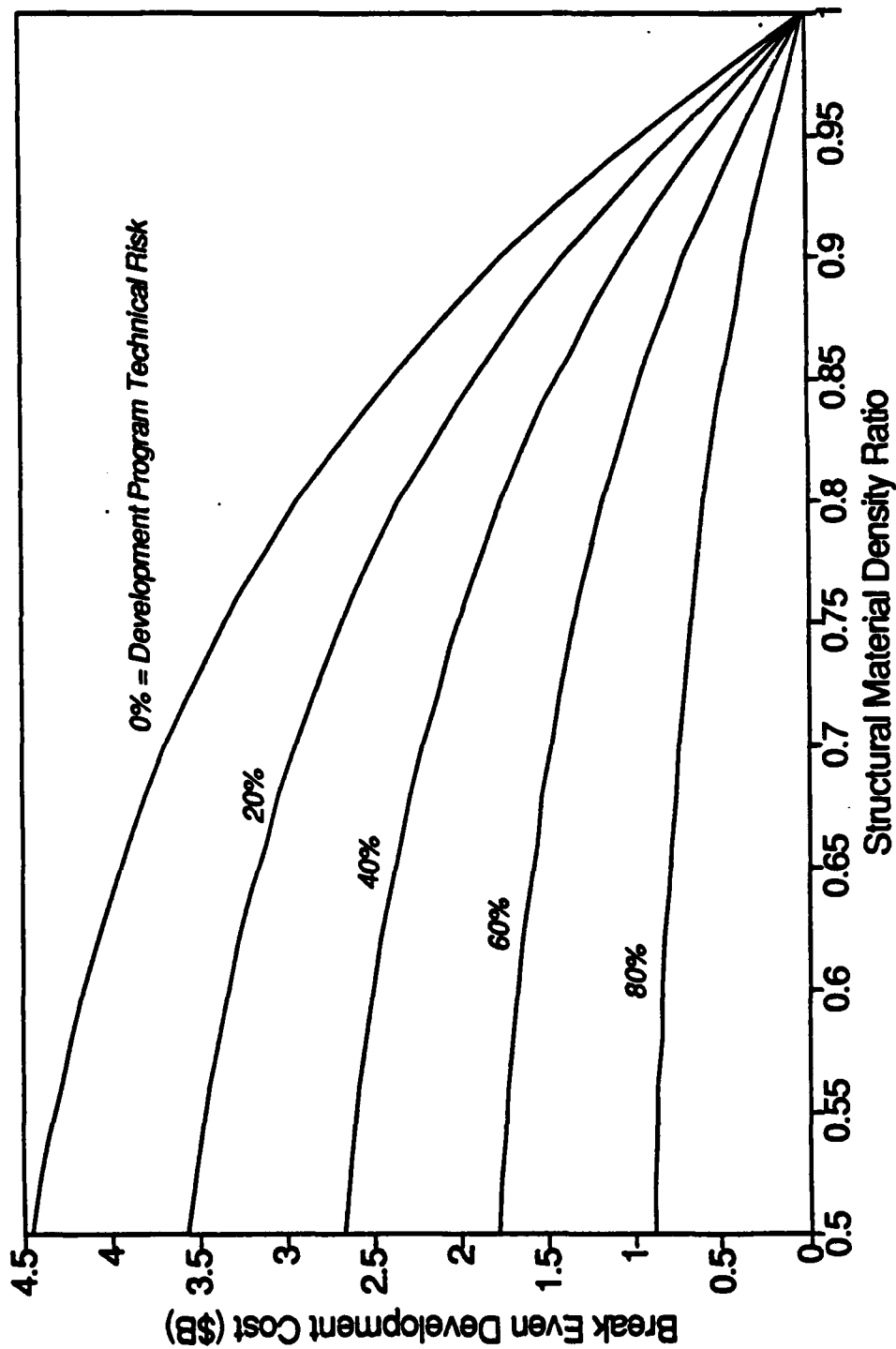


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Slide Title: Break Even Development Cost vs. Material Density Ratio

Text: This slide compares the break even development cost to the material density ratio.

Break Even Development Cost vs Material Density Ratio Compared to More Aircraft Using Typical Life Cycle Cost



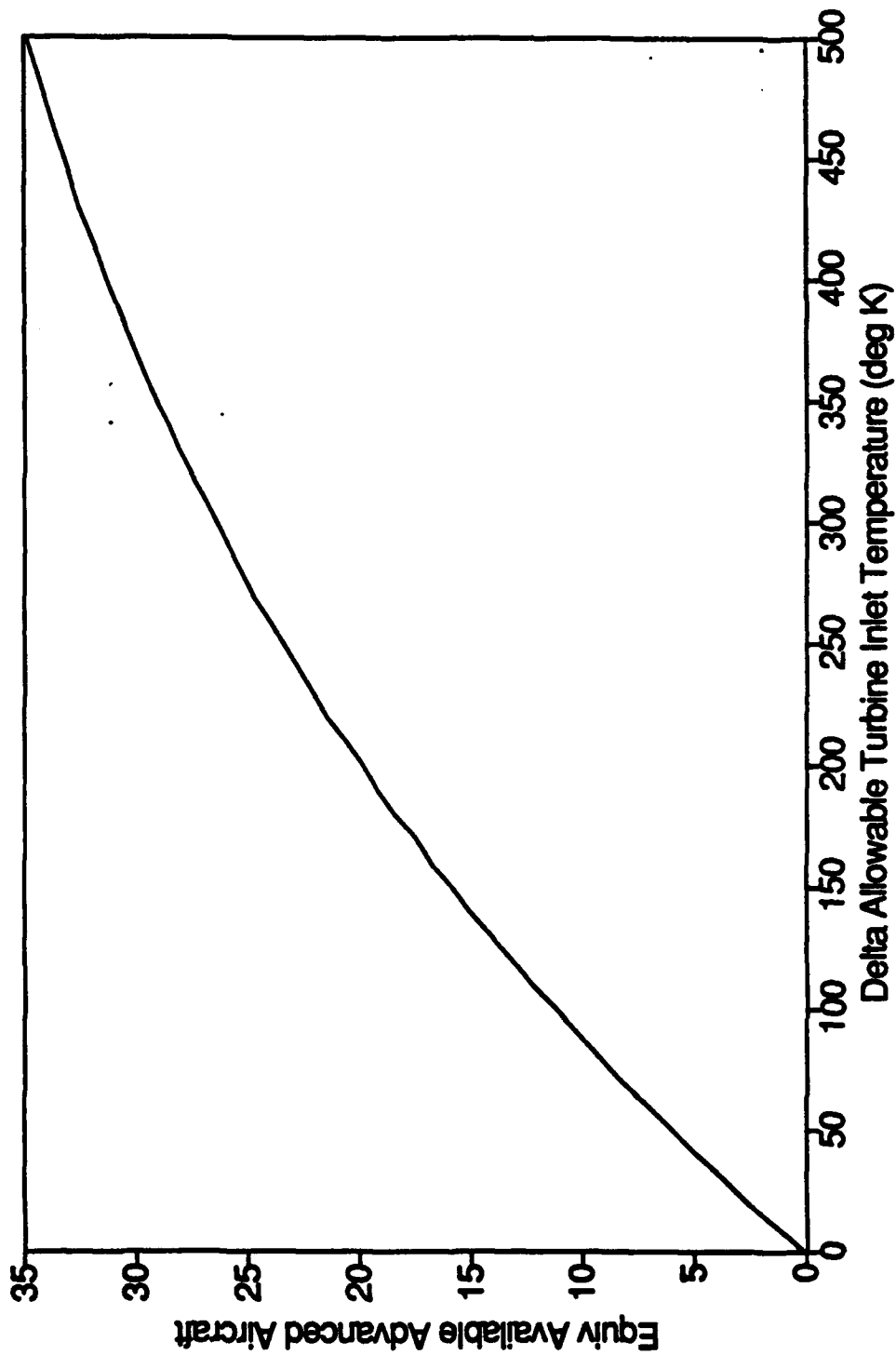
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Slide Title: Equivalent Available Aircraft vs Delta Turbine Inlet Temperature

Text:

This slide shows the equivalent number of additional advanced fighter aircraft required to achieve the same delta P (red success) produced by using an advanced material which allows increases in engine turbine inlet temperature.

Equip Available Advanced Aircraft vs Delta Allowable TIT
"Available" = In Place At Beginning Of Conflict



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Slide Title: Break Even Development Cost vs Delta Allowable TIT

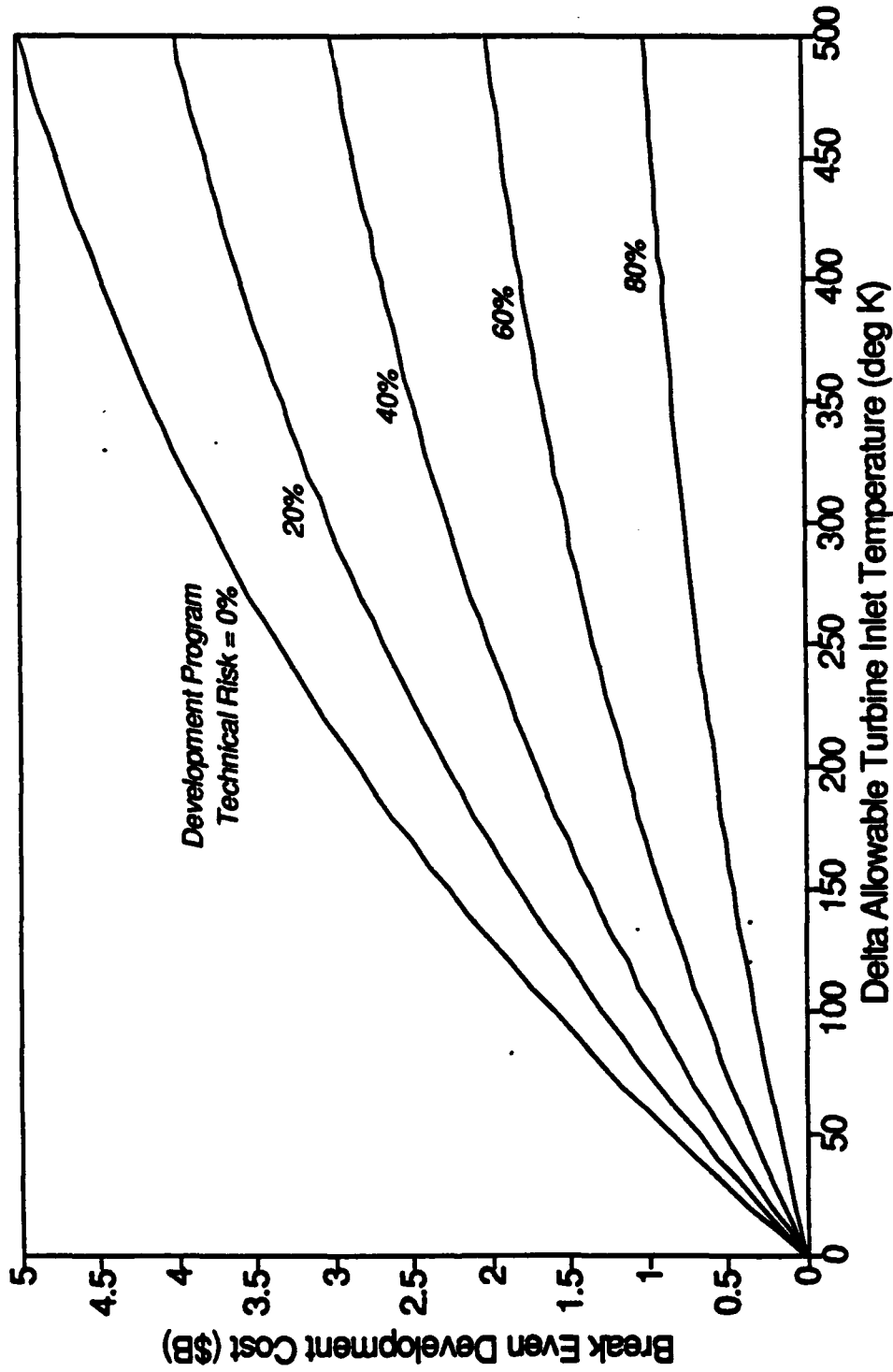
Text: We can then develop this curve, which depicts what the government should be willing to pay to develop a new material for the engine hot section, compared to spending the money on more airplanes. This was arrived at by comparing the ΔP (Red success) for increasing TIT to the ΔP (Red success) for buying more advanced fighters. The technical risk of failure of the development program to achieve the TIT goals is also depicted. The costs considered were:

- \$35 million/aircraft for procurement
- Ratio of life cycle cost to flyaway cost = 2.7
- Standard force planning allowances for:
 - Training (+25%)
 - Backup aircraft inventory (BAI -- +10%)
 - Attrition reserve (300 hrs/aircraft/year, 2 losses/100,000 flying hours)

Note that the cost of getting the aircraft into combat from the start (pro-rata share of additional tanker, airlift, etc.) was not considered.

Curves such as these for the various properties imparted by new materials, structures, radar, weapons, etc, can be used by planners to determine those areas of research which will have the greatest payoff.

**Break Even Development Cost vs Delta Allowable TIT
Compared to More Aircraft Using Typical Life Cycle Cost**



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Slide Title: The Bottom Lines

Text: In today's world of shrinking budgets and force reductions, it is necessary for military planners to find new tools to assist them in making development and procurement decisions for existing and new technology.

The key benefit provided by any combat system is its effectiveness in projected conflict scenarios. A comparison of the combat effectiveness of different elements on the battlefield can only be performed using a theater-level campaign model.

To address this need for theater-level campaign analyses, STR has developed the Force Planning Analysis Framework (FPAF). The FPAF consists of:

- 1) Optimal Marginal Evaluator III (OME III), which models the air portion of a campaign over time
- 2) The Ground Battle Model (GBM) which models the ground portion of a campaign over time
- 3) A set of projected conflict scenarios
- 4) An integer linear program which determines which mix of options maximizes effectiveness within cost and other constraints.

OME III and the GBM are unique in that they use game theory and dynamic programming to determine the best force employment strategy for both sides -- hence overcoming the flaw in past theater level effectiveness analyses.

THE BOTTOM LINES

We have developed a comprehensive process for estimating the contributions of advanced materials and structures to campaign effectiveness at the theater level

This process can be used for analysis of any weapon system in the conventional theater

The key to the analysis is STR's structured Force Planning Analysis Framework (FPAF). Consists of the Kent "Strategy to Task" construct, within which operate:

- **Optimum Marginal Evaluator III (OME III) model - the CRUCIAL ELEMENT**
- **Ground battle model**
- **A set of projected conflict scenarios**
- **Tools for decision analysis (data bases, effectiveness and cost parameters, mixed integer linear program, etc.)**

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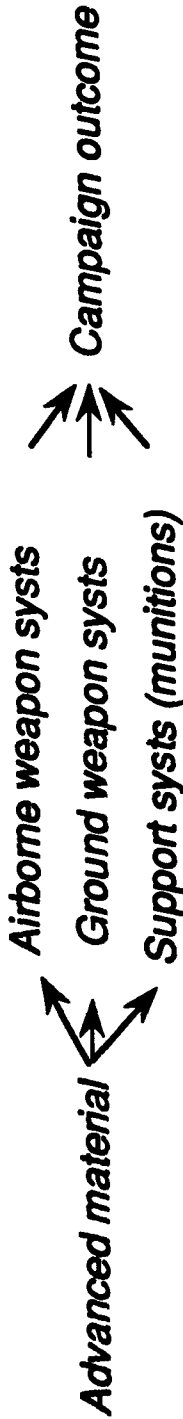
Slide Title: Other Considerations

Text:

We believe we have successfully demonstrated the ability to measure the potential combat value of inserting advanced materials and structures into weapon system components, through the use of the OMEll and GB models. The methodology is wide in scope and is totally flexible in execution. By estimating how an advanced material could be applied to the spectrum of weapon and support systems, the total combat value of a material can be determined. The value of a material with an application to a single weapon, but a large impact on that weapon, can be compared with one that applies to many systems, but has only a small impact on each. Materials with applications to ground weapons can be compared to air weapon applications or any combination of applications.

The system of parametrics developed for the project will solve the time dilemma of using combat modeling to support the decision process. Six months of lead time will not be required to get a result. As long as the scenarios and assumptions hold the modeling is pre-accomplished.

Other Considerations

- We have demonstrated the capability to map changes in the engineering characteristics of advanced materials to campaign level outcomes
 - The defined method is flexible and has wide application
 - By examining likely applications for an advanced material the total potential impact of the material on the campaign can be determined
- 
- ```
graph LR; AM[Advanced material] --> AWS[Airborne weapon systs]; AM --> GWS[Ground weapon systs]; AM --> SS[Support systs (munitions)]; AWS --> CO[Campaign outcome]; GWS --> CO; SS --> CO;
```
- This allows comparisons of materials that potentially affect ground systems only with one that affects air systems or ground and air systems
  - The system of parametrics developed for the project will assure an advanced material assessment can be made when it is needed
    - Extensive model runs will not be required

**Slide Title:** Other Considerations (Continued)

**Text:** The methodology that has been defined in this project has application beyond the assessment of advanced materials which was the object of the project. The tool could be used to compare the potential value of spending money in the area of materials and structures with other technologies. We demonstrated how the tool could be used to examine the tradeoff between advanced materials development and force structure. The same technique can be applied to trade offs between other technology areas such as advanced computational capability.

Lastly, The project demonstrated the capability on a Mid East planning scenario. Prudence, however would dictate that decisions be based on analyses conducted across a spectrum of scenarios, not just one.

### ***Other Considerations (Continued)***

- The method has application beyond materials into other technologies.
- Examples
  - Increased performance resulting from an advanced material with a change in force structure (demonstrated)
  - Could allow competing an advanced material with a change in computational power of on board computers
  - Or (any other participant in conventional conflict) with (any other participant)
- Prudent planning dictates that decisions be based on analyses conducted across the spectrum of worrisome planning scenarios.

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***Slide Title:*** Phase II Project Description

***Text:*** The next two slides describe our proposal for the Phase II project.

## **PHASE II PROJECT DESCRIPTION**

### **Task 1. Engineering and engagement analyses**

- In coordination with the sponsor define the set of materials/weapon system components of interest
- In coordination with the sponsor or sponsor designated agencies define the engineering parameters of the selected set of materials and weapon system components
- Using defined engineering parameters conduct engagement level analysis to determine the impact of the selected set of material/weapon system components at that level.

### **Task 2. OMEIII/IV and GB Campaign level modeling**

- Review planning scenario, forces and assumptions with the sponsor and adjust data bases as required
- Conduct base case modeling
- Conduct material/weapon system component modeling
- Conduct sensitivity analysis on the range of materials properties.
- Brief sponsor on the results of the analysis, run additional cases considered necessary

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## **PHASE II PROJECT DESCRIPTION (CONTINUED)**

### **Task 3. Advanced Materials Parametric Application System**

- Design the Parametric Application System necessary to apply the system to problems not specifically modeled
- Code the designed system for use on personal computers
- Document the system to allow efficient transfer to designated users

### **Option 1 Additional scenarios**

- Develop additional scenarios, data bases and assumptions
- Conduct base and material/weapon system component modeling over each of the developed scenarios using OMEIII/IV and the GBM
- Incorporate results into the Parametric Application System

### **Option 2 Cost/Risk Estimation Model**

- Research and identify the major factors which drive cost and technological risk as they apply to advanced material development
- Design and develop an algorithmic model which predicts cost and risk as a function of the defined parameters

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# ***BACKUPS***

**STR**

***Slide Title:*** General Scenario Characteristics

***Text:*** This slide contains general data pertaining to the Middle East theater.

## GENERAL SCENARIO DATA

|                       | <u>BLUE</u> | <u>RED</u> |                       | <u>BLUE</u> | <u>RED</u> |
|-----------------------|-------------|------------|-----------------------|-------------|------------|
| Shelter area (sq ft)  | 3750        | 3750       | P(acquis by SAM)      |             |            |
| Dive angle (degrees)  | 20          | 20         | Airfield attack       | 0.40        | 0.40       |
| Avg dist to FLOT (nm) | 75          | 155        | Sweep                 | 0.40        | 0.40       |
| Total airbases        | 20          | 25         | Force protection      | 0.40        | 0.40       |
| P(Det airbase)        | 0.95        | 0.95       | Defense suppression   | 0.30        | 0.30       |
| Shelters/airbase      | 72          | 45         | Ground support        | 0.40        | 0.40       |
| P(Det shelter)        | 0.82        | 0.80       | Mobile belt lethality |             |            |
| Revetments/airbase    | 36          | 22         | Losses/1000 sorties)  | 10          | 7          |
| P(Det revetment)      | 0.90        | 0.90       | Front length (nm)     | 400         | 400        |
| Total SAM sites       | 70          | 70         | Corridor width        | 100         | 100        |
| Missiles/site         | 12          | 12         | No. of Corridors      | 3           | 3          |
| Reloads/site          | 10          | 10         | Depth of theater(nm)  | 180         | 100        |
| Penetration depth(nm) |             |            | Length of Mission     |             |            |
| Airfield attack       | 155         | 75         | Airfield attack       | 2.5         | 2.5        |
| Sweep                 | 155         | 75         | Sweep                 | 2.2         | 2.2        |
| Force protection      | 155         | 75         | Force protection      | 2.3         | 2.3        |
| Defense suppression   | 90          | 50         | Defense suppression   | 2.1         | 2.1        |
| Ground support        | 70          | 70         | Ground support        | 1.8         | 1.8        |
| Pk (by SAMs)          |             |            | Air defense           | 1.0         | 1.0        |
| Airfield attack       | 0.10        | 0.15       | A/C coord capacity    | 400         | 300        |
| Sweep                 | 0.10        | 0.15       | Sorties to close afld | 27          | 27         |
| Force protection      | 0.10        | 0.15       |                       |             |            |
| Defense suppression   | 0.07        | 0.07       |                       |             |            |
| Ground support        | 0.15        | 0.15       |                       |             |            |

**STR**

***Slide Title:*** Fighter Air-to-air Capability

***Text:*** Air-to-air engagement lethality and survivability results were obtained from TAC Brawler runs. The data include six vs. two, four vs. four, and two vs. two aircraft in both low and high states of situation awareness. Data are included for each Blue aircraft type vs. each Red aircraft type. Because of the level of detail and classification of these data, these results are not specifically provided in the report of this demonstration.

## ***FIGHTER AIR-TO-AIR CAPABILITY***

- Air-to-air engagement lethality and survivability:
  - TAC Brawler runs
  - Each Blue aircraft type vs. each Red aircraft type
- Data included:
  - six vs. two      • four vs. four
  - two vs. two
- Engagements evaluated in two levels of situation awareness
  - High situation awareness
  - Low situation awareness
- Not specifically provided in the report

**STR**

**Slide Title:** Fighter Air-to-ground Data

**Text:** Specific data for individual aircraft types regarding expected kills , terminal attrition etc. are classified. To keep this report unclassified, these data have been averaged and weighted by the numbers of aircraft. Specific data is presented for our notional fighter since these numbers are estimates and do not reflect an existing aircraft. Blue data reflects the average allied aircraft and Red data the average Iranian aircraft.

## FIGHTER AIR-TO GROUND DATA

| <u>AIR-TO-GROUND DATA</u> | <u>ADV FTR</u> | <u>BLUE</u> | <u>RED</u> |
|---------------------------|----------------|-------------|------------|
| EK against                |                |             |            |
| Shelters                  | 0.98           | 0.98        | 0.43       |
| SAMs                      | 0.75           | 0.62        | 0.33       |
| Total Cluster             |                |             |            |
| Submunitions              | 2600           | 4514        | 2721       |
| Term Attrition vs         |                |             |            |
| A/C in Shelters           | 0.0020         | 0.0047      | 0.0078     |
| A/C in Open               | 0.0030         | 0.0047      | 0.0078     |
| A/C in Revetments         | 0.0010         | 0.0029      | 0.0043     |
| SAMs                      | 0.0030         | 0.0047      | 0.0078     |
| Ground Forces             | 0.0029         | 0.0029      | 0.0035     |
| Sortie Rate               |                |             |            |
| Day 1-6                   | 2.80           | 2.40        | 2.24       |
| Day 7-20                  | 1.10           | 1.19        | 1.22       |

**STR**

***Slide Title:*** Expected Kills Against Ground Targets

***Text:*** Expected kills against each ground target in the front and rear are summarized on this slide. Cluster munitions and missiles are shown for Blue and Red, top attack munitions apply to Blue only.

# **EXPECTED KILLS AGAINST GROUND TARGETS**

## **BLUE VS RED TARGETS**

|         | <u>Missile</u> |      | <u>Top Atk</u> |       | <u>Cluster</u> |      |
|---------|----------------|------|----------------|-------|----------------|------|
|         | Front          | Rear | Front          | Rear  | Front          | Rear |
| Tanks   | 3.45           | 1.90 | 12.09          | 15.49 | 0.02           | 0.02 |
| APCs    | 3.45           | 1.90 | 12.83          | 17.57 | 0.08           | 0.06 |
| SP Arty | 3.45           | 1.90 | 12.58          | 16.79 | 0.09           | 0.07 |
| T-Arty  | 3.45           | 1.90 | 0              | 0     | 0.06           | 0.04 |
| Trucks  | 3.45           | 1.90 | 10.26          | 11.86 | 1.40           | 1.11 |
| Person  | 0              | 0    | 0              | 0     | 8              | 0    |

## **RED VS BLUE TARGETS**

|         | <u>Missile</u> |      | <u>Cluster</u> |      |
|---------|----------------|------|----------------|------|
|         | Front          | Rear | Front          | Rear |
| Tanks   | 2.56           | 1.38 | 0.02           | 0.01 |
| APCs    | 2.56           | 1.38 | 0.06           | 0.05 |
| SP Arty | 2.56           | 1.38 | 0.07           | 0.05 |
| T-Arty  | 2.56           | 1.38 | 0.04           | 0.03 |
| Trucks  | 2.56           | 1.38 | 1.10           | 0.85 |
| Person  | 0              | 0    | 6              | 0    |

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