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TITLE: INFRARED SUPPRESSION AND COUNTERMEASURES

METHODOLOGY FOR ADVANCED STRATEGIC AIRCRAFT

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TABLE OF CONTENTS

	<u>PAGE</u>
ABSTRACT AND KEY WORDS	4
1.0 INTRODUCTION AND SUMMARY	5
2.0 DESCRIPTION OF IR SUPPRESSION AND COUNTERMEASURES TRADES	7
2.1 Total Aircraft Radiation Phenomena	7
2.1.1 Hot Engine Parts, Skin, and Exhaust Plume Radiation	8
2.2 Background Effects	8
2.3 Atmospheric Attenuation	9
2.4 Seeker Performance Characteristics	10
2.4.1 Seeker Modulation Efficiency	10
2.4.2 Seeker Lock-On Range	10
2.5 IR Countermeasures Requirements	13
2.5.1 Determination of IR Jammer and IR Decoy Intensity (J)	14
3.0 ANALYSIS OF IR SUPPRESSION AND COUNTERMEASURES METHODOLOGY	16
3.1 Supporting Avionics Trade Studies	16
3.2 IR Suppression and Countermeasures Effectiveness	17
4.0 CONCLUSIONS	18

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LIST OF FIGURES

<u>FIGURE NUMBER</u>		<u>PAGE</u>
1.0-1	Infrared Suppression and Countermeasures Trade Methodology	6
2.3-1	Method for Determining Effective Irradiance Versus Range as a Function of Target Radiation, Atmosphere and Seeker Response	11
2.4-1	Seeker Modulation Efficiency for Extended and Point Source Targets	12

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ABSTRACT

The methodology for establishing optimum infrared suppression and countermeasures requirements for a strategic or tactical aircraft penetrating an infrared threat environment is developed. The methodology recognizes that the critical factor for successful countermeasures is management of spectral energy effectively at the IR seeker rather than at the source. The effects of total air vehicle radiation, atmospheric phenomena, and IR missile seeker performance on IR countermeasures requirements are considered. An equation is developed for calculating IR jammer output power at the source.

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KEY WORDS

IR Suppression
IR Countermeasures
IR Jammer Output Power
Missile Seeker Lock-On Range

1.0 INTRODUCTION AND SUMMARY

Introduction

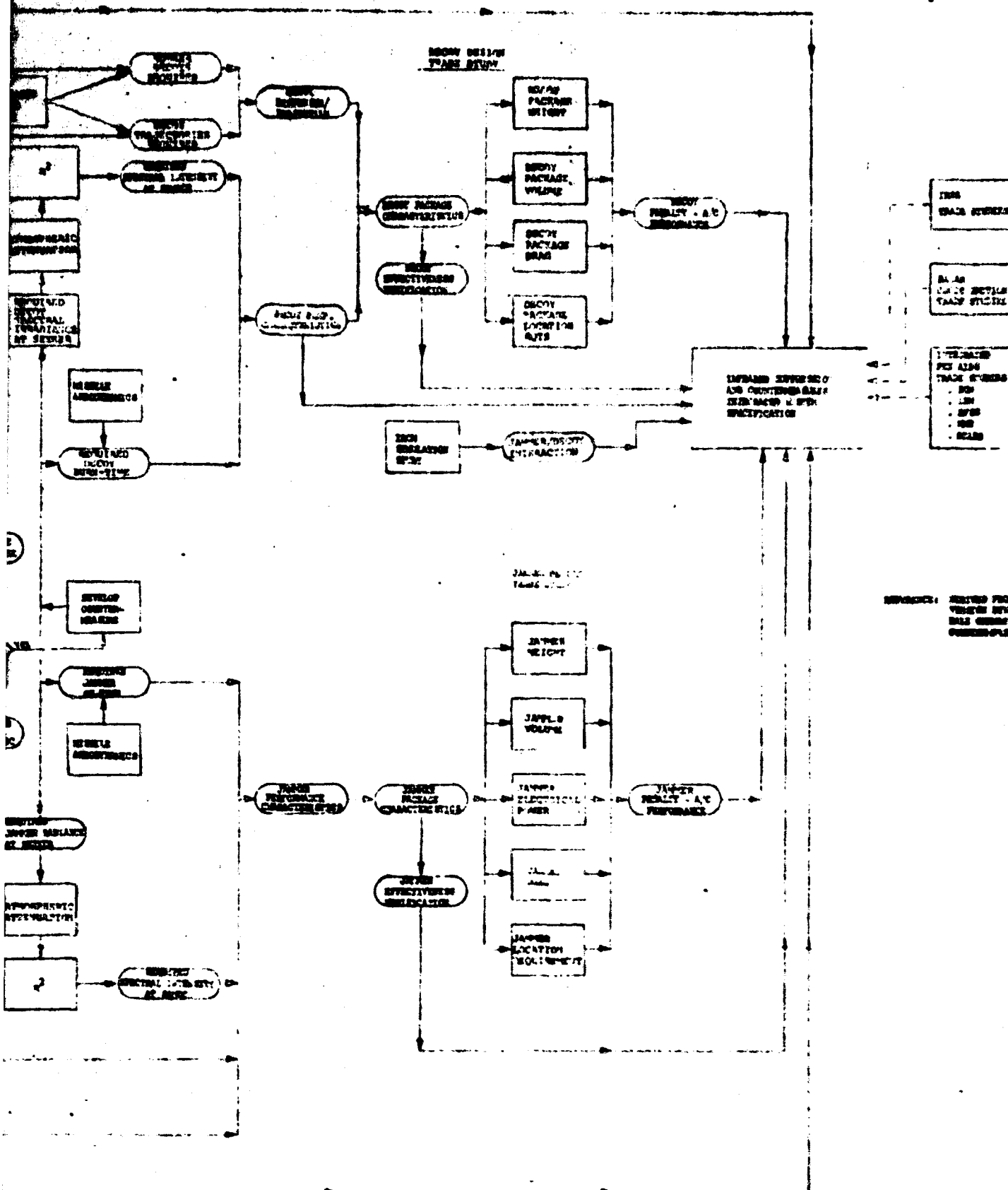
This document was written to record the basic methodology for determination of IR countermeasures requirements for military aircraft.

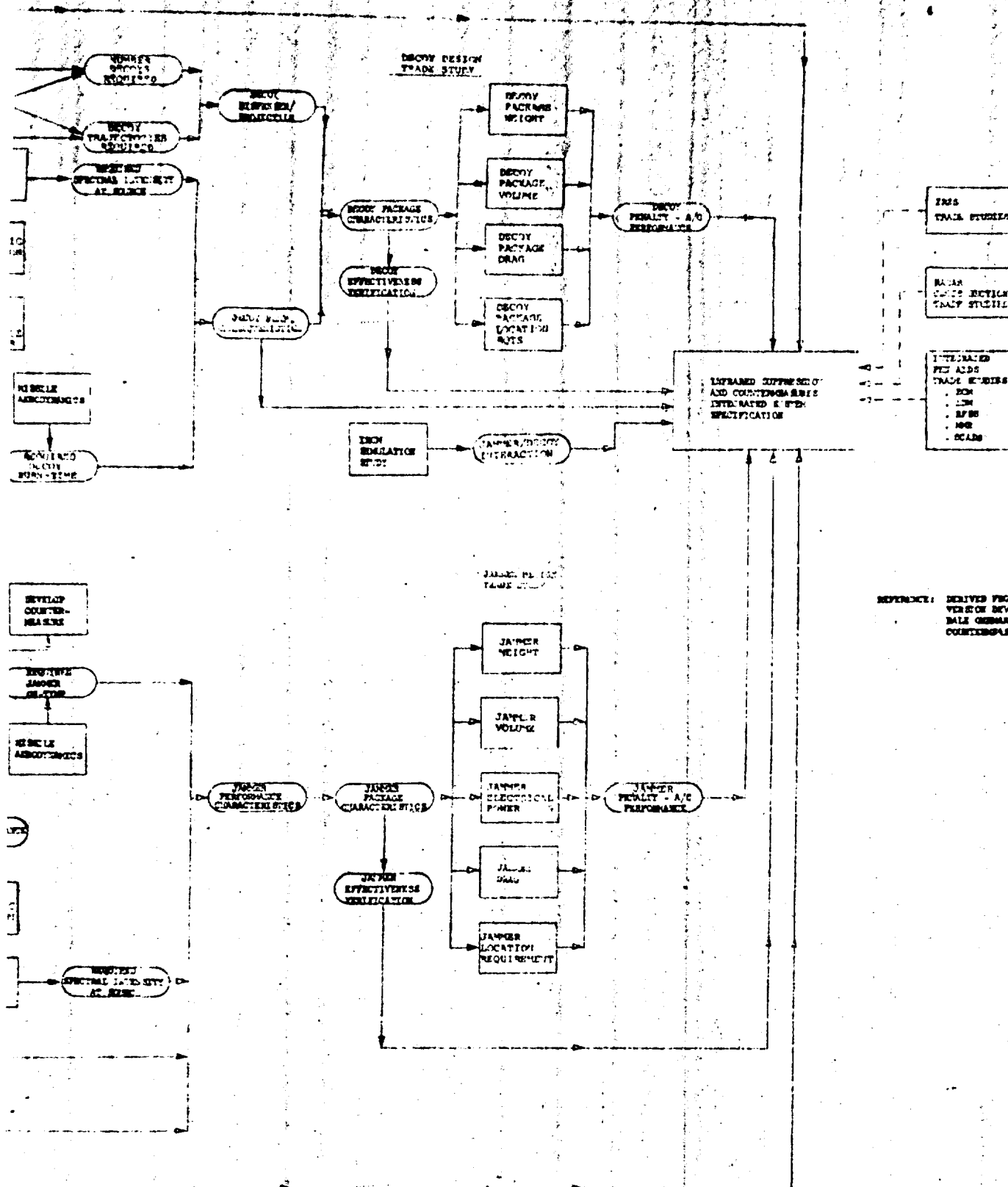
The development of an advanced aircraft weapon system which will effectively penetrate an infrared threat requires consideration of several conflicting subsystem requirements which can only be resolved through design compromises. These design compromises involve aircraft propulsion, aircraft performance, IR threat performance capability, and IR countermeasures, and are realized through a logical sequence of iterative analytical exercises, or trade studies, which finally result in an optimum set of integrated weapon system design specifications.

Summary

The methodology for establishing A/V IR radiation suppression levels and IR countermeasures is described in the trade study flow diagram of Figure 1.0-1. Essentially, the methodology directs itself to assessing two conditions:

(1) A/V IR radiance suppressed to levels which limit the IR seeker capability to effect weapon closure; and (2) suppression and countermeasures required to degrade capability of IR seeker to effect weapon closure.





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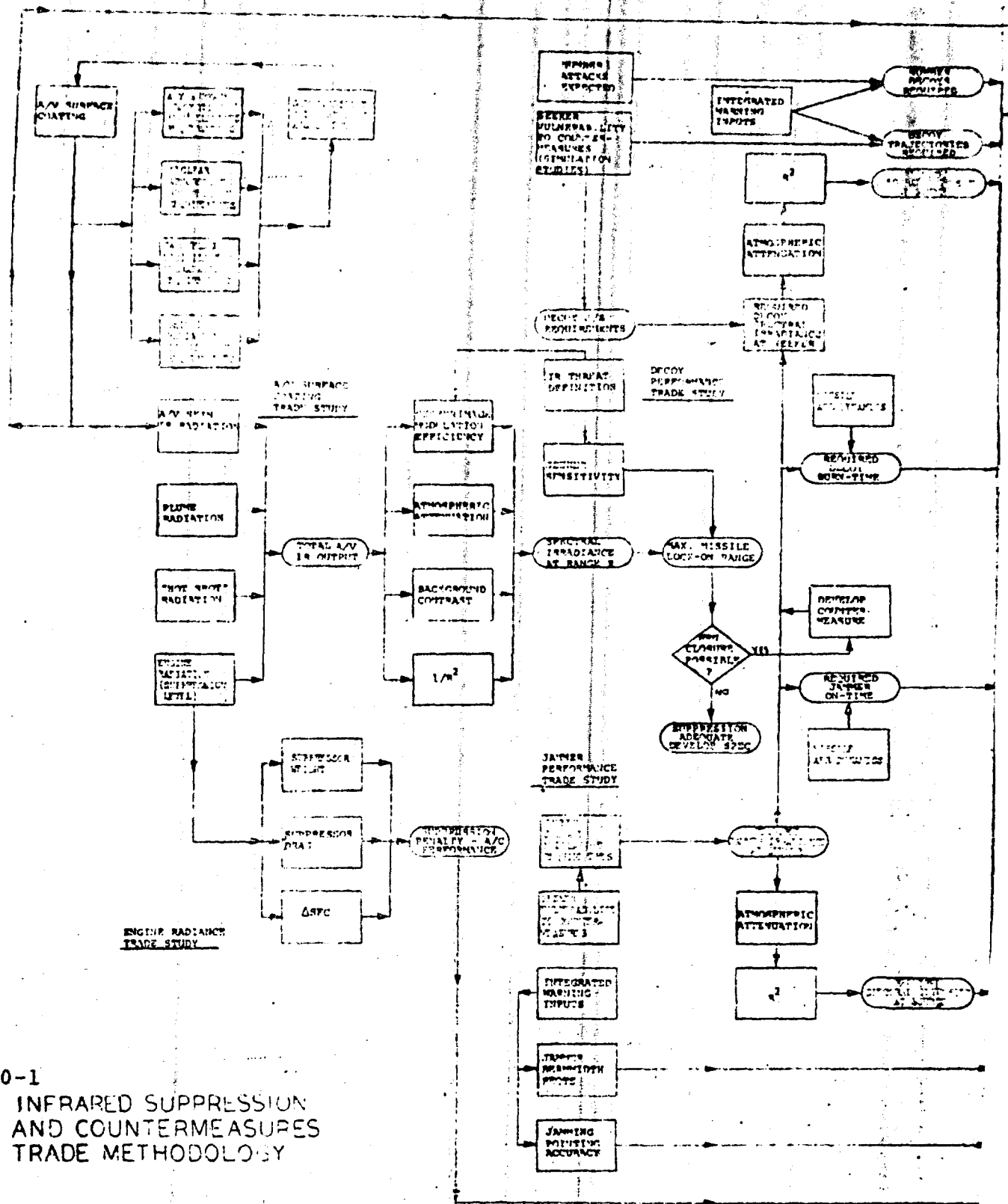
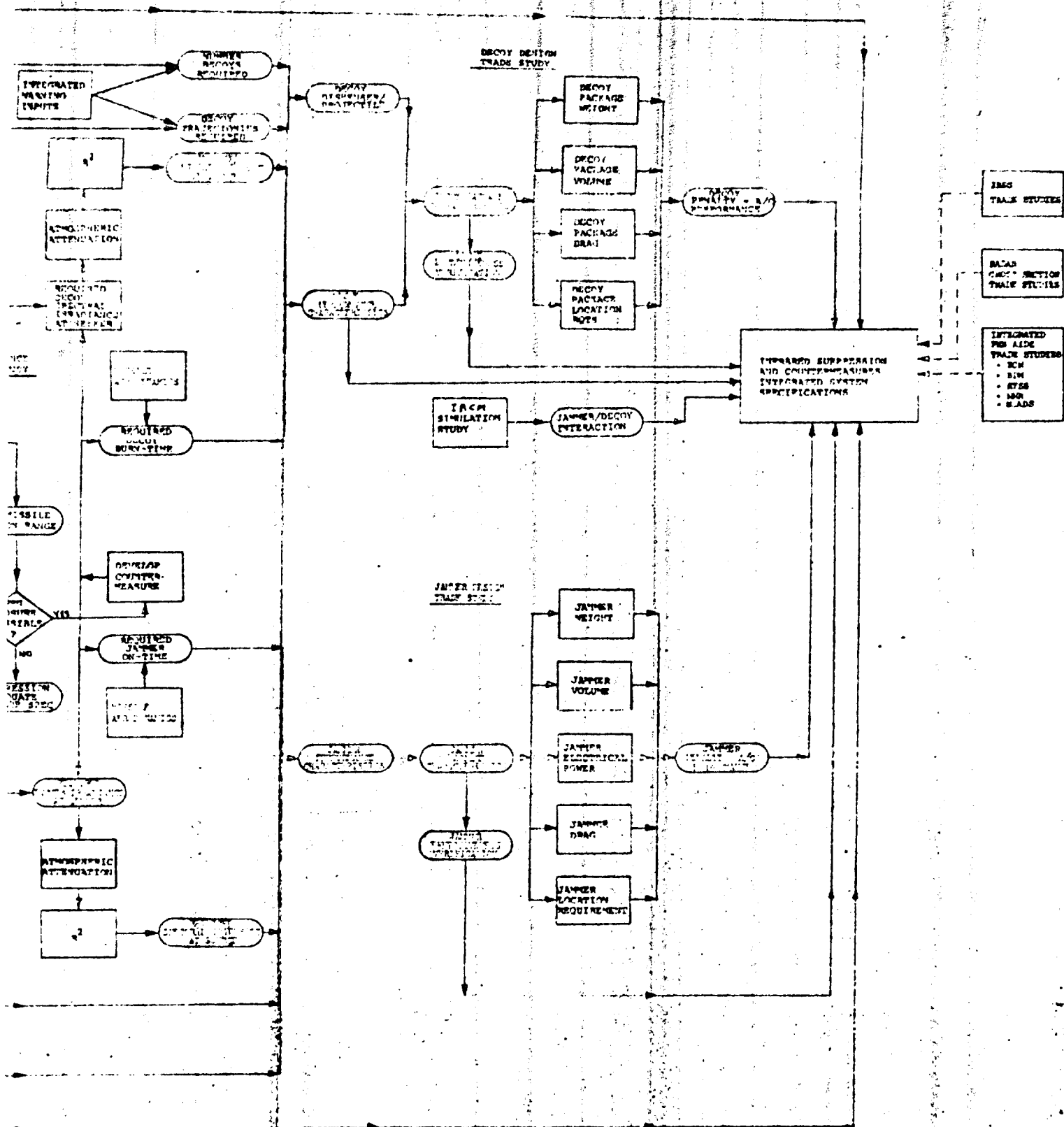


FIGURE 1.0-1
INFRARED SUPPRESSION
AND COUNTERMEASURES
TRADE METHODOLOGY



2.0 DESCRIPTION OF IR SUPPRESSION AND COUNTERMEASURES TRADES

Referring to Figure 1.0-1 the trade study initiates on the left hand side of the diagram with: the sources considered for the total aircraft radiation; and progresses through the determination of the threat missile seeker lock-on range and weapon closure; to the determination of the IR countermeasures requirements; and to the development of the aircraft IR suppression and IR countermeasures integrated system specifications. Initially, the IR threat lock-on and launch capabilities are evaluated against the aircraft for various levels of IR suppression. Since the threat capabilities are a function of the total aircraft IR radiation in contrast with competing backgrounds (i.e. total radiation of the aircraft above the background radiation), analytical techniques are applied to determine the target to background contrast, and accounting for atmospheric attenuation phenomena. The IR countermeasures requirements are then established for the threat maximum lock-on range.

2.1 Total Aircraft Radiation Phenomena

The total aircraft radiates in a manner determined by its surface emissivity, size, geometry and various temperatures and by the composition, state and condition of its propulsion components. As the radiation propagates outward from the aircraft, its density is reduced geometrically in proportion to the projected area, and the absolute intensity in any

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given direction is further reduced by atmospheric absorption and scattering. When the radiation reaches an IR missile, it is collected and imaged by optics and chopped by passage through a reticle. The modulated energy then falls on a detector and produces an electrical output. Simultaneously, radiation from the background against which the aircraft is viewed is similarly attenuated, imaged, chopped and detected. When the detector signal produced by the target exceeds that due to the background by a sufficient amount, missile lock-on and track occurs.

2.1.1 Hot Engine Parts, Skin, and Exhaust Plume Radiation

Sources, considered for estimating total aircraft IR output include the hot metal engine exhaust parts, the skin and various secondary sources such as heated radomes, heat exchangers and anti-icers, and the exhaust plume radiation. The level of engine suppression must be traded against the total aircraft radiation at all aspect angles. Excessive engine suppression should be avoided to prevent unnecessary penalties in weight drag, and thrust, and also decrease the aircraft performance capability.

2.2 Background Effects

Although the total radiation values at the source represent what the aircraft actually emits, they have little significance in a real world situation since the IR seeker system must detect the contrast of aircraft radiation with that

from a background; i.e., total A/V radiation above background. The background may be sky or ground surface, uniform or broken, warm or cool; its radiation will depend on these factors, and on time of day, weather conditions and other variables.

2.3 Atmospheric Attenuation

An aircraft is essentially a diffuse radiator, and the irradiance incident on the collecting aperture of the seeker at various distances from the aircraft varies as the inverse of range squared. The irradiance is further reduced by atmospheric absorption and scattering. The magnitude of both of these phenomena varies with wave length. The average transmission over a particular wave length interval is a function of the spectral distribution of the radiation being transmitted. The center of the emission bands in plume radiation, for example, corresponds almost exactly to the center of the atmospheric absorption bands (due to carbon dioxide and water in both cases), and the radiation from relatively cool non-afterburning plumes is almost totally absorbed by short atmospheric paths at low altitudes. The other aircraft emitters; i.e., hot engine parts and skin, as well as IRCM and IR decoys are essentially grey-body. The effect of atmospheric attenuation on target radiation is determined by integrating the point by point product of the target radiant intensity times the atmospheric transmission coefficient over the desired wave

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length band of the IR threat seeker. Figure 2.3-1 shows the method for determining the effective irradiance versus range as a function of the target radiation, atmosphere and seeker response.

2.4 Seeker Performance Characteristics

2.4.1 Seeker Modulation Efficiency

Infrared guided missiles are generally designed to track point source targets and to discriminate against extended background sources because of their very narrow instantaneous field of view. A typical aircraft skin represents an extended source even at fairly long ranges (5-10 nmi) due to its large surface area, and is tracked less efficiently than a point source; i.e., with the same total intensity. Typical seeker tracking (or signal modulation) efficiency curves are shown in Figure. 2.4-1. On these curves, a value of 2.0 indicates that the missile is tracking the aircraft skin as efficiently as it would track a point source. The rear quadrant is not plotted because engine radiation predominates. The effect of seeker modulation efficiency must be considered in determining the maximum lock-on range.

2.4.2 Seeker Lock-On Range

IR missile lock-on ranges are determined using the factors discussed in the preceding paragraphs. The radiation in each spectral band of interest from engine, skin,

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ATMOSPHERIC TRANSMISSION PROGRAM

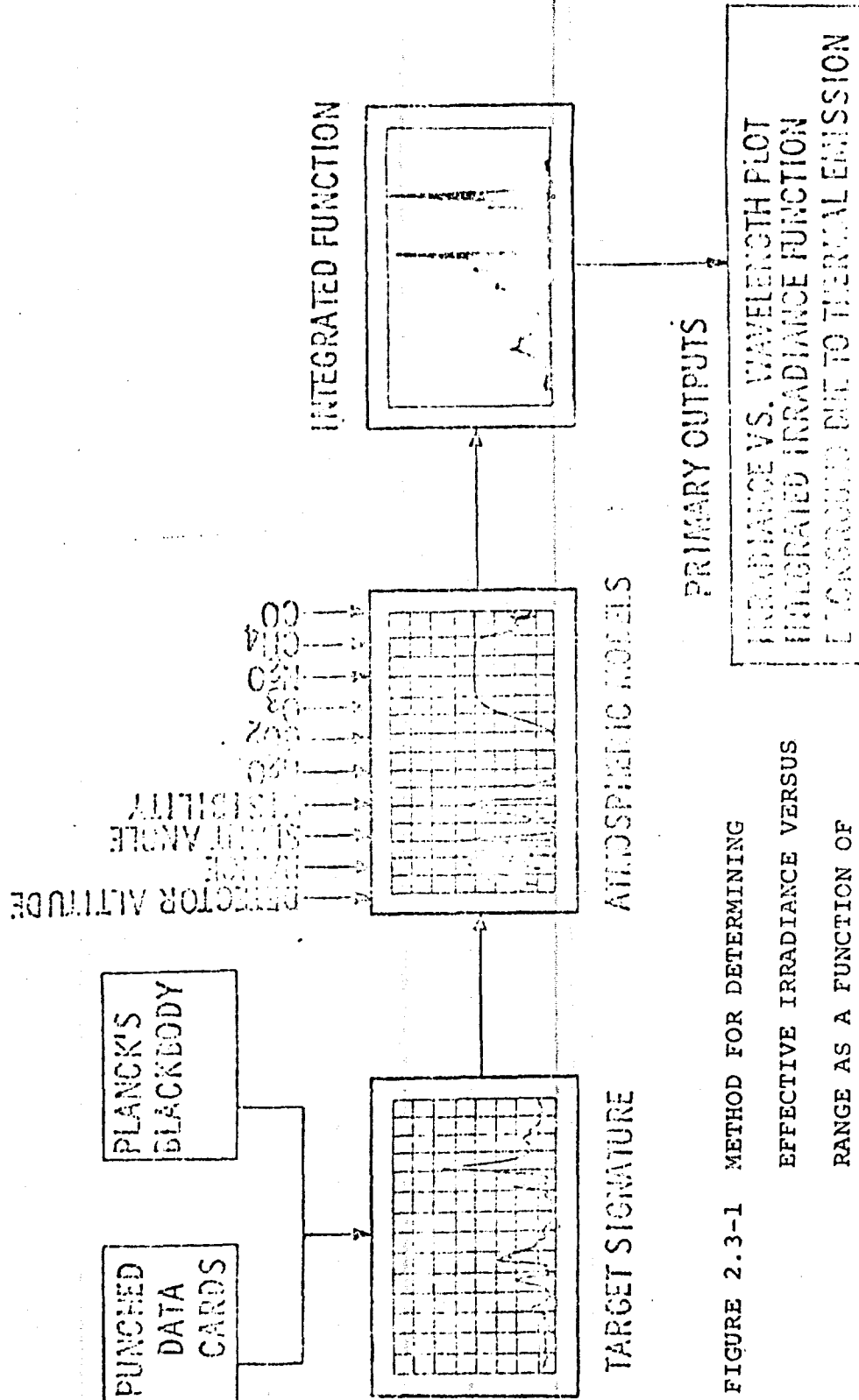
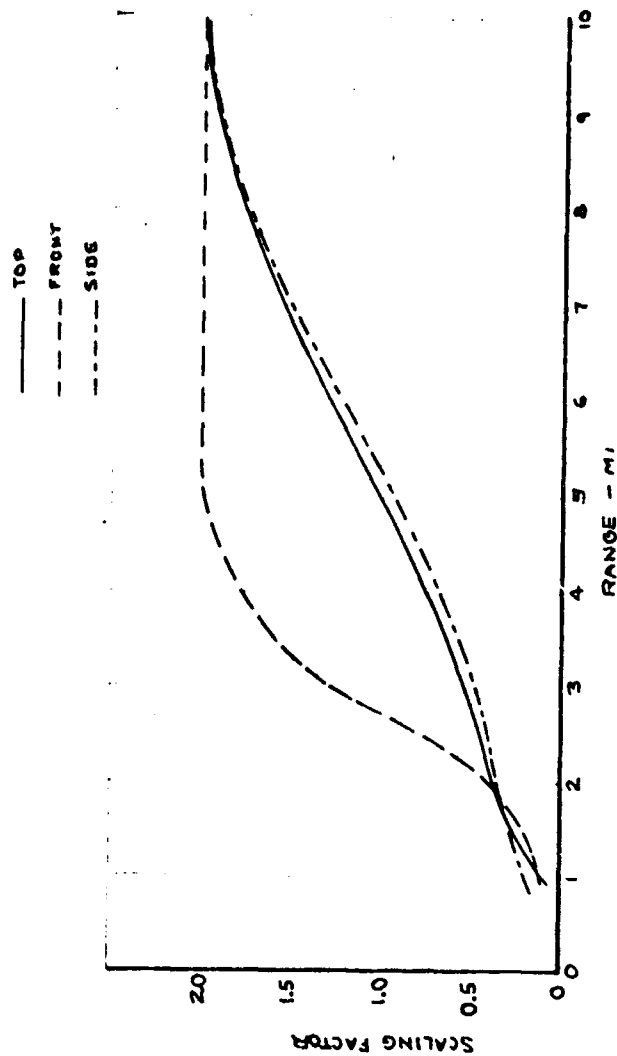


FIGURE 2.3-1 METHOD FOR DETERMINING
EFFECTIVE IRRADIANCE VERSUS
RANGE AS A FUNCTION OF
TARGET RADIATION, ATMOSPHERE,
AND SEEKER RESPONSE

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SURFACE AREA FOR TYPICAL AIRCRAFT



SEEKER MODULATION EFFICIENCY FOR EXTENDED AND POINT SOURCE TARGETS

FIGURE 2.4-1

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and secondary sources must be calculated on the basis of temperatures, emissivities and projected areas. These values must then be individually contrasted with a given background and passed through a given range of atmosphere with appropriate attenuation by absorption and R^2 . The skin radiation must be multiplied by the appropriate signal modulation efficiency to yield an effective skin radiation value for the chosen range. The contributions from the hot engine parts and skin sources must be summed at the seeker to give the total effective irradiance in the desired wave length region at the given range. These calculations must be repeated for various ranges; the range at which the effective irradiance equals the missile sensitivity (minimum detectable irradiance) is taken as the maximum lock-on range.

2.5 IR Countermeasures Requirements

The IR countermeasures system consisting of IR jammers and IR decoys is required to radiate a sufficient power level (J/S factor) in order to counter a given seeker. This value in a strict sense, is required at the missile seeker to provide the desired IR countermeasures capability for effective penetration. This interpretation permits realistic definitions of IRCM intensities (J) at the source. The J/S values need only be met at the missile seeker at ranges equal to or less than the maximum missile lock-on range, since missile launch can only be achieved after

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The intensity (J) at the source should be determined by first calculating the seeker maximum lock-on range resulting from the total IR radiation from the A/V contrasted against a given background. The unmodulated component of the radiation of the IR jammer must also be considered as part of the total A/V source. At the maximum lock-on range, the total effective A/V source irradiance is equal to the seeker minimum detectable irradiance. The jammer intensity (J-Watts/St) at the source is then determined by multiplying the product of the total effective irradiance at the missile seeker times the J/S factor by the square of the missile lock-on range, and divided by the atmospheric transmission coefficient for the countermeasures source temperature.

$$J_{\text{(Jammer)}} = (J/S \text{ factor}) \times H_{\text{(Minimum detectable irradiance)}} \times \frac{R_L^2}{T_J}$$

Where H (Minimum detectable irradiance) = total B-1 effective
irradiance incident on the missile at the lock-on
range

R_L = The maximum lock-on range determined from the total B-1 radiation against a given background

T_J = Transmission coefficient for the countermeasure
source temperature

The total aircraft effective irradiance is given by:

$H(\text{eff}) = H(\text{engine}) + H(\text{skin}) + H(\text{plume}) + H(\text{modulator dC component of jammer})$

$$H(\text{eff}) = \frac{J(\text{engine}) \times T_E}{R_L^2} + \frac{J(\text{skin}) \times T_J}{R_L^2} + \frac{J(\text{plume}) \times T_P}{R_L^2} + \frac{J(\text{jammer dC}) \times T_J}{R_L^2}$$

and is determined by the sum of the individual irradiance values. Each value of irradiance is determined by integrating the point-by-point product of the radiant intensity (J), calculated for the corresponding source blackbody temperature, times the atmospheric transmission coefficient, and divided by the square of the maximum lock-on range.

The effective irradiance of the IR jammer at the seeker is given by:

$$H(\text{jammer}) = \frac{J(\text{jammer modulated component}) \times T_J}{R_L^2}$$

Where $\frac{J(\text{jammer modulated component})}{R_L^2}$ is equal to

the integrated irradiance values determined by integrating the point-by-point product of the radiant intensity (J) of the IR jammer (modulated component) times the atmospheric transmission coefficient. R_L is the maximum seeker lock-on range at which the IR jammer is designed to operate with the required J/S ratio.

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3.0 ANALYSIS OF THE IR SUPPRESSION AND COUNTERMEASURES METHODOLOGY

As shown in Figure 1.0-1, the IR suppression and countermeasures methodology includes the following major trade areas:

- a) A/V surface coating
- b) Engine suppression
- c) IR missile performance
- d) IR decoy and IR jammer performance
- e) IR decoy and IR jammer design
- f) Engine suppression penalty
- g) A/V performance

A change in any given trade area will impact on each of the other major trade areas. The overall impact on the A/V weapon system in terms of penetration must be determined for the total spectrum of threats, flight conditions, environments, etc., by an iteration of the parameters within the individual trade areas.

3.1 Supporting Avionics Trade Studies

Additional avionics equipment trade studies are also required to support the A/V for penetration against the IR threat. These studies are shown on the right hand side of Figure 1.0-1, and include: 1) an IR surveillance system (IRSS); 2) radar cross section; and 3) the integrated pen aids.

Selection of the optimum A/V weapon system that must penetrate against an IR threat is a complex problem that requires in depth trade studies in each of the above major trade areas.

3.2 IR Suppression and Countermeasures Effectiveness

The effectiveness of IR suppression and IR countermeasures can be determined by establishing a given vulnerability level for a given threat, and iteratively, varying the parameters within each major area to meet the given requirement. A probabilistic technique must be utilized to evaluate the capability of each major trade area in order to standardize the effectiveness evaluation.

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4.0 CONCLUSIONS

The assessment of IR suppression and IR countermeasures for penetration against an IR threat requires an iterative analysis of a multi-variable trade study.

The effectiveness of a given level of IR suppression and a given IR countermeasure must be determined on a probabilistic basis considering the total spectrum of IR threats, environment, A/V performance, and integrated avionics system performance.

The output power of a given IR jammer or IR decoy (watts per steradian at the source) should be determined: 1) by considering the total radiation of the A/V above that of the background it is observed against; and 2) by applying the J/S factor at the seeker, for the maximum lock-on conditions, rather than at the A/V (source).

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21