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THE SIGNIFICANT PARAMETERS AFFECTING THE
MODELLING OF TARGET ACQUISITION OF GROUND
COMBAT TARGETS FROM TACTICAL HELICOPTERS

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THESIS

THE SIGNIFICANT PARAMETERS AFFECTING THE
MODELLING OF TARGET ACQUISITION OF GROUND
COMBAT TARGETS FROM TACTICAL HELICOPTERS

by

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The Significant Parameters Affecting The Modelling
cf Target Acquisition of Ground Combat Targets
from Tactical Helicopters.

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ABSTRACT

The acquisition of ground targets in combat from tactical helicopters, employing low-level flying techniques, is a complex process. The author examines the air-to-ground target acquisition process and investigates the parameters affecting this process. The tactical environment of helicopters is outlined and those parameters deemed significant and/or peculiar to this environment are identified. Current mathematical models of air-to-ground target acquisition are reviewed. Those which are considered relevant to this particular problem are described. The author concludes that there are no validated models for predicting target acquisition from tactical helicopters.

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I. INTRODUCTION

The use of tactical helicopters is now an accepted part
of modern land warfare. Their effective utilization depends
on the ability of an airborne observer to detect, identify
and locate objects as possible targets for subsequent
engagement by weapons aboard the helicopter, or to direct
accurate fire from ground sites. The tactical use and
employment of helicopters is constantly being studied and
analysed by means of tactical exercises, wargames and
computer battle simulations. These studies will not be
realistic unless the inter-relationship between the
helicopter borne observer and the ground target is
adequately defined and understood. Realism and reliable
results can be obtained only if analysts have used
appropriate sub-models to describe the target acquisition
process[29]. Whether the mission of a tactical helicopter is
reconnaissance, surveillance, close air support, or
anti-tank engagement; these missions rely on the human
eye/brain combination to initiate the target acquisition
process(TAP).

There is a need to examine the models in use to-day and
to determine if they accurately describe the circumstances
peculiar to the tactical helicopter flying close to the
ground. Further to this, there is a need to identify the
significant parameters that influence the TAP. The existence
of realistic models will allow worthwhile analysis of combat
effectiveness of tactics, weaponry and organization[29].
Knowledge of significant parameters will be useful in
planning test and evaluation of new equipment, and may be of
benefit in the training of pilots and observers.

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This thesis was inspired by the authors inability to locate a ready reference that dealt specifically with air-to-ground target detection and how this could be accurately modelled. It was considered necessary to conduct a search of the available literature to identify and collect the pertinate date relating to this specific area of target acquisition. It was perceived as necessary to have an introductory treatise that would explain the basic concepts, highlight the important aspects, and indicate further reference sources for more detailed information.

Reference 22 states "Good research in air-to-ground target acquisition requires an applied physics meteorological-electronic-physiological psychologist trained as a pilot, and with a broad experience in military operations." This statement sums up the reasons for the vast scope of this field, and the inevitable confusion. Hence the purpose of this thesis is to:

(1) Define terminology and describe the target acquisition process, and relate it to the tactical environment.

(2) Identify those parameters that affect air-to-ground target acquisition and describe those which are considered to be most significant for observers in tactical helicopters.

(3) To describe the original theory and experiments that led to the development of the early target detection models. This will include relating search techniques to the target detection/acquisition process.

(4) To index the analytic models that are in use to-day and to indicate their applicability or otherwise to target acquisition from helicopters. The relationship between the models and empirical field data will be indicated.

II. TARGET ACQUISITION PROCESS

This section will deal with the definition and explanation of terminology used in the area of target acquisition. The process of target acquisition will be outlined and related to the tactical environment in which tactical helicopters are employed. The TAP has many descriptions and a multitude of various definitions that are not in agreement. Target acquisition is not well defined in concept or in recognized standards and terminology. This is due to its interdisciplinary nature and to the absence of an authorative organization to establish standards[22]. The best statement of this lack of commonality comes from Reference 6.

The three most commonly used and confused terms employed to describe the visual problems of targeting are detection, recognition, and identification. In general, they refer to progessive refinements of target acquisition. Detection is the determination that some object is present at a location compatible with its being the target; recognition is the determination that the detected object is a member of that subclass of objects for which the observer is looking (tanks, trucks, ships, four-engined aircraft, or whatever); and identification is the determination of which member the target is of the subclass of interest.

In this report, target acquisition is used as a generic term to cover any or all aspects of targeting. Target acquisition is thus a neutral term in that it can mean detection, recognition, identification, or whatever problem of targeting the test or experiment is concerned with. If the target problem which a system

has to solve in order to work succesfully is only target detection, then the system has acquired its target when it has detected it; if the system cannot go into operation until it has been provided the serial number of the target, then it has not acquired its target until it has identified it.

In military operations, the problem of visual acquisition of ground targets is actually five different problems, one for each of five different missions: (1) reconnaissance or surveillance, (2) navigation, (3) attack on targets of opportunity, (4) attack on targets identified in prebriefing, and (5) vectored attack with no search or limited search required. Each of these five missions presents a target acquisition problem different from each of the others.

For a given target in a particular background at a particular hour on a specific day (and all other things being equal), there is no reason to expect the same target acquisition ranges for any two of these five missions. Therefore, to be meaningful a discussion of target acquisition (detection, recognition, identification, or whatever) must be prefaced by a specification of the mission, and consideration of the significance of target acquisition ranges or probabilities should be restricted to a particular mission. In the studies conducted, this has almost never been done, and the fact that it has almost never been done is one of the important sources of error in the design, conduct, and interpretation of experiments and flight tests in this field.

Four of the five missions described above require preacquisition search. A tremendous complication is added to the relatively simple problems of detection and recognition by the requirement of searching for the target in a moving visual field, but only a fraction of the tests and experiments include search of a moving visual field as part of the task.

A final consideration of importance in the interpretation of target acquisition work which is frequently not treated explicitly in reports is the relationship between what the observer was looking for and what he actually saw; i.e., the correspondence between expectation and reality. All sorts of elements go into making up the observer's expectations: prior experience with the type of mission or experiment, familiarity with the particular stimulus material (terrain), nature of the task (reconnaissance versus attack; detection versus identification), type and specificity of briefing (instructions; set), etc. The precise degree and kind of similarity between expectation and actuality make a very great difference in probability and range of acquisition. The foregoing considerations concern the adequacy of the test design in the sense of whether the test or experiment is designed to shed light on the actual problem of interest or on some more or less remotely related problem-- whose degree of remotness may not be recognized by the experimenter.

An additional difficulty in target acquisition work is that the term "target" is not specifiable in an objective way. A target is anything that anybody is interested in finding and doing something about. It may have no visual representation (an underground bunker);

it may have an ambiguous representation (a command post or headquarters); it may have a visual representation which changes drastically with the aspect from which it is viewed (a tank) or the altitude from which it is viewed (a radio tower) or the presence or absence of sun and glint (a polished aircraft fuselage); etc. This ambiguity does not prevent meaningful work on specific targets, but it suggests that an all-inclusive solution to the problem of visual target acquisition is unlikely.

For the purposes of this study, terms employed are as defined in the Glossary of Terms, Appendix A. The TAP is described and defined by the following sequence of events[22].

Observer: The individual who is acquiring targets.

Target: The object class for which visual search is conducted.

Detection: The observer decides an object in his field of view should be inspected further (e.g., man-made object). Object may have been visible before detection but was not distinguishable enough from other objects to cause inspection decision

Recognition: The observer decides the object belongs to a particular class (e.g., vehicle). There are hierarchies of class names; the particular hierarchy for recognition decision is determined by scenario and pre-briefing.

Identification: The observer decides the object is in a particular subclass (e.g., tank). The subclasses are dependent upon class, scenario, and pre-briefing.

The definition of "detection" is different from the dictionary meaning which is based on the revelation or discovery of the presence of an object. The meaning as used in the TAP requires that not only are objects visible and revealed to the observer, but the additional element that an

object is classified as a potential target. Detection in this case implies that an object of military interest has been sensed, yet some arbitrary level of specificity of description has not yet been obtained[31]. Detection assumes the prior conditions of visibility and perception. Perception is defined as the process of reception of stimuli corresponding to a target area, immediately preceeding confirmation or rejection by the brain of detection, recognition, or identification[9]. Visibility is the degree to which the target energy parameters exceed the energy requirements of the human eye[30].

The visual acquisition process is often considered as being made up of search, detection, recognition, identification, and placing the weapons sights on the target[19]. The definition used in this paper differs from this in that search is not included and the fixing of the weapons sights on the target is generalized to the ability to effectively engage with a weapon, which could be indirect fire. Search has been deliberately excluded not because of its lack of importance but rather its primary importance. The target acquisition process cannot occur until the observer is looking at the area in which the target is located. Search is therefore dealt with separately for it is a variable which is crucial to the TAP. Search is also inter-related very closely with the tactical environment.

From an operational point of view, detection, recognition, and identification cannot be separated. Detection has to occur prior to or simultaneously with recognition. For instance, in an operational situation a pilot has to navigate to the general area of a target and then, depending on the tactical situation and prior knowledge, he must locate the target area, search the target area, evaluate potential targets and finally detect, recognize and identify the actual target. This process will

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be affected by the classification of the target. Class hierarchies depend on the tactical situation, knowledge of observer, and prior information. The object will be placed in a class and then a subclass and finally identified as friendly or hostile and then fixed in relation to geographic land marks before the process is complete. It can be seen that target acquisition is a process of elimination. Identification is most important for it is considered useless to merely detect or recognize an object, without identifying it as an hostile target. This is a prerequisite for engagement. Some authors[19], downgrade the importance of identification and refer to the acquisition of real and false targets. They justify this by stating "under normal tactical conditions applying to land combat, the sighting of a vehicle-like object by a tank commander in a likely direction of threat would probably motivate him to initiate action against the object before attempting to make a positive identification." This viewpoint is not accepted for in modern mechanized warfare, with its degree of mobiliyy and flexibility, tactical conditions will exist where the battle is extremely fluid and the chance of shooting up ones own "tin-cans" is quite likely. With tactical helicopters, where the target area being searched will include friendly and hostile objects, the observer must be capable of identification before engagement.

Target acquisition requires the classification of objects. These classifications will vary constantly depending on the observer, and the current tactical environment. The tactical environment has a direct bearing on the prior knowledge of an observer engaged in target acquisition. This knowledge will influence the search pattern of the observer and his target acquisition. Hence the general tactical environment must be considered in this survey, but in particular it must be remembered that each

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and every combat mission by a tactical helicopter will have
a specific tactical environment which must be known and
specified before any meaningful analysis can take place.

The main use of tactical helicopters is in combat
support missions or closely related missions such as
reconnaissance, surveillance, or fire direction and control.
Hence only real-time target acquisition is relevant to this
survey. The likely targets are ground tactical-type targets.
These can vary from individual soldiers, pieces of
equipment, defensive positions, to an amalgamation of men
and equipment in tactical units deployed on the ground. The
observer must therefore have knowledge of equipment, ground
force unit formations and tactics in order to be able to
correctly classify visible objects in the TAP. The
importance of the human observer cannot be overemphasized.

The prior knowledge of an observer will be influenced
by the briefing received prior to a mission. This can vary
from pre-flight briefing of a set-piece operation with
detailed missions in which known or suspected enemy
positions are described and located, to the very general and
unspecific mission of reconnaissance and surveillance in a
fluid battle where the location of the FEBA may be vague and
any briefing is minimal.

Tactical helicopters because of their vulnerability to
ground fire and surface-to-air hand held missiles will
employ flying techniques to minimize their exposure. These
techniques are often called contour flying or nap of the
earth(NOE) flying. These terms have specific meanings. Nap
of the earth flying is defined in Appendix A, and involves
reaching a designated point by any route which affords
maximum cover, concealment and takes advantage of all
natural terrain features, such as hills and river beds. This
involves frequent change of direction. In contrast contour

flying involves flying a pre-selected course, as close to the ground as possible rising only to clear objects along the selected course[16]. In either case the pilot and/or observer has to compensate for spatial dislocation. Their viewpoint is more akin to that of a ground observer than the large overview available to a high altitude aircraft. In subsequent sections the influence of the tactical environment on the significant parameters of target acquisition becomes apparent.

III. SIGNIFICANT PARAMETERS AFFECTING TARGET ACQUISITION

This section will investigate those factors which are considered most significant in the TAP. All the factors that are relevant to varying degrees in air-to-ground target acquisition are listed in Figure 1. This comprehensive list was taken from Reference 22, which was compiled from factors investigated or described in the published literature. These factors are grouped as follows.

1. Target/Background Factors.
2. Environment Factors.
3. Observer Factors.
4. Aircraft Factors.

These groupings are arbitrary for all the factors interact. For instance the seat position in an aircraft will influence the field of view which may affect the observers search pattern. The number of parameters shows the scope of published works in this field. In each group certain factors have greater effect on TAP then do others and some are more specific to the low altitude, slow speed of tactical helicopters using NOE or contour flying.

For this section the major reference source is Reference 22. To avoid repetition all references to this publication are omitted. References will be made to other specific sources.

TARGET/BACKGROUND

Some of the most critical factors affecting the TAP are discussed in this grouping. Detection and recognition depends on the interaction of variables associated with both the target and background. The most extensively investigated factors are found in this group, and they are contrast, target size and terrain type.

TARGET/BACKGROUND

Type
Size
Shape
Contrast
Luminance-Reflectance
Texture
Motion
Shadow
Terrain Type
Vegetation
Masking
Camouflage
Clutter
Cues

Distinctiveness
Conspicuity
Embeddedness
Ambiguity
Confusability

AIRCRAFT

Altitude
Range
Speed
Offset
Target Exposure Time
Aircraft Type
Crew Size
Seat Position
Apparent Motion

ENVIRONMENT

Visibility
Cloud Cover (Sky-Ground Ratio)
Sun Angle
Illumination Level
Diurnal Variation
Seasonal Variation
Scintillation
Glare
Attenuation
Transmittance
Apparent Contrast
Modulation Transfer Function

OBSERVER

Fixation
Search Time
Search Pattern
Visual Acuity
Experience
Training
Expectation
Motivation
Task Load
Stress
-
Number of Observers
Pre Briefing
Cueing
Search Aids

Figure 1.   TYPICAL PARAMETERS: AIR-TO-GROUND TARGET ACQUISITION PROCESS

Target Type

Target type is important in determining target acquisition performance, and is very closely related to the tactical environment. The target type has a significant effect on the classification of objects in the TAP. Familiarity with target type or knowledge of the appearance and names of specific military objects is necessary for target identification. Target type differences are related to the differences in other variables such as target size, contrast, shape, and cues to the observer.

Contrast

Target/background contrast is the most important parameter in target acquisition and the most researched. The most extensive studies and the basis for most present day models and analysis is the work done by Blackwell in 1946[23]. In the original experiment observers viewed a screen of uniform brightness on which a circular target (darker or lighter) would be superimposed. Subjects indicated if they detected the target (i.e., observed contrast). The level of contrast resulting in the .50 Detection Probability was defined as "threshold contrast". Contrast is defined as;

$$C = (Bt - Bb) / Bb$$

where Bt = brightness of target, and Bb = brightness of background are measured at zero distance[19].

Contrast can be negative or positive depending on whether the target or the background is the brightest. Normally no distinction is made since little difference has been found between them in terms of detection, with the exception of large stimuli and low background luminance, for which Blackwell determined 20% lower thresholds for negative

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stimuli. This contrast is the inherent contrast. As the range between the observer and target increases the effect of the intervening atmosphere is to reduce the apparent target/background contrast. In the limit the contrast will approach zero. The attenuation effect is described by Koschmieders law[19].

$$C = C' \cdot \exp(-a.R)$$

where
C = apparent target/background contrast at range R
C'= inherent contrast at near zero range
a = attenuation coefficient of atmosphere for prevailing conditions.
R = slant range from observer to target

The attenuation coefficient is determined by the meterological range V [19] where; $a = 3.912/V$. These equations used in conjunction with the appropriate data for atmospheric conditions and the inherent contrast can be used to estimate the threshold contrast.

Extensive analysis and lab experimentation has been conducted of the effects of contrast for various targets against a uniform background. Basic contrast thresholds have been incorporated into many models of the TAP. However very few experiments or field tests have been conducted using heterogeneous background in field conditions. Analysis has shown that the higher the apparent contrast for any target the greater is the detection probability or identification range, and the shorter the detection time. Work on acquisition slant ranges for targets[1], using T.V. simulation techniques showed that the same target image on different backgrounds produced a large variation in detection time and probability, even with image size, contrast, and resolution held constant. Clearly the

target/background interactions were very significant. Other work at the Martin Marietta Corp.[5] showed that the variation in performance due to changes in target/background contrast levels was the strongest effect. This work indicated that once the contrast level reached 25% and above it ceased to influence the detection process.

Target Size

Target size has been the subject of many laboratory studies, simulation experiments, and field trials. Work by Whittenberg and others has shown that it is one of the primary target/background variables. Size in these circumstances refers to the apparent size of a target to the observer. Apparent size, expressed in square mils, is the solid visual angle subtended by the target at the observer's eye. Apparent size is determined by the actual size of a target, the slant range to the target and the angle of the observer relative to the object. The importance of apparent size would seem to follow logically from an understanding of visual acuity (i.e., the size of detail that the eye can resolve). It has been found that the apparent size of a target had to exceed the visual acuity threshold by a considerable amount. Research indicates that the apparent size of a target required for detection depends significantly on the search parameters. These will be discussed in a later section. If search for a target was needed the apparent size of a target to obtain detection was almost double the visual acuity threshold. All things being equal larger targets are more easily detected, recognized, and identified.

Target Shape

Target shape is also a significant factor for the TAP that is dependent on the tactical environment. Laboratory expirements have shown that targets with large length/width ratios were found to be most difficult to detect, but a

ratio below 10 had no effect on detection[12]. The aspect ratio of a target changes depending on the altitude of the observer. For low altitude flight the varying aspect ratio is not significant. However a target because of its complex shape will present a different image to the observer depending on which side is presented to his view. The image received by the observer which is two dimensional has to be interpreted into something that can be recognized and identified. Hence complex shapes make the task more difficult [29].

Masking

Masking is a critical factor in detection of targets from low flying aircraft. A target can only be detected if there is line of sight between the observer and target. If line of sight is partially or completely obscured by some objects, it is said to be masked. Tactical low-level flying deliberately restricts line of sight. In addition the terrain contours, type of vegetation, clutter and camouflage all tend to produce masking. Camouflage may interpose a barrier between the target and the observer. Experiments have shown that target recognition decreases as the number of targets in a complex visual field increases. This is partially due to the higher probability that in a cluttered visual field one or more objects are likely to completely or partially mask the target. Reference 13 mentions that as altitude increases up to an optimum level, there is less terrain masking and there is better detection at greater ranges.

The range at which unmasking occurs is critical, for this combined with speed determines the period of time the target is exposed to the observer, and hence directly influences the probability of target acquisition. It is only when unmasking has occured that the other factors come into effect. Masking has not been studied in systematic field

trials, but photographic simulation studies produced the interesting fact that heavy masking resulted in shorter target acquisition times (time to acquire target after line of sight was established). This may be attributable to the observers compensating in the search techniques by looking at the near distance of the exposed search area, or it may be just that the physical factors of contrast, size, and shape were dominant at the close range at which unmasking occured.

Target Motion

Target motion was found to be significant for low altitude target acquisiion. In studies conducted at 500 ft. altitude, and low-speed (350 kts) moving targets were more easily acquired then stationary targets. It was also noted that the direction of motion relative to flight path was important. Detection due to motion can be attributed to: (1) cues created by motion ; such as dust clouds; (2) change in location, due to motion, being detected; (3) motion itself attracts attention which must be different from apparent angular velocity of target due to aircraft motion.

In Figure 2 there is a group of subjective factors listed at the bottom of the target/background group. These are the characteristics listed by Zaitzeff(1971)[22] in a different approach to defining target variables. This was based on the belief that in real world situations the target variables cannot be separated from background. The approach is to quantify these variables using techniques of psychometric scaling, which would result in a measure more closely related to the dynamic real world situation than the present measurement of physical aspects. This has yet to be done.

ENVIRONMENT

The environment in which the observer and the target
are located affects the detection and recognition of the
target. This environment is primarily that of the
atmosphere and we are interested in how it affects the
visual process. An object is said to be at the limit of
visibility when the target/background apparent contrast
equals the threshold contrast of the eye. This distance is
called the "visual range". Visibility is the degree to which
target energy parameters exceed the energy requirements of
the human eye. Visibility determines if a target is detected
or not. Light emanating from the distant target and
background is removed from the line of sight by absorption
and scattering due to water vapour, dust and matter in the
atmosphere. Some light is added along the line of sight due
to the scattering effect. Hence the atmosphere has an effect
on the TAP, since an object cannot be detected until it is
within visual range. It does not really have to be stated
that weather conditions like fog, rain, or snow degrade
visibility, but there are other factors which can enhance or
degrade visibility.

One factor is that of illumination of the visual scene.
Cloud cover and time of day (diurnal variation) affect
overall illumination as well as shadow effects. However the
results of studies of these factors are not conclusive or
have shown the factors were not significant. At low levels
of illumination, target detection increases assymptotically
as illumination is increased to a level at which there is no
longer any significant illumination effect. It has been
determined that the sun has an influence on visual range.
Both the elevation of the sun and the azimuth relative to
the observer target line have an effect. The sun produces
glare and scintillation(shimmer). If the observer is looking
into the sun vision is reduced, but if the sun is behind the
observer, studies have shown improved target acquisition

performance. The sun also heats up the atmosphere causing rapid and irregular changes in the index of refraction of the atmosphere. This produces shimmer and laboratory studies suggest that this phenomenon is one of the reasons for the large disparity in predicted visual slant range and those measured in field studies.

Field studies have shown that if visible range is above 3 miles there is little effect on target acquisition. If visual range was between 4 and 10 miles the probabilities of detecting a target were not significantly different. In contrast it was found that poor visibility due to haze had a distinct effect on a pilot's ability to navigate and detect targets.

Modulation Transfer Function (MTF)

Modulation Transfer Function(MTF) is a measure of the resolution of a component of an imaging system. It is usually applied to optics, cameras, video amplifiers, displays etc. In recent years it has been applied to the atmosphere and/or the human visual system in an effort to describe, analyse or predict the performance of human vision as a system rather than by measurement of separate characteristics. Estimating the MTF requires the use of Fourier analysis techniques to determine how the system responds to spatial sine wave patterns of different frequencies and amplitudes. Based on measured response to patterns the response to more complex stimuli can be predicted. To determine the sine wave response of the human visual system requires indirect procedures. MTF's have been obtained for the human visual system, with the greatest sensitivity occuring in the 3-6 cycles/degree region[8]. To derive a MTF for the human visual system requires the assumption of (1) linearity, (2) average display luminance, (3) accomodation distance. The human visual system is non-linear so this is an immediate difficulty. However the

MTF is a useful predictive tool if the MTF was obtained under condition as similar as possible to those under which the prediction is being made. The MTF has been shown to be a more comprehensive, predictive systems-oriented tool for studying human visual response, but has not been used in predicting target acquisition. In theory target acquisition could be predicted by the resultant combination of the atmospheric MTF and the human visual MTF.

OBSERVER PARAMETERS

This group of factors concerns the performance of the observer and his sensor "the eyeball". The pertinent characteristics of the environment or the target and its background will only come into effect once the observer directs his eyes to the area in which the potential targets are located. The eye has only a small foveal area where most of the fine resolution occurs. Target acquisition requires that the target image be directed onto the fovea. Hence the human performance of the observer is an essential parameter of the TAP. Visual acuity of observers would normally be a significant factor, but the selection process for military pilots and observers will eliminate those without a minimum satisfactory level. Similarly intelligence by a combination of selection and training is not a major factor. What does appear in both laboratory and field studies is that search technique is the significant factor. Reference 4 concluded that a pilot, having reached the vicinity of his target, then spent 80% of his time searching for the target, 18% acquiring and 2% identifying it. This is indicative of the importance of search.
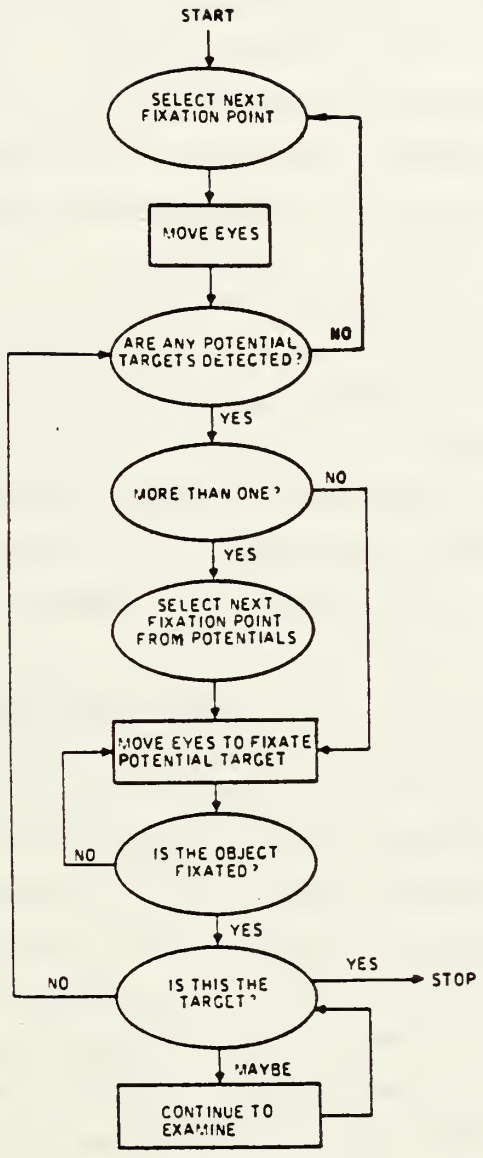
Figure 2. The General
Search Process

Visual Search

The time at which opposing sides sense the location of their opponents weapons has substantial effect on tactical outcomes. Unaided visual search continues to play a dominant role in military operations[19]. In visual search the observers eyes do not scan evenly and continuously over an area, even though the observer thinks they do. The eyes actually jump from one position to another. During these jumps there is a reduction in visual sensitivity. The visual field is only perceived when the eye fixates (pauses momentarily). These pauses are called fixations and last for about .33 seconds. Hence visual search is a series of visual fixations eventually stopping at an object or target. These patterns or fixations are called search patterns, and can be natural or learned. A diagramatic representation of this search process is shown in Figure 2 [22].

Natural Search Patterns

Natural search patterns can be random or cue induced. Studies of fixation patterns have shown that for large display areas (50-90 degree visual angle) the mean fixation time is .33 seconds. For a small display area (less than 9 degrees visual angle) the duration increased to .60 seconds, and a high percentage of the fixations fell outside the search area. This suggests that observers initially use a repeated random pattern of fixations, and then use possible cues or expand the search area if no cues are present. In the test reported in reference 11 it was concluded that natural patterns tend to be random rather than systematic and prior knowledge induces a more systematic approach. Other studies have indicated that the movement of the eyes has been determined by peripheral vision before eye movement and fixation actually occurs. Observers tend to fixate on objects which have the specifications they expect the target to have. Fixation in air-to-ground simulation have been

shown to be concentrated in a small portion of the visual scene. They were concentrated near the horizon in the center of the field of view, and also tended to concentrate on terrain factors like roads or clearings. Those observers who had shorter fixation times also tended to report longer target acquisition ranges. This infers that these observers were able to cover a search area more effectively and hence observed the targets at the greater range. In-flight studies of eye movement during field tests have not been conducted.

Learned Search Patterns

It has been stated that for nearly all air-to-ground search conditions the observer wastes more than 40% of his time in useless search activity during the period after the target has become available but before it is reported as acquired. Improvement over natural patterns would be desirable. Evaluation of search patterns used by Army pilots in low altitude slow speed search showed that some patterns were better than others. A side to side and forward and back combined movement was the best. More study is needed to define the characteristics of "good" versus "poor" search and an "organized trained search" versus "naive random search".

Operational Search

In terms of operational conditions there are three search situations. The situation will greatly influence the observers probability of detecting a target, and in most cases the observer has no influence over the situation.

1. Line search: the observer knows approximatelt where the target is located and is searching for it along a pre-selected route. Normally this would be at low altitude and the target would be unmasked for a very short time. If

the observer is not searching at the correct location the target will be unobserved. This is typical of route reconnaisance.

2. Area Search: A target is known to be in a specific area, but its exact location is unknown. The task is to locate the target and pin-point its location for effective fire.

3. Random Search: Targets are unknown in both time and location. This is typical of most operational search situations. If nothing is known about the area or target, the probability of acquisition is very low.

Search Time

The time it takes to search for and acquire a target in any operational situation depends on how long the target is exposed to the observer (i.e., the period of time during which line of sight exists). The period of exposure is related to the factors of aircraft speed, observer field of view, masking, and altitude. In a tactical situation an observer has limited control over these factors and in most cases the time the target is visible will be of short duration. Hence if the target is not found quickly it will not be found at all. During the period of target exposure it is necessary that the observer's search techniques, influenced by such variables as prior knowledge, briefings, and expectation, allow the eye to fixate on the target. If this occurs then acquisition will result depending on target/background relationships or environmental parameters. Search techniques can be improved by training, use of cues, effective briefings, and prior knowledge. Improved search techniques will result in better target acquisition.

Training and Experience. Results of laboratory tests relating search performance to experience in search tasks are not conclusive. Tests between pilots and nonpilots in visual search have indicated that general experience is not

significant. However the experienced personnel had better results with target identification. It was found that practice on search tasks or experience related to a specific search area improved performance. Training in search techniques was found to be useful in improving target acquisition performance. Tests of U.S. Army observers were conducted by the Army Aviation Human Research Unit at Fort Rucker, Alabama, and reported by F.H. Thomas in 1964. Four necessary visual search skills were identified (1) detecting targets by methodical search; (2) identifying targets quickly; (3) maintaining geographic orientation; (4) determining location of targets. An experimental course emphasizing these skills resulted in students with only 32 hours of training performing as well as conventionally trained Army aircraft observers.

Motivation. No data is available concerning the effects of - motivation on the TAP. In laboratory studies of visual search, where money was used as an incentive to test subjects, positive results were reported. Search performance improved, although the false alarm rate also increased, but not to the same extent. In actual warfare the author postulates that the motivation for effective search would be present, since it may be a race against time to determine if the enemy is acquired and destroyed before there is a chance of retaliation from the ground troops. The interaction between more target acquisitions and more false alarms makes it difficult to postulate if this motivation would result in an improved TAP.

Search Aids. Search performance is improved if the observer has some guidance on what to look for and where to look. Mental conditioning or a preconceived idea on what to expect and where to expect a target have been shown to significantly increase visual capability. Search aids can improve an observers expectation of being able to acquire a target and this has been found to be directly related to his

actual capability. Search aids include pre-briefing and search cues. Pre-briefing consists of information about the target area, such as terrain and complexity, and the target itself. Pre-briefing can include maps, aerial photos and verbal description. Studies have shown that map-reading skills are also important. Cues on when and where to look are significant. Natural cues exist in the natural setting of the target area, and are particularly important to tactical helicopters. Cues are related to the mental picture that the observer has of the target area and target. This picture is related to his prior knowledge and to the pre-briefing. Terrain features related to a mental picture of the area will allow the observer to reject areas not worthy of search, and induce him to search more intently in others. For instance an observer would reject swamp or marshy ground as likely areas for tank targets, but would concentrate on rolling ground with trees and brush providing camouflage. For helicopters flying NOE cues are especially important for re-detection which occurs when a target is acquired initially and then becomes masked as the helicopter moves to a more favorable position to engage the target. Without natural cues, the ability to re-detect would be reduced. The USACDEC Experiment 43.6, concerning attack helicopters and the Visual Acquisition System Evaluation(VASE), as reported in Reference 32, showed that the helicopter aircrews gave their subjective impression that the greatest detection cues were dust from target, target motion, simulated weapon smoke, and target size.

The most significant observer parameter is the individual's search technique. If the observer has the necessary physiological attributes (e.g., visual acuity), and this is combined with proper search techniques, training, and experience to gain prior knowledge, then the probability that search will be effective is increased.

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AIRCRAFT PARAMETERS

Aircraft parameters are important in as much as they influence or affect the target-atmosphere-observer chain. The physical design of an aircraft can influence the observers performance. Vibration has been found to impair visual accuity, with its effect being the greatest at about 10-25 Hz, depending on the amplitude of vibration. Visibility towards the ground is related to the geometry of the cockpit and other obstructions. The observer's seat position in different types of helicopters has resulted in differences in target acquisition. Zaitzeff, in a paper given at the Aerospace Medical Panel of the Advisory Group for Aerospace Research and Development, in May 1969 reported the use of a two-man crew rather than a single member resulted in target acquisition at 30% greater ranges with fewer targets missed. This seems to result from doubling the search effort applied to the same area at the same time.

Apparent Motion

The speed and altitude of an aircraft affect the apparent motion of a target relative to the observer. Visual acuity itself has been found to vary as a function of angular velocity, which causes the observer to change his fixation techniques. Observers tend to jump ahead, fixate on a point and look at that point until the aircraft approaches it, then again fixate forward. In an aircraft an object appears to move towards the observer. This apparent motion, caused by a continuous change in line of sight, has a degrading effect on visual detection and recognition. The angular subtense of an object grows in size, and relative positions of target and background change. Horizontal, lateral and vertical proportions of a target change at different rates, causing complex visual geometry. This tends to cause changes in apparent brightness and contrast of a

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target. These effects due to motion interact with the normal
static variables. These all reduce the effectiveness of
search after line of sight has been established.

Target Offset

Target offset occurs due to errors in navigation by the
pilot, conditions of low-level flight imposed by the
terrain, or by aircraft design which requires side looking
observers. Classified results of tests are not available,
but in general show that target acquisition performance
decreases with increasing lateral offset. Reference 14 lists
distance of target from flight path as one of the
significant contributions to overall degradation in
low-level target acquisition.

Target Exposure Time

The above parameters are not significant when compared
with target exposure time. Speed and altitude considered
together influence the total target exposure time. Field
tests, conducted in Southeast Asia and reported by Blakeslee
in 1963, of visual search from U.S. Army aircraft at low
altitudes and low speeds show that with an increase in speed
target acquisition decreased. Unfortunately with tactical
helicopters low-altitude target search results get
confounded with masking effects. Studies have shown that
wherever the targets were unmasked, there was a higher
probability of target recognition at 50 feet altitude rather
than at 100 feet. This is due in part to the aspect angle of
the target, being very much like the normal way an observer
perceives the world. Few if any low-altitude studies have
specifically reported data on masking effects. What has been
observed in trials is that the detection probability from
low level (below 100 ft.) contour flying helicopters has
been low. The maximum range of detection for tanks was 1400
yards, with a median range of 300 yards(274m). Given
detection, recognition was very high. In 1974 further tests

at the Naval Weapon Center with a normal altitude of 150 ft.
gave a median range of detection of 347 meters.

SUMMARY

. From the review of the literature and the summary of
parameters presented in this report, the author has
determined those factors which are considered to be most
significant in the TAP. Given a specific tactical
environment, the relatively slow speed typical of
helicopters, and low altitude NOE or contour flying
techniques, the following are the parameters which will
determine the degree of success in target acquisition.

Search Techniques. Improved observer performance, due
to the use of effective search techniques, will counteract
the effect of short target exposure time inherent in
low-level flight. This in turn will increase the probability
of more target acquisitions. The techniques employed will be
determined by the training received by observers, their
prior knowledge, effective pre-briefing techniques, cues,
experience or knowledge of search area, and human
engineering design of aircraft.

Masking.Terrain contours combined with height, depth
and density of vegetation will determine the degree of
target masking. Buildings and other clutter in the target
area will also cause complete or partial masking. Line of
sight between observer and target must exist before the
target acquisition process can begin.

Target Exposure Time. The time for which a target is
exposed is related to the masking effects and the speed of
the aircraft. Altitude changes in tactical low-level flight
will be small, and their effect on target exposure time is
normally confounded by masking.

Apparent Target Contrast. This appears to be the most significant factor related to the performance of the human eye. Apparent contrast is determined by the target and background characteristics, and all the attenuating and degrading factors of the atmospheric environment.

Target Size. This is the second most important factor affecting the human visual system. At low level altitude the vertical dimension is more important than apparent lateral dimensions. The target must be large enough such that its angular subtense is a considerable amount larger than the visual acuity threshold.

Apparent Motion. Apparent motion is determined by altitude, speed and flight path of the aircraft relative to the target position. Apparent motion degrades dynamic visual acuity.

IV. TARGET ACQUISITION MODELS

Having considered and evaluated the parameters involved
in target acquisition it is necessary to determine if the
significant ones are effectively used in analytic models. It
has been shown that the tactical environment of the low
flying helicopter has made certain factors more important
than others. A review of the literature on current
air-ground target acquisition models was made to decide
which were best or most suitable for the special
circumstances of tactical helicopters and ground combat
targets. In order to evaluate the approaches to modelling it
was necessary to review the original models of search and
detection since most models to-day have the same origins.
The literature also gave an indication of how the models
related to laboratory and field experimental data.
Information on the validity of models is essential in
determining their suitability for use in specific
circumstances.

The two major references for the models in existence
were Greening[12] and the Martin Marietta Source Book[22].
Many models are in existence for unaided visual search.
Greening lists 20 different models, and reference 22
re-considered these plus 17 additional models. However both
references had to delete many models for detailed
consideration since they were not well documented, or were
not widely used. Reference 22 listed 10 models that were
considered to be unique, well validated or widely used.
These models were assessed as to their suitability for
certain tasks. Figure 3 lists these models. Based on these
models and their limitations conclusions are made on their
suitability for modelling target acquisition from tactical
helicopters.

OPERATIONAL CONDITIONS EFFECTIVELY CONSIDERED IN TYPICAL ACQUISITION MODELS

TYPICAL MODELS	TARGET TYPE SMALL (INFANTRY WEAPONS)	MEDIUM (TRUCKS, TANKS)	LARGE (AIRFIELD, BUILDINGS)	DENSITY FEW	MANY	BACKGROUND CLUTTER	MASKING	TERRAIN	SPEED SLOW <200 KTS	FAST >200 KTS	LOW <1500	ALTITUDE (FEET) MEDIUM <10,000	HIGH >10,000	SENSOR EYEBALL	E-O	SEARCH	OBSERVER AXIS OF VIEW
CAL-RYLL	x	x		x			x	x	x		x			x		Systematic	±45° Off Center Axis
GRC A	x	x		x		x				x	x	x		x	x	Random	Fixed FOV
MARSAM II		x	x		x	x	x			x		x	x	x	x	Systematic	Fixed 5° Forward
VISTRAC			x	x			x	x		x	x			x		Systematic	Fixed Forward
Autonetics			x	x			x		x	x	x	x		x		Fixed	Fixed Forward
Franklin & Whittenburg	x	x		x			x	x	x		x			x		Systematic	±45° Off Center Axis
CRESS/SCREEN	x	x			x		x	x	x		x			x	x	Systematic	±45° Off Center Axis
Boeing			x	x			x	x		x	x	x		x	x	Systematic	Forward
Bailey	x	x		x		x	x	x		x		x	x	x	x	Random	Forward

Figure 3.

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EARLY MODELS

The history of target acquisition models parallels that
of target acquisition research. The first model of the
air-to-surface visual search process was developed during WW
II by the Operations Effectiveness Group under B.O. Koopman.
This model is still highly influential. The portion of the
model dealing with visual detection was proposed by E.S.
Lamar. Lamar used data obtained by Craik in the United
Kingdom with respect to detection ranges for targets of
given contrast, size and angle from the observer's line of
sight[12]. This data in conjunction with other data relating
single glimpse probability of detection to apparent
threshold contrast, allowed Lamar to develop his concept of
a "visual detection lobe." This was a convenient way of
expressing the average probability of an observer seeing a
target in a single glimpse. A visual lobe is conceived as
being a volume in space surrounding the visual axis of the
glimpse and within which a target will always be seen. In a
sense it is the locus of threshold contrast points (Figure
4). This lobe defines the value of the threshold contrast
which would be barely discernable, as a function of target
size and angle off the visual axis. This lobe encloses a
volume, but when the eye is directed at the ground a plane
of intersection is formed which is the amount of search area
covered in a single glimpse. This lobe is a hard-shell or
"cookie cutter" approximation of the probability of
detecting a target, in which a target inside the lobe is
seen, and outside the lobe is not seen.

The lobe shape results from the fact that targets at
extreme range can only be focused on the fovea of the eye,
but at closer ranges the target may be seen peripherally or
off the fovea. Lamar defined his visual lobe by the
following equations[12,19]:

$$Ct = .0157 + 0.152/\beta^2 \qquad \text{for } \theta \leq .8^o$$

$$Ct = .0175 + \sqrt{\theta} + 0.19\theta/\beta^2 \qquad \text{for } .8^o < \theta \leq 90^o$$

where β = angular subtense of target (min of arc)
           θ = angle off visual axis (deg)
           Ct = Contrast Threshold (probability)

Lamar then developed an expression for single glimpse
probability of target detection for linear and area search
as a function of target subtense, contrast and search area.
The expressions are based on assumptions of random search
which are appropriate for air-sea situations and are
validated by laboratory experiments. The work reported by
Blackwell, on threshold contrast, and later by Taylor at the
University of California Visibility Laboratory, provided
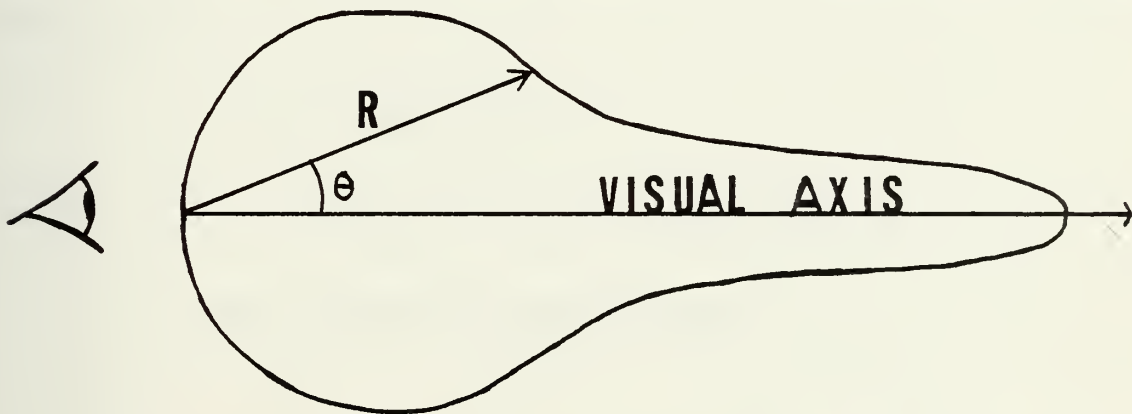additional scurces of data for determining visual lobes.

FIGURE 4. Visual Detection Lobe

This theoretical model of the single glimpse
probability is related to the overall target detection
process by the glimpse theory of search. This is a
theoretical explanation of search in which it is assumed
that search takes place in a series of distinct glimpses,

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distributed over the search area in a random or systematic
order. This is based on the physical fact that observers
fixate their eyes for brief periods when searching an area.
Each glimpse as explained above yields an independent
probability of seeing the target. These individual
probabilities can be combined in many ways, depending on the
pattern of search, to produce a model of search.

A random search model tends to fit the results obtained
from laboratory experiments better than a systematic search
model. Problems also arise in obtaining a good model where
the search area is small or the time available for search is
lengthy. The model assumes that each independent glimpse
covers a certain amount of the search area, depending on the
size of the visual lobe. If it is assumed that each glimpse
probability(p) is constant during the search, and that each
glimpse takes T seconds and total time during search is t
seconds then the cumulative probability of seeing the target
is[21,27];

$$P = 1 - \exp(-\gamma t)$$

where γ = detection rate = $-\ln(1-p)/T$

         $1/\gamma$ = expected detection time

In cases where the individual glimpse probability
changes over time the detection rate also changes. In this
case the cumulative probability would be expressed as;

$$P = 1 - \exp\left(-\int_0^t \gamma(t)\,dt\right)$$

MODEL APPROACHES

There are two general ways of developing models of the
target acquisition process. They are the
analytic-constructive approach, and the operational
approach. The first is more research oriented and the second
is directed towards field test data.

Analytic-Constructive

This approach to modelling is based on using research
data and ascertaining the relative importance of various
factors. The research data is qualitative and usually
pertains to measurable performance of the human visual
system. Using this data the model is developed in segments.
Most best known models have been developed using this
approach. The search and detection process has been
modelled, based on laboratory experiments (e.g., Blackwell
etc.) modified by field "fudge" factors and then other
elements are added to account for the factors that determine
recognition and identification. These include such things as
clutter, target size and shape. Human behaviour factors are
usually not considered, as the model builders tend to use
quantitative variables obtained from laboratory experiments.
These models require extensive mathematical processing.
Typical of such a model is the MARSAM II model in which the
various segments or sub-models are described as
probabilities which are assumed to be independent and are
multipled together to obtain a single numerical value as
follows:

$$P = Pl \cdot Pf \cdot Pd \cdot Pc$$

$$P'r = P \cdot Pr$$

where   P = probability of detection
           Pl = probability of line of sight

Pf = probability of fixating and dwelling on an
object

Pd = probability of detectability

Pc = probability of confusion, target and
non-target objects

Pr = probability of recognizing a detected target

P'r= joint probability of detection and
recognition

Operational Orientation

This approach to modelling is based on field test data obtained under specific conditions. The model is constructed empirically to best fit the data. This approach is not mathematically elegant and may be less precise, but for predictive purposes it may be better. Predictive capability will depend on the similarity between the original test conditions and the situation being predicted. Few models have been constructed in this manner, but the Franklin and Whittenburg (F and W) model is such a model[22]. It was based on the operating characteristics of army air observers and was characterized by (1) reliance on field data, (2) reduction in variables, and (3) simplicity of form. It is unique in that detection, recognition, and identification are intermingled, and it omits such standard variables as threshold contrast, luminance and meteorological visibility.

The F and W model was based on low altitude(200ft) and low speed(100mph) detection of targets with nearest slant ranges of 230-900 ft. This model was based on these variables: target size, target shape, luminance, contrast, clutter, terrain, altitude, range at closest approach, and platform speed. These variables were grouped together to determine apparent size, target distinctiveness, and exposure time measures. These were combined to fit the test data, as follows:

$$Se = S' \cdot C \cdot Te$$

where   Se = effective target size
         S' = average apparent size
          C = target distinctiveness
         Te = exposure time

The probability of detection/identification(Pdi) was then predicted by the expression.

$$Pdi = 1 - \exp(-0.0167 \, Se)$$

GENERAL COMMENTS ON MODELS

The authors of References 12 and 22 examined many models and based on this they made some general observations on Air-Ground Target Acquisition Models. These comments give an insight into the state of models in this field and are summarized. As Greening states " the aggregate modelling work... is out of balance, compared with the known influences on observer performance. The great bulk of the effort has been expended on threshold discrimination of contrasting patches on uniform patches." The major driving functions in models are contrast and target apparent size. Unfortunately the classic models of Lamar/Koopman disregard the observer. It is no longer realistic to discuss the TAP entirely in terms of liminal visual performance.

The models in existence use varying search models, mostly derived from the Lamar/Koopman models, and have little or no validation[12]. No consideration is given to the influence of the observers "response set," training or prior knowledge and ignores benefits of cueing. Another obvious defect is that none of the models examined included target motion as a factor in detection. Most models try to account for target masking in the calculation of the

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probability of line-of-sight, but the likelihood of line-of-sight is difficult to estimate stastically. This will continue to cause problems in realistic modelling.

Because of the lack of continuous work in this field, development of models has been sporadic. The result has been no synthesis or cross-fertilization among model approaches. This may be attributed to the fact that models are difficult to compare because of different forms of output or deficiencies in documentation. Hence when a model has been needed it has been easier to develop a new model rather than amend or update an existing model. The only exception to this has been the British work. Recent work led by E.B. Davies at the Royal Aircraft Establishment(RAE) has continued to develop models based on the visual lobe concept. They have refined the models to (1) eliminate wasting of the visual lobe outside the search area, (2) compensate for targets near visual threshold levels, (3) have better approximations of shape of visual lobe intersection with ground and (4) more closely match field test data. A second group led by G.P. Owens has developed the VISTARAQ model. This model is classified, however it is based on a single glimpse probability derived from a "stimulus value" of a target. This value is determined from the "critical feature" of the target object. The model also includes a search area factor and a line-of-sight factor.

SPECIFIC MODELS

Of those models listed in Figure 3 only three models have the capability of effectively dealing with low altitude, relatively slow speed, and small ground targets. They are the CAL-Ryll model, the F and W model and the SRI-CRESS/SCREEN model. The conclusions drawn by the authors of reference 22 were obtained after careful analysis of the models, including validation. The CAL-Ryll model is an analytic-constructive type and the other two are

operationally orientated. The F and W model has no current work being done with it, and since it was used as a basis for the development of the SRI model it will not be considered further.
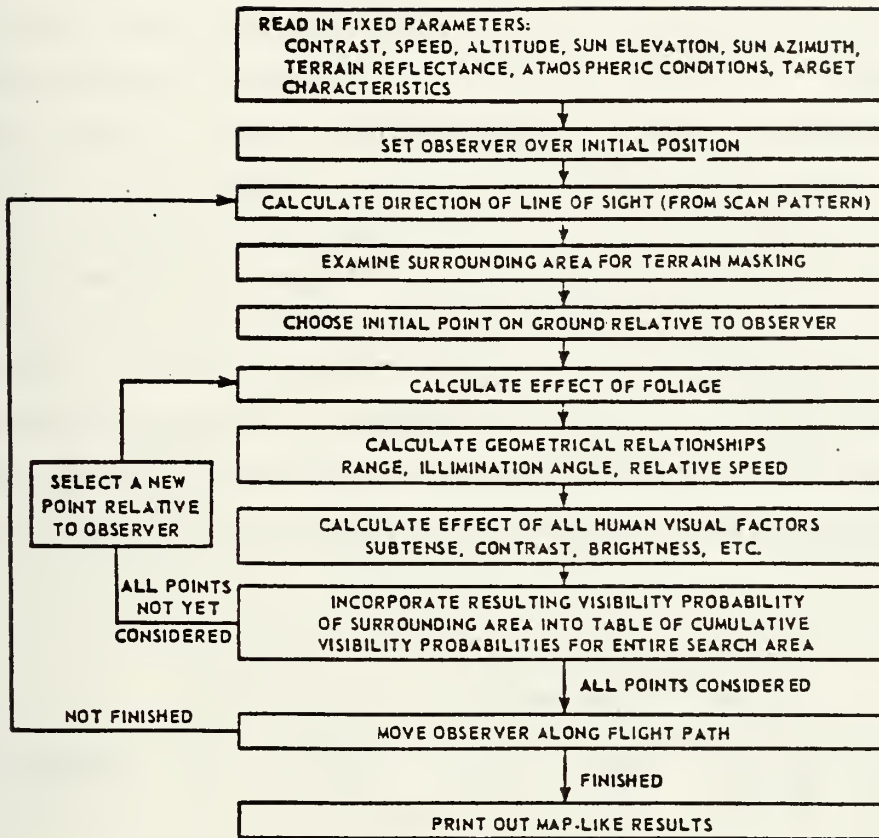
CAL-Ryll

This model was developed at Cornell Aeronautical Laboratories by Ryll for the U.S.Army. Its objective is the prediction of observer performance from low-speed, low-flying aircraft. This model deals particularly with the problem of terrain and vegetation masking. It systematically covers many variables such as speed, altitude, sun position, contrast, atmospheric conditions, line of sight, pseudo targets, different search methods etc. A detailed flow chart is shown on pages 6-12 to 6-17 of Reference 22. Figure 5 which follows is a flow chart of this model. The output of this model is a matrix giving the single glimpse probability of seeing the target for each point in the search area. Outputs are given for different combinations of altitude, airspeed, and look-down angle. The single glimpse probability is determined as follows:

$$P = Ps \cdot Pc \cdot Pn$$

where
$$P = \text{single glimpse probability}$$
$$Ps = \text{probability target is unmasked}$$
$$Pc = \text{probability of detecting contrast}$$
$$Pn = \text{effect of trees and non-target objects}$$

```
┌─────────────────────────────────────────────────────────┐
│ READ IN FIXED PARAMETERS:                                 │
│   CONTRAST, SPEED, ALTITUDE, SUN ELEVATION, SUN AZIMUTH,  │
│   TERRAIN REFLECTANCE, ATMOSPHERIC CONDITIONS, TARGET     │
│   CHARACTERISTICS                                         │
└─────────────────────────────────────────────────────────┘
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SOURCE: RYLL, 1962

Figure 5. Basic Flow Chart for Ryll Aerial Observer Model

<u>SRI-CRESS/SCREEN</u>

This observer model was developed by the Stanford
Research Institute as part of a comprehensive model CRESS
(Combined Reconnaisance, Surveilance and SIGINT) which was
later modified and called SCREEN (SRI Counter-Surveillance
Reconnaisance Effectiveness Evaluation). The basic structure
of the model is shown in Figure 6. It can be seen that it is
conceptually similar to the F and W model mentioned
previously. The model requires input information about the
targets and backgrounds, search geometry and environment.
The outputs are probabilities of detection, identification
and recognition plus non-detections and false targets. This
model is the only one that handles complexes of targets. A
target array giving type characteristics, locations,
camouflage status, clutter factor, etc, is used as an input.
The output is an elaborate decision matrix. Reports of field
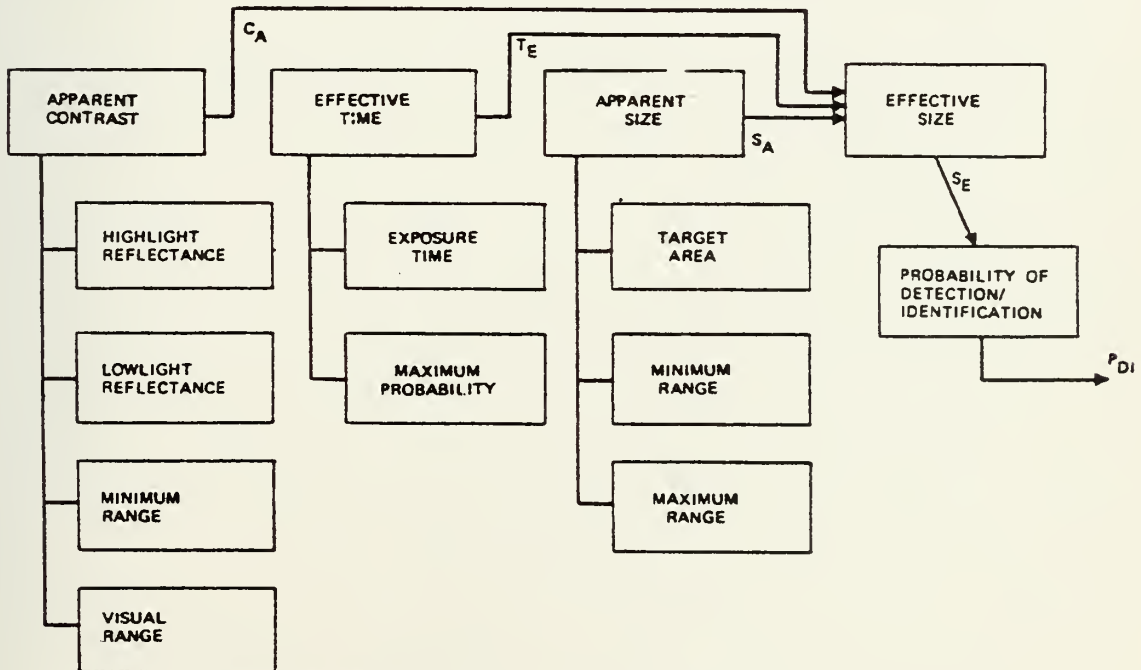test validation of this model are not available.

Figure 6.   SRI CRESS/SCREEN Model Structure

SUMMARY

The investigation of available air-to-ground target acquisition models as outlined above can be summarized as follows.

(1) A reasonable well validated mathematical model of visual search does not exist. Models have been only validated with laboratory data.

(2) Models are difficult to compare because of different forms of output.

(3) The building block approach of constructing models with use of sub-models for particular variables seems most appropriate as it will allow sub-models to be validated separately.

(4) The main function in current models are target/background threshold contrast and target apparent size. Observer variables are largely ignored.

(5) Only the SRI and the CAL-Ryll models can handle the tactical environment related to the TAP from tactical helicopters. The SRI model appears to be better suited for modelling a typical battle field with many targets.

V. CONCLUSIONS

The target acquisition area is not well defined conceptually or with respect to standard terminology. This has resulted in mixed or overlapping concepts. This no doubt is due in part to the interdisciplinary nature of the subject, with various aspects being studied by different persons or groups. This has led to voluminous quantities of literature. The great number of variables and the varying degree of research and definition applied to each have resulted in the target acquisition area being "messy" and confusing. The target acquisition process consists of the observer searching an area, detecting an object as a possible target, and then by recognition and identification classifying it as such.

The investigation of the parameters affecting the target acquisition process and their relationship to the particular problem of tactical low flying helicopters has resulted in these parameters being considered the most important.
(1) Search Technique. The behaviour of the observer is critical, but because it is not amenable to easy quantification or modelling this area has been largly ignored.
(2) Masking. The terrain and vegetation in conjunction with the tactical flying techniques will produce severe masking of potential targets. Line of sight between observer and target has to exist.
(3) Target Exposure Time. In contour or NOE flying this is determined by the helicopter speed and the masking effects. The observer must have sufficient time to search the area containing the target once line of sight has been obtained. The time must be sufficient to allow the eye to make contact with the object, detect it as a potential target, and then recognize and identify it.

(4) Apparent Target Contrast. This is one of the important factors affecting the performance of the observer. The eye/brain combination must perceive a sufficient difference between a target and its background in order for an object to be detected.

(5) Target Size. This parameter is also extremely important in detection of objects by the eye. The target apparent size must be substantially larger than the acuity threshold for target acquisition to occur.

(6) Apparent Motion. The movement of the aircraft causes apparent motion of the target which degrades visual acuity.

The models that exist for the prediction of human visual target acquisition are not well validated. The models are difficult to compare because of different outputs. The observer search performance is largely ignored in most models. The emphasis is on target contrast and apparent size. The models in many cases were developed such that they fitted laboratory data. Unfortunately in most cases they have not been validated with field data. In those few cases where this has been done the models had to be modified with compensating factors. Only the CAL-Ryll and the SRI-CRESS/SCREEN models appear capable of handling the modelling of target acquisition of tactical ground forces from tactical low flying helicopters. SRI has the capability of handling groups of small targets. Until the areas of observer search techniques and target masking are sufficiently well investigated, modelled and validated, the results of predictive modelling of target acquisition from helicopters will be open to question.

VI. RECOMMENDATIONS.

Based on the authors review of the literature and the conclusions reached on target acquisition as it pertains to tactical low-flying helicopters certain general recommendations need to be made. It is necessary to bridge the gap between laboratory data and field data if the realism of predictive models is going to be improved. The "fudge" factors presently used in some models need to be validated by further field test data. In the tactical environment relating to low-flying helicopters more research is required on the effect of masking and observer search performance.

More research on observer search performance is needed to obtain more data on the characteristics of "good" versus "bad" searchers. This could lead to development of better models of the search process and hence better target acquisition prediction. Training observers in search techniques, such as how to search, what to search for, and the use of cues, is recommended.

At present target masking during low-level flight tends to confuse test results pertaining to observer performance. More work is required to classify the relationship between masking and terrain, vegetation, and target clutter. This information in conjunction with typical tactical flight patterns might lead to better predictive models.

It is recommended that a new model specifically for target acquisition from tactical helicopters be developed. The CAL-Ry11 and the SRI models would be good starting points. A new model should be optimized for the classes of targets specific to the ground combat environment. The model should concentrate on typical targets such as troops, defensive positions, and vehicles rather than airfields and

similar targets. The actions recommended might lead tc the
development of a well validated predictive model of the
target acquisition of ground combat targets from tactical
helicopters.

APPENDIX A

GLOSSARY OF TERMS

The following definitions of target acquisition terms are used in this thesis. These definitions are extracted from Reference 29. The primary sources for these definitions are:

1. U.S. Joint Chiefs of Staff Publication 1; Department of Defense Dictionary of Military and Associated Terms.

2. U.S. Joint Test Project Plan of Combat Air Support Target Acquisition Program SEEKVAL,July 1973.

ACQUISITION: Process of detection, recognition and/or identification of a target in sufficient detail to permit the effective employment of a weapon against a target. A generic term covering all aspects of targeting.

ACQUISITION⌐DIRECT VISUAL: Acquisition by use of the unaided eye.

ACUITY-VISUAL: In general the ability of the eye to see fine detail.

CLUTTER: Objects, natural or artificial in the general area of the target other than the target which tend to hinder target acquisition because of their perceived similarity to the target.

CONES: The receptors for the optic nerve, located in the retina and concentrated in the fovea and macula, which are concerned with sharp vision, high ambient light, and color vision.

CONTRAST, APPARENT: For a given range, the difference between the luminance of a target and the luminance of the background, divided by the luminance of the background; includes the effects of atmospheric attenuation.

CONTRAST, INHERENT: For luminance measurements taken close to the target, the difference between the luminance of a target and the luminance of its background, divided by the background luminance.

CUE: An item, feature, or signal that enhances target detection or acts as an indication of the nature of the object perceived.

DETECTION: The determination that an object classifiable as a target has been seen, i.e., the decision that a possible target is present in the scene being searched.

FOVEA: The retinal region of the eye that contains only cones; it is the area (approximately 1.5 degrees) that mediates the highest degree of visual acuity.

GLARE: Any brightness within the field of vision of such character as to cause discomfort, annoyance, interference with vision, or eye fatigue.

LUMINANCE: The photometric term corresponding to radiance; specifies the amount of luminous flux radiated from an extended body per solid angle and per projected area of radiating surface; expressed in lumens per steradian per square meter.

MASKING: The concealment or partial concealment of a target from view. Targets are masked by natural or artificial features.

MODULATION TRANSFER FUNCTION: A characterization of an acquisition system in the spatial frequency domain - specifically, the magnitude of the Fourier Transform of the line spread function (the line spread function describes the display output of an acquisition system viewing an extremely narrow straight line).

NAP-OF-THE-EARTH FLIGHT: Flight performed as close to the earth's surface as vegetation and obstacles will permit and generally following the contours of the earth. Airspeed and altitude are varied as influenced by the terrain, weather and the enemy situation.

OBSERVER: One who acquires and designates targets; includes forward ground observers, aeroscouts, forward air controllers, and other aircraft crew members.

PERCEPTUAL EMBEDDEDNESS: The degree to which a target appears to be part of a larger area , either background or foreground, thus providing a pattern which is difficult to detect or recognize as a target.

RECOGNITION: The decision that an object detected can be specified as a particular object or member of a particular class of objects.

RETINA: The innermost coat of the back part of the eyeball, consisting of cells sensitive to light.

ROD: A light sensitive cell in the retina and concentrated on the periphery of the fovea. It is the only photoreceptor functioning under low levels of illumination.

SLANT RANGE: The range from the observer directly to the target along the line of sight.

SLANT RANGE OF VISIBILITY: The slant range for which the contrast between an object and its surrounding is equal to the threshold contrast of the human eye.

THRESHOLD: The amount of signal required to cause a sensor to respond to that signal. In psychophysics, a probabilistic concept often defined as the amount of energy required for a subject to detect a stimulus on 50 percent of the trials.

VISUAL ANGLE: The angle subtended by an object in the visual field at the nodal point of the eye. This angle determines the size of the image on the retina.

APPENDIX B

TARGET ACQUISITION LITERATURE

In the research for this thesis it became apparent at an early stage that the published work in this field was extremely large. The bibliography listed in this report are only those publications reviewed by the author that were used to write this thesis. Others were discarded as being irrelevant. The best reference was Reference 22, the Source Bock, published by the Martin Marrietta Corp. This reference lists 1750 entries in its 133 page bibliography. In Appendix A of this same publication it gives an 11 - page subject index to the bibliography, for quick reference. This index is classified by the important variables in air-to-grcund target acquisiticn. Those readers wanting to obtain more detailed information sources are urged tc use this extensive bibliography which is indexed by the fcllowing variables.

Target/Background Parameters

Type	Size
Shape	Contrast
Color	Luminance/Reflectance
Texture	Motion
Shadow	Terrain Type
Vegetation	Masking
Counter Surveillance (Camouflage)	Clutter
Cues	Distinctiveness
Conspicuity	Embeddedness
Ambiguity	Confusability

Aircraft Parameters

Altitude   Range
Speed   Offset
Target Exposure Time   Type Aircraft
Seat Position   Apparent Motion

Environment Parameters

Visibility   Cloud Cover
Sky-Ground Ratio   Sun Angle
Illumination Level   Diurnal Variation
Seasonal Variation   Scintillation
Glare   Attenuation
Transmittance   Apparent Contrast
MTF

Sensor/Display Parameters

Sensor Type   Field of View
Resolution   Contrast Ratio
Gamma   Signal to Noise
Frame Rate   Interlace
Integration Time   Pointing Angle
Display Size   Aspect Ratio
Viewing Distance   Displayed Signal-to-Noise
Color Spot   Wobble
Scene Rotation   Display Freeze
Enhancement   Imaging Quality and
                             Assessment

Observer Parameters

Fixation

Search Pattern

Experience

Expectation

Selection

Stress and Fatigue

Prebriefing

Search Aids

Search Time

Visual Acuity

Training

Motivation

Task Loading

Number of Observers

Cueing

Models Modelling and Evaluation

Identification Submodel

Detection Submodel

Atmospheric Model

Mission Parameters

Navigaticnal

Operation Submodel

Training

Multi-Spectral

Multi-Target

Validaticn Data-Simulator

Cueing Variable

Resolution Sensitive

Fatigue and Vigilance

Recognition Submodel

Search Submodel

Terrain Submodel

Validation Data-Flight

Sensor Submodels

Inherent Contrast

Johnson Criterion

Multi-Sensor,

Multi-display

Clutter Variable

Weather Submodel

Motion

Automatic Methods

Flares

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