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13. ABSTRACT (Maximum 200 Words) The purpose of this thesis are as follows: (1) to determine the requirements of a visual ground to air marking system for use by ground combat or patrol type units in a counterinsurgency environment; (2) To report the results of an experiment designed to give the answers to the problem above; (3) To make recommendations as to a possible way to get workable marking systems in the US Army inventory. Chapter I presents the background. Chapter II contains the experiment design. Five variables are tested: smoke, panels, red cross marker, pyrotechnics, and a balloon system. Chapter III contains a detailed description of the experiment. Chapter IV presents the reduced data. Chapter V contains the findings, conclusions, and recommendations.				
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REQUIREMENTS OF A GROUND TO AIR MARKING SYSTEM

A thesis presented to the Faculty of the U. S. Army
Command and General Staff College in partial
fulfillment of the requirements of the
degree

MASTER OF MILITARY ART AND SCIENCE

CHARLES D. CANHAM II, Lieutenant Colonel, Infantry

Fort Leavenworth, Kansas
1966

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Date 23 May 1966

The opinions and conclusions expressed herein are those of the individual student author and do not necessarily represent the views of either The United States Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

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THESIS ABSTRACT

The purposes of this thesis are as follows:

- (1) To determine the requirements of a visual ground to air marking system for use by ground combat or patrol type units in a counterinsurgency environment.
- (2) To report the results of an experiment designed to give the answers to the problem above and conducted as a part of the graduate program of the United States Army Command and General Staff College.
- (3) To make recommendations as to a possible way to get workable effective ground to air marking systems in the United States Army inventory.

Chapter I presents the background of the problem to include the historical precedence, the author's personal involvement in the problem and some references to the Army's test of the air mobility concept.

Chapter II contains the experiment design which includes the logic behind the approach taken to solve this problem. The model construct consisting of the interaction of six variables is explained. These variables are; the five systems tested (smoke, panels, red cross marker, pyrotechnics, and a balloon system), the flight altitude of the observer aircraft, three types of landforms used (flat, rolling and hilly), three types of ground cover (grass, bushes or trees

not forming a continuous canopy and continuous canopy), the location of the principal light source with regard to the ground site location and the visibility.

Two sets of criteria are described. The first, the preliminary criteria, are ones against which the five systems are assessed prior to the actual use of the system in the field. These are; weight, cube, reusability, self-sterilization, persistency, coding capability and covertness. The second set are those measures of effectiveness which deal directly with the use of the system in the field, e.g. versatility and visibility.

Chapter III contains the description of how the experiment was conducted to include a detailed description of the nine experiment sites used, the five systems tested as a part of the experiment, the scientific standards used, and a summary of the test series. The test series consisted of a total of 696 possible observations to include 168 each of smoke, panel and red cross marker and 96 each of pyrotechnics and the balloon system.

Chapter IV presents the reduced data from the field portion of the experiment. Included are details on each of the five systems tested with examinations of the critical variables which influence the success or failure of the system. The evaluations include the effect of landforms, ground cover, flight altitude and direction of flight. These evaluations show that against the versatility criteria, only two systems, pyrotechnics and the balloon, are satisfactory. Considering the visibility criteria, the balloon was 76 percent

effective, the pyrotechnics 69.8 percent, smoke 59 percent, panel 39.8 percent and the red cross marker 31.5 percent.

Chapter V contains the findings, conclusions and recommendations derived from the evaluation of the experiment results and the performance of the five systems.

The conclusions drawn from the results of this experiment are:

(1) It is possible to apply a systematic approach to the solution of a problem such as the one which is the subject of this experiment.

(2) There is not presently in the inventory of visual ground to air marking systems a satisfactorily universal system or device, e.g. one that will assure a high degree of success in the various and varied environments in which it must be used.

(3) To be effective for airplanes flying over various types of terrain and ground cover, a system must get above the surrounding cover and should have sufficient persistency to remain there as long as necessary.

(4) The ground emplaced systems tested in this experiment were much more effective when viewed from 2000 feet than at nap of the earth altitudes.

(5) Of those standard representative systems tested, none provided both the long range observation capability necessary to get the aircraft to the general location, and also the pinpoint accuracy to get it to the exact location.

(6) A system which will work when emplaced

on a parade ground will not necessarily work in the other eight basic types of combinations of landform and cover in which it should be able to work.

ACKNOWLEDGMENT

The author acknowledges with deep appreciation the assistance of Charles D. W. Canham III, age eleven, John P. Canham, age ten, and Daniel C. Wardrop, age eleven, without whose help I could not have begun to accomplish the ground portion of the field work for this experiment.

To Majors A. Benson, W. B. Harper, P. W. McGurl, A. R. Pollard, B. B. Quedens, J. F. Rutkowski, F. J. Toner and all of the other army aviators who so conscientiously performed the air portion of the experiment, and to Colonel John D. Sapp, my thesis monitor, goes a special debt of gratitude.

My wife, Jacelyn P. Canham did her usual outstanding job of deciphering my writing, typing and proofreading the thesis.

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CHAPTER I

INTRODUCTION

Historical Precedence

"I'll give him fifteen minutes more to live, unless we can get him out of here," were the prophetic words of the Battalion Surgeon, 2nd Battalion of the 28th Regiment, 1st Division concerning Lieutenant Colonel George Eyster who was wounded while leading his troops in Vietnam. Associated Press writer, Peter Arnett, eye witness to the event went on to say in his account, "the helicopter sent to evacuate him had trouble finding the landing area, but finally spotted the clearing and swooped down."¹ (emphasis added)

It is with this problem - how to identify a spot on the ground from the air - that this paper deals. More specifically, with the worst case possibility of how to do this in an area poorly or not mapped; an area where it is militarily infeasible to emplace sophisticated navigational aids; an area possibly covered by a dense jungle canopy and finally an area in close proximity to an enemy.

There is ample historical justification of one of the author's basic premises - that, in fact, the problem can be one of major magnitude, and that no satisfactory system

¹The Kansas City Times, January 17, 1966, p. 1.

exists to adequately do this job.

Consider - July 25, 1944. Lieutenant General Lesley J. McNair, Chief of Army Ground Forces was to observe a massive carpet bombing planned by 8th Air Force to soften up the enemy just south of the St. Lo - Periers road. This was no "jury-rigged" affair, but rather, a carefully planned and coordinated operation designed to demonstrate the efficacy of heavy bomber support of tactical ground operations. A total of 2,446 assorted airplanes made the attack and dropped over 4,169 tons of various types of bombs. Despite the fact that the nearest friendly troops were 1500 yards to the near edge of the target, that these forward lines were marked with cerise and yellow panels and that the target was marked with red smoke, thirty-five heavy bomber loads and forty-two medium bomber loads dropped within friendly lines. The end result which was "102 army personnel killed, included Lt. Gen. Lesley J. McNair, and 380 wounded."²

Consider - the Chindits of General Wingate whose task was, by deep penetration into the enemies rear area, to cut communications lines between Mandalay and Myitkyina and Lashio. This force was supplied almost totally from the air, which at that time, in that theater, and with resources available was a herculean task. The amount of supplies and equipment kicked out of the doors of the 15th Air Force's C-47's which never reached the Chindits on the ground can never be ade-

²Wesley F. Craven and James L. Cate (eds.), The Army Air Forces in World War II (Chicago: The University of Chicago Press, Vol. III, 1951), p. 234.

quately verified, however, Doctor Joe G. Taylor, writing in USAF Historical Study, Volume 75, Air Supply in the Burma Campaign, commented on several occasions on the difficulty of marking drop zones so that they could be detected from the air. The most pointed of these comments was:

Sometimes not enough transports were available to deliver all of the supplies requested, and a considerable proportion of the supplies which were dropped were not recovered. Losses were due to dropping at the wrong place, to inaccuracy that scattered the supplies over too large an area, or to Japanese pressure that forced columns to move away from a DZ before all supplies dropped could be recovered. Since the Chindits were on short rations at the best, the loss of any part of the required items was serious, and weakness from hunger brought about a decided decrease in efficiency.³ (emphasis added)

The principal marking device available for use at this time was the marking panel. Dr. Taylor commented that "the panels prescribed by regulations were too small for pilots to see easily, and 36th Division required a minimum length of thirty feet for panels and preferred them longer, up to seventy feet." Another difficulty encountered was the ease with which this system was compromised:

Some Chinese units set up unauthorized DZ's and by this stratagem secured supplies intended for some other unit. Because of this practice on the part of the Chinese, it was suspected, though never proved, that the Japanese too set up markers and received supplies from allied aircraft.⁴

³U.S. Air Force, Historical Division, Air Supply in the Burma Campaigns, (Study No. 75; Maxwell Air Force Base: Air University, 1957).

⁴Ibid.

Corporal Harry A. Center, a member of an eleven man air support party working with the guerrillas on Cebu in the Philippine Islands at the same time lends further credence to this probability:

For the safety of the guerrillas, ground markers came into play. Panel sheets were laid out to designate both friendly positions and the nips. When the nips imitated the panels to confuse the pilots, the guerrillas outfoxed them with a variety of symbols.⁵

Despite twenty years of applied technology and millions of dollars expended to improve the aerial vehicle, the same marker panel is the mainstay of the ground marking system presently in existence.

Unfortunately, the book on United States operations in Korea and Vietnam reads the same way, countless examples of friendly troops being fired on by our aircraft; units on the ground failing to receive necessary supplies or support because of the inability of the pilots to find their location on the ground. In Vietnam, because of the lack of a clearly defined front line, innocent civilians have too often been the unfortunate recipients of misdirected aerial fire.

After drafting the preceding paragraph in the early evening hours of February 2, 1966, this author was not surprised to hear on the ten o'clock news that same night that a U. S. Army helicopter had discharged its rocket cargo into a U. S. Army unit in the field in Vietnam - initial body count

⁵Harry A. Center (Cpl.), "Guerilla Lightning," Air Force, (September 1945).

one killed, nine wounded. If we could consistently do as well against the enemy, in my opinion the war in Vietnam would undoubtedly be shortened by many months.

Suffice it to say that for our purpose here, there has been within the active duty experience of the author, sufficient justification for the development of a foolproof system with which units employed in ground operations could mark their location on the ground for detection from the air. The sad fact is that no such system exists or is presently under development within the formal research and development structure of the Army, despite the fact that the problem has been generally recognized since at least 1944 - twenty-two years.

Personal Interest

The author became personally concerned with this problem in 1952-53, when as a company commander of G Company in the 23rd Infantry Regiment in Korea, I came to the realization that my regimental commander had acquired a proclivity for placing G Company on every outpost or exposed position the Regiment had. It only takes one misguided pilot, over eager to expend his ordnance, to convince the most broad-minded ground commander that there should be some positive means of insuring that that ordnance should not be directed against his troops.

It was not until 1962-63, when as the commander of B-1 Special Operations Detachment of the 5th U. S. Special Forces in Vietnam that this problem became critical to the author. In this capacity I was responsible for planning,

conducting, and leading a battalion-size force in extensive operations in the Mekong Delta area. The advantages possible from the complete integration of both U. S. Air Force and U. S. Army aviation support in these operations made it imperative that they be able to accurately locate our forces on the ground. It came as somewhat of a shock to discover that the means available to accomplish this task in 1962 were the same available exactly ten years earlier in Korea and the same available twenty years earlier in World War II.

It was at this time that the initial effort was expended which has led to this experiment. After a cursory evaluation of the problem, I arrived at the realization that to achieve the greatest effectiveness, it would be necessary to have a marking system which could get off the ground and above the ground cover canopy. After a great deal of unauthorized local procurement, a system was put together which involved a hydrogen filled balloon, a set of streamers, and a ground anchor cable. See Plate I.

This system was used by the author on a number of occasions and proved to be highly effective. Since it was a pilot model made from locally available resources, it had a number of drawbacks. These were beyond our capability to correct at the time.

The author's last two months in Vietnam were spent as the Special Forces member of The Office of the Secretary of Defense (OSD), Advance Research Project Agency (ARPA), Research and Development (R&D) Field Unit Vietnam. In this capacity the general parameters of the system were written up and submitted

to Washington as part of the field unit's quarterly report. It was wrongly assumed that the project would be picked up and incorporated as a recognized R&D project as a result of this action.

The project was not to remain dormant long, for upon returning to the United States, the author was assigned to help evaluate the Army's Air Assault concept.

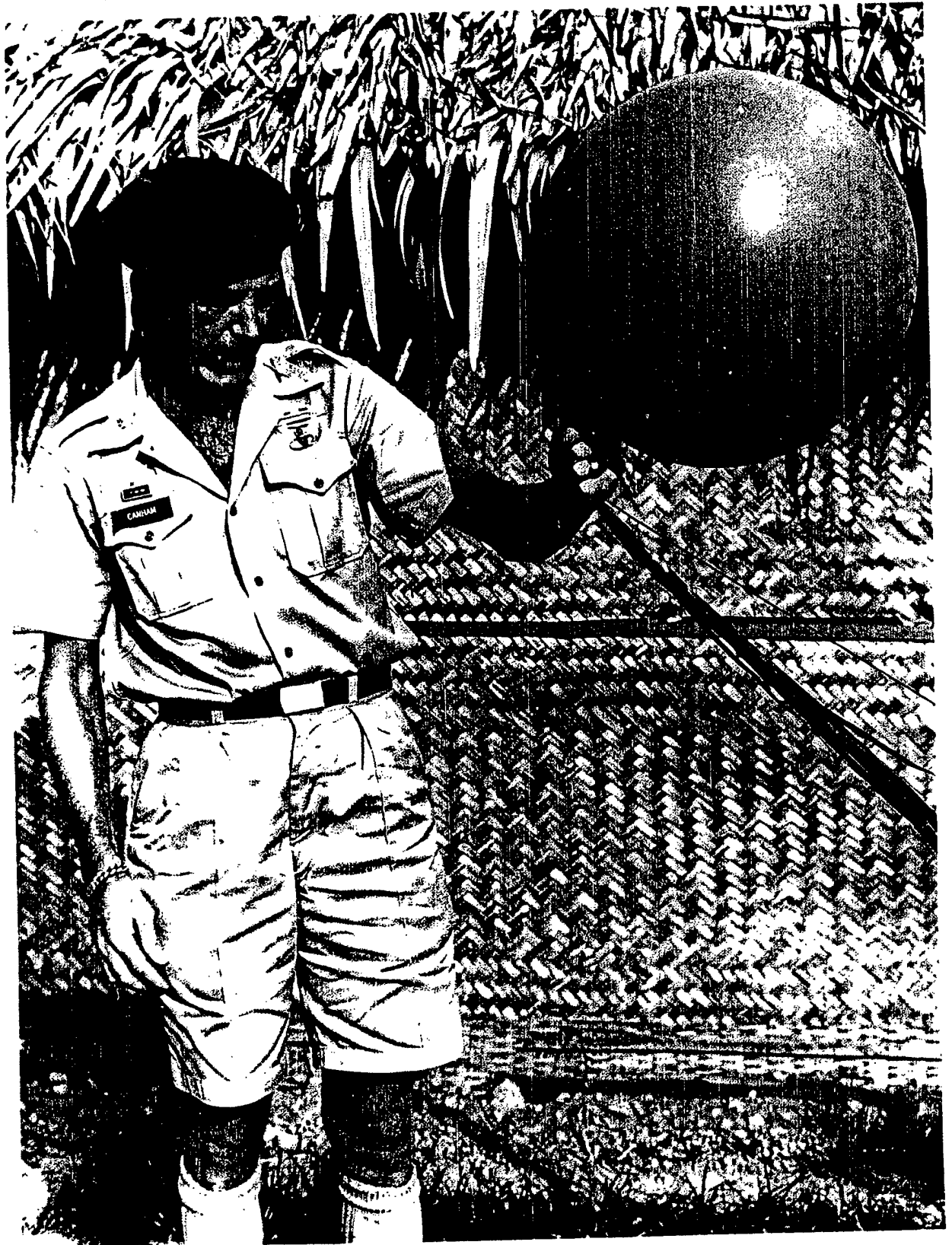
Air Assault Test Results

It so happened that the author's job encompassed the evaluation of all aspects of logistical support for the air assault division. In the exercise of these responsibilities, it again became painfully clear that we were trying to coordinate the most advanced aerial concepts with ground operations, using antiquated means.

The culmination of the evaluation of the Army's air assault concept was a highly controlled and documented test of the air assault division in a simulated combat environment. Prior to this test, Air Assault II, we determined from an extensive war game that it would be necessary to assess over 2,400 casualties if the test was to achieve a realistic degree of validity. This aspect of the test was designed to determine the efficacy of total reliance on air ambulance evacuation of casualties in the Air Assault/Air Mobile environment.

Major Albert Benson, my principal assistant for medical service evaluation, and a superbly qualified medical evacuation pilot, in his student treatise, Medical Evacuation and Treatment in the Air Mobile Division, written while a

STATE I



member of the Fall 1965 Associate Course at The Command and General Staff College, made the following comment concerning this problem:

The average delay time of fifty-three minutes required by the air ambulance platoon to pick up a patient after receipt of the evacuation request was partially contributed to navigational difficulties. There were no means of identification of the patient pickup site from the air, except for visually sighting personnel waving their arms or an aidman displaying a Red Cross panel. Flares and smoke would have compromised the tactical commander's position. Low level, nap of the earth flying, resulted in many pilots not immediately locating the pickup sites. On numerous occasions pilots had to gain altitude and resurvey the area before locating the correct coordinate. This procedure also compromised the location of friendly troops. The average elapsed time could be reduced significantly if the medical aidman had a small navigational aid which would enable pilots to either home in on his position or a visual aid that could be sighted while flying at low altitudes.⁶

As damning as the above observation is, it is extremely kind for he was here speaking of the occasions when the casualties were actually found by the air evacuation means. The final report of this test did not consider the several hundred times when a casualty was reported and never picked up. Many of these occurrences were a result of the failure of the pilot to find the location of the casualty on the ground. I am not blaming the pilots for these failures, but rather, the lack of a system to adequately mark the location of the casualty on the ground.

⁶Major Albert Benson, "Medical Evacuation and Treatment in the Airmobile Division" (unpublished treatise, U. S. Command and General Staff College, Fall Associate Course, 1965), pp. 10-12.

This problem would be bad enough if one man lost his life as a result of the fact of such a system. What is much more sobering is the thought that during this exercise, in which the pilots had many hours flying over terrain which is relatively easy to navigate, upwards of a thousand of these simulated casualties were never evacuated. Granted, many of them tore off their casualty cards and went on about their business, but, there was a significant percent who could not be found and therefore had to move out with their units when the tactical play of the problem called for a unit displacement.

After the final evaluation of the air assault concept was written the commanding general of the Test, Evaluation and Control Group formed a special group to determine if the necessary research, development, test and evaluation (RDT&E) work was being done to support the Army's Air Mobile Concept. This author was among the eleven officers chosen for this task and it was here that this same problem came back to haunt me, for it was my job to evaluate the current RDT&E being undertaken to integrate the aerial vehicle into the ground environment. After a very detailed study of current and proposed R&D projects and several liaison trips to the Army agencies concerned with this overall problem, it became obvious that no significant systemic effort was being expended to solve this relatively minor problem. Rather, what partial solutions had been arrived at were a result of product orientation; i.e., "why not use smoke?", or "xyz company has an interesting gadget which might work."

After all of the preliminaries above, the author decided to do something about this problem. This thesis and the experimental work which has gone into it are the result of that decision.

CHAPTER II

EXPERIMENT DESIGN

General

This paper is the report of an experiment conducted on the Fort Leavenworth, Kansas military reservation. The purpose of the experiment was to determine the requirements of a ground to air marking system for use in a counterinsurgency environment. This environment includes areas in which it is not feasible to emplace airway control systems and areas in which the lack of easily recognizable man made or terrain features make it difficult to navigate visually.

The experiment tested various selected ground to air marking systems presently in use within the United States Army, and one experimental model, under varying conditions in order to arrive at valid conclusions as to the requirements for workable daylight marking devices.

In order to reduce the problem to manageable proportions, it was necessary to make several decisions as to what constituted the critical variables effecting the use and effectiveness of ground to air marking systems. These are discussed below.

Model Construct

The test design decided upon contained the controlled

interaction of six sets of variables. These sets are: the systems to be tested; aircraft flight altitude; landform types; ground cover types; visibility classifications; and the direction of flight in relationship to the location of the principal light source. These variables were selected after a careful evaluation of the types of environments that such systems should be capable of functioning in and an analysis of how to measure the effectiveness of these systems.

Systems tested--Five different marking systems were used throughout the experiment, e.g., smoke, marking panels, red cross marker, pyrotechnics, and the balloon marking system developed by the author. These are all described in detail in Chapter III. In order to arrive at a measure of their individual worth and effectiveness, it was necessary to observe each of these systems a significant number of times under the different possible combinations of the other sets of variables.

Aircraft flight altitude--Two flight altitudes were selected. The first, "nap of the earth", has been described in official Army publications:

The aircraft normally fly at the lowest altitude above the terrain within technical safety requirements. Low altitude reduces the enemy's capability to detect the movement and to place long-range, large caliber weapons fire on the aircraft in flight. By flying low, aircraft take maximum advantage of irregularities in the terrain, thus gaining some protection from small arms fire.¹

¹U.S. Department of the Army, Airmobile Operations, (FM 57-35; Washington: U. S. Government Printing Office, November 1960).

The second was 2000 feet, actual, which is generally out of the effective range of small arms fire, but not so high as to cause a high level of attenuation of visibility because of atmospheric conditions.

Landform classification--The Army uses three general classifications of terrain: open - flat, slightly rolling terrain; median - rolling, lightly covered with trees; close - rough heavily wooded, mountainous terrain.² These classifications were considered to be inadequate for use in this experiment in that they were too general and not sufficiently descriptive of the various combinations of landforms and ground cover encountered in military operations. For this reason they were not used. Three types of landforms were selected: flat, rolling, and hilly. Locally available sites adequately represent the spectrum of possible derogation of effectiveness of ground marking systems which could be caused by terrain.

Ground cover classifications--There were also three representative types of ground cover possibilities selected: grass, bushes or trees not forming a continuous canopy, and forest or jungle type cover forming a canopy. Using the above descriptions, it was possible to classify a particular ground location both as to landform and ground cover. A numeric system was adopted for ease of identification, the first digit of which defined the landform: 1 - flat, 2 - rolling, and 3 - hilly. The second digit provided the ground

²U.S. Department of the Army, Maneuver Control (FM 105-5; Washington: U. S. Government Printing Office, April 1964), p. 146.

cover classification index: 1 - grass, 2 - bushes or trees not forming a continuous canopy, and 3 - forest or jungle type cover forming a canopy. A 1/3 site then was flat ground covered with forest or jungle type cover forming a continuous canopy.

Principal light source--In order to offset the difficulty of flying into the sun and to insure that all possibilities were taken into consideration, each set of experiments was flown from four directions, initially with the sun to the rear of the line of flight, then into the sun, and then two passes at right angles.

Visibility--The most difficult variable to work with was visibility. Since there was no way to control this factor, it was decided to conduct a sufficient number of replications of the experiment to insure that representative conditions were encountered.

The model--The model arrived at, then, contained the six major elements described above. It was one of the author's basic contentions that by making a statistically significant number of observations of the different marking systems employed under a variation of the other five elements of the model, meaningful data could be collected from which could be drawn valid conclusions as to the requirements of a universally workable marking system.

A number of students at the Command and General Staff College who were army aviators assisted in the experiment. Each of those selected was asked to contact the author whenever he was going to perform his monthly minimum flying re-

quirement. These flights were then integrated into the experiment. Each pilot was oriented on the requirements of the experiment.

Prior to an experiment series the pilot would be given the grid coordinates of the experiment site to be used that day. The aircraft and ground radio would be coordinated to insure that the individual on the ground could talk to the pilot in the aircraft and vice versa. The pilot would then be given a time to arrive over the experiment site. After making these arrangements, the author and his assistants would proceed to the site where they would emplace the static making devices and prepare the others.

When the pilot arrived overhead and a final communications check was made, the pilot would be instructed to fly toward the sun for approximately four minutes, execute a 180° turn and proceed toward the target area at nap of the earth height. Upon executing his turn, the pilot would notify the ground station that he was on his inbound run. This time would be recorded as the first of many pertaining to this particular run of the experiment. The pilot was instructed to report immediately when he detected any marking devices. These times were recorded as reported. The pilot would also report his estimated ground speed for each run.

Upon passing over the ground station, the pilot would continue to fly in a straight line for another four minutes when he would again execute a 180° turn and repeat the same process as on the first run. Once over the ground station he would turn right 90° and fly for approximately four minutes

when he would once more execute a 180° turn in order to start the third run.

Once over the ground station for the third run, he would continue on the same heading in preparation for the fourth run at nap of the earth altitude. Upon completing the fourth run, the pilot would climb to 2000 feet actual altitude at which time he would complete four more runs of exactly the same orientation as the first four.

For each run the ground station personnel would detonate the pyrotechnics and smoke grenades at a predetermined time after the pilot reported he was inbound on a run.

The eight runs listed above constituted an experiment series in which eight sightings were made (or not made) on all five of the marking systems. This process was continued throughout the year utilizing all nine experiment sites under varying weather and visibility conditions. The technique explained above made possible the accumulation of a great amount of data about all five systems under the varying conditions cited.

Criteria Development

The first, and by far the most important characteristic of a ground to air marking system is that it must work. It must do the job it was intended for and it must do it in the area or at the point which best satisfies the requirement of the ground commander. The tactical situation on the ground often dictates that the unit involved is not able to search for an open or cleared area in order to emplace a

marker. The commander should have the capability of initiating the marking device wherever and whenever it best suits his requirements.

Arrayed alongside this major overall requirement are many lesser but still important requirements of such a system. To the knowledge of the author no one had established a set of standards of performance for devices such as those under consideration in this experiment. For this reason, it was necessary to analyze as objectively as possible the requirements for ground to air marking systems. Based on the experience of the author and discussions with other officers, two sets of criteria were established; one against which the systems were assessed prior to their employment, and the other which had to do with the actual effectiveness of the system while in use.

The preliminary criteria selected were: weight, cube, reusability, self-sterilization, persistency, coding capability, and covertness. To provide a measure of relative effectiveness for each of the systems tested, each was evaluated against these criteria and against each of the other systems. A numerical and percentile rating was established for each system as a result of this assessment.

The field test decided on evaluated the relative effectiveness of the systems when actually used under the varying conditions of visibility, landforms and ground cover. The two criteria of versatility and visibility were selected as providing a good measure of the overall effectiveness of the system in use.

Weight--The load on the foot mounted tactical unit engaged in extended operations over rough terrain against an elusive enemy often determines the success or failure of an operation. It is almost axiomatic that to stage a successful counter-guerrilla campaign, it is necessary to achieve a mobility differential over the guerrilla. One of the keys to achieving this advantage is the capability of operating efficiently for extended periods in the guerrilla environment. To achieve this high degree of efficiency, it is necessary to hold to the minimum the load on the individual soldier. This requirement assumes very real proportions when it is necessary to manpack the food and ammunition needed to sustain an individual in jungle combat. It is very difficult to "live off the land" and perform military operations, even the skilled woodsman would require most of his effort just to sustain himself in many of the areas in which military operations have occurred in the past. These considerations demand that any additional weight be judiciously imposed on ground type units. Considering just the factor of weight, a relative rating of the five systems evaluated was determined:

<u>Score</u>	<u>System</u>
10	balloon
9	
8	marker
7	
6	pyrotechnics
5	
4	smoke

<u>Score</u>	<u>System</u>
3	
2	panel
1	

Cube--For many of the reasons above, the size of the marking device assumes critical importance. The marking panel, for example, is not particularly heavy, but it is of a very awkward configuration which cannot conveniently be carried by an individual. It will not fit in the standard military pack. It has no provision for strapping on an individual and is so long that when carried by an individual in jungle or forested areas tends to snag or hang up on underbrush. Ideally, of course, a marking system should be insignificantly small. However, accepting the state of the art, it should not be too much to ask that it at least fit into a pocket on the individual soldier's uniform, or as such is the case with the smoke grenade be conveniently carried on the standard field harness. Assessing the five systems used in this experiment against this criteria provided the following evaluation:

	10	balloon system
satisfactory	9	
	8	smoke
marginally	7	marker, pyrotechnics
satisfactory	6	
	5	
unsatisfactory	4	panels
	3	
	2	

Reusability--If the marking device is reusable, a minimum number can be carried on any particular tactical operation. If, on the other hand, the device is not reusable, more of them must be taken in order to cope with any contingency. Of the systems tested in this experiment, the panel and marker are reusable and were given a satisfactory rating of ten. The other systems were given an unsatisfactory rating of five.

Self-sterilization--This criteria was established because of the necessity to clean up the battlefield, not in the sense that so many people can remember from World War II or Korea; but rather to reduce the possibility of confusion on the part of pilots flying over areas where there are markers left from previous operations.

A prime example of this would be a possible system discussed at a brainstorming session conducted by the author on this subject in South Vietnam in 1963. This idea was to utilize a launching system generally similar to the ground signals used in this experiment. This launcher when clear of the canopy would burst to shower out a dye marker which would stain the upper layers of the canopy, which in turn could be observed from the air. Such a system without provision for dye which would fade out and neutralize itself could be very confusing from the air.

Another aspect of this problem has to do with the debris left after a device has been used. For example, the ground signal system is a very "dirty" device. No one in his right mind would carry one out of its carrying case for any distance for the exposed firing pin makes this device suscep-

tible to premature initiation. This means that when it is used there remains in the hands of the user several pieces of hardware which must be disposed of; in addition, the rocket motor and parachute fall to earth. Of particular concern are the three metal tubes, all of which are suitable for making landmines. This debris must be disposed of and for this reason detracts from the overall effectiveness of the system. Applying the same ten to one scale applied to the size consideration, values were assigned as indicated below:

	<u>Self-sterilizing</u>	<u>Debris</u>	<u>Composite</u>
	10 panel, marker	panel, marker	panel marker
satisfactory	9		
	8 smoke		
marginally satisfactory	7 balloon		
	6		balloon smoke
	5 pyrotechnic	balloon	
	4	smoke	
unsatis- factory	3		
	2	pyrotechnic	
	1		

Persistency--Many occasions call for aircraft to arrive overhead at a set time without communication with the units supported on the ground. This possibility and the fact that it is very difficult to hear aircraft for long distances in jungle type terrain make it necessary that a device be capable of being emplaced or initiated and left until detection from the air.

The pilot has two major problems in locating units

on the ground. First, to get to the general area, and second to locate the friendly unit exactly. A typical general mission might be to resupply ground element "x" at grid coordinates ----- at 1600 on 19 January 19-- (three days hence). The first major difficulty the pilot has is to get to the general area. In order to help, the ground commander should be able to put up some device which can be seen for some distance. There are several devices which can do this. However, there is none which can do this for any appreciable length of time. Two of the available means used in this experiment, i.e., smoke and pyrotechnics burn out in much less than five minutes. If a ground unit could be sure that the aircraft would be in the general area at 1600, it could detonate either of these devices with some hope that they would be seen from a distance. Because of the difficulty of navigating in the types of terrain with which we are concerned, and other difficulties such as enemy action, it is very difficult to determine such a time. It is, therefore, desirable to be able to emplace the long range signal somewhat in advance of the expected time of arrival and have it have the necessary persistency to do its job. The second part of the problem - how to find the exact spot on the ground will be discussed under accuracy.

The criteria for persistency arrived at is over ten minutes, satisfactory; five to ten minutes, marginally satisfactory; and one to five minutes unsatisfactory. Applying this criteria to the five systems evaluated, the following ratings were determined:

satisfactory	10	panel, marker
	9	balloon
	8	
	7	
marginally satisfactory	6	
	5	
	4	
	3	smoke
unsatisfactory	2	pyrotechnics
	1	

Coding capability--The Chinese, during the Korean War, kept on hand a large selection of different type pyrotechnics which they would shoot off indiscriminately, or whenever the United Nations forces used pyrotechnics, the Chinese would respond almost immediately with a combination of different and the same type signals with the expressed purpose of confusing the signals. This technique worked very well, especially after a heavy artillery preparation prior to an attack when at least some of the land communications lines would be cut. Coupled with a good capability to jam the United Nations radios, this ability to disrupt the coding of visual signals gave the enemy a distinct advantage which was difficult to overcome. The ability to code ground marking systems can be just as important. The difficulty of duplicating a type system plays an important part in satisfying this criteria as does the flexibility of selection, several different colors, and configuration possibilities. The values assigned to our five systems are:

satisfactory	10	
	9	balloon
	8	pyrotechnics
marginally satisfactory	7	
	6	smoke
	5	
unsatisfactory	4	panel
	3	
	2	marker
	1	

Covertness--Quite often it is highly desirable to be able to emplace or initiate a marking device without any noise which might give the ground location away to an enemy. The systems under consideration vary from the silent emplacement of the marker to the express train sound of the pyrotechnics.

satisfactory	10	marker, panel
	9	
	8	
marginally satisfactory	7	
	6	
	5	
	4	
unsatisfactory	3	smoke
	2	
	1	pyrotechnics

Accepting the criteria used above and the assessment of the five systems against these criteria, the following summation applied:

<u>Criteria</u>	<u>Balloon</u>	<u>Panel</u>	<u>Marker</u>	<u>Pyrotechnics</u>	<u>Smoke</u>
Weight	10	2	8	6	4
Cube	10	4	7	7	8
Reusa- bility	5	10	10	5	5
Self-steri- lization	6	10	10	2	6
Persistency	9	10	10	2	3
Coding Capability	9	4	2	8	6
Covertness	9	10	10	1	3
Summation	58	50	57	31	35

The remaining two criteria are the measure of how well each of the systems worked in the field under the varying conditions of visibility, landforms and ground cover. Versatility--The measure of versatility assigned was in its simplest terms - could the system be used effectively in the different environments in which it was to be tested. This specifically referred to the different landform and ground cover possibilities covered by the nine different combinations used in this experiment. The criteria for versatility related to the success or failure of a system in all nine of the locations and was a composite of the effectiveness at all sites.

The effectiveness rating at each site was established as:

Satisfactory -- over seventy-five percent;

Marginally satisfactory -- between fifty and seventy-five percent;

Unsatisfactory -- less than fifty percent.

The versatility criteria established was: to be adjudged satisfactory, a system should satisfy the above criteria for satisfactory at least at six sites, marginally satisfactory at two and unsatisfactory at not more than one. To be adjudged marginally satisfactory, it should have at least three satisfactory sites, five marginally satisfactory and not more than one unsatisfactory.

Visibility--The determinants of success or failure of the systems evaluated were: How well did the various systems work at each experiment site; how far were they seen if seen at all; what were the effects of the different landforms, ground cover and atmospheric conditions on each. The author's best professional judgement called for a criteria of satisfactory for a system which was observed at least seventy-five percent of the times it was used, marginally satisfactory for one observed between fifty to seventy-five percent and unsatisfactory for one observed less than fifty percent of the time.

The composite of the ratings of each system applied against all of these established criteria defined the degree of performance of the system.

CHAPTER III

CONDUCT OF THE EXPERIMENT

Site Selection

During the early planning stages of this experiment an extensive reconnaissance was conducted from the air and ground to determine the feasibility of conducting this type test in this area. Nine locations were selected as test sites on the Fort Leavenworth reservation. It is fortunate that the terrain on such a small reservation (800 acres) contained the variety of ground forms and cover to provide the degree of variety necessary for this experiment.

The initial reconnaissance did disclose a potentially major problem--the deciduous character of the ground cover in this area. Once the problem was recognized, the solution became obvious. The field work for the experiment was programmed so that the replications for sites 1/3, 2/3, and 3/3 were completed before the leaves fell off of the trees.

A minor problem was the flight restrictions in the area. These restrictions broke down into three categories: first, the NIKE Site located at UP328586 was a restricted overflight area; second, Sherman Army Airfield and its related flight paths had to be crossed with caution and, in some instances, clearance from the tower; third, common sense dictated that the build up area of the Post should not be over-

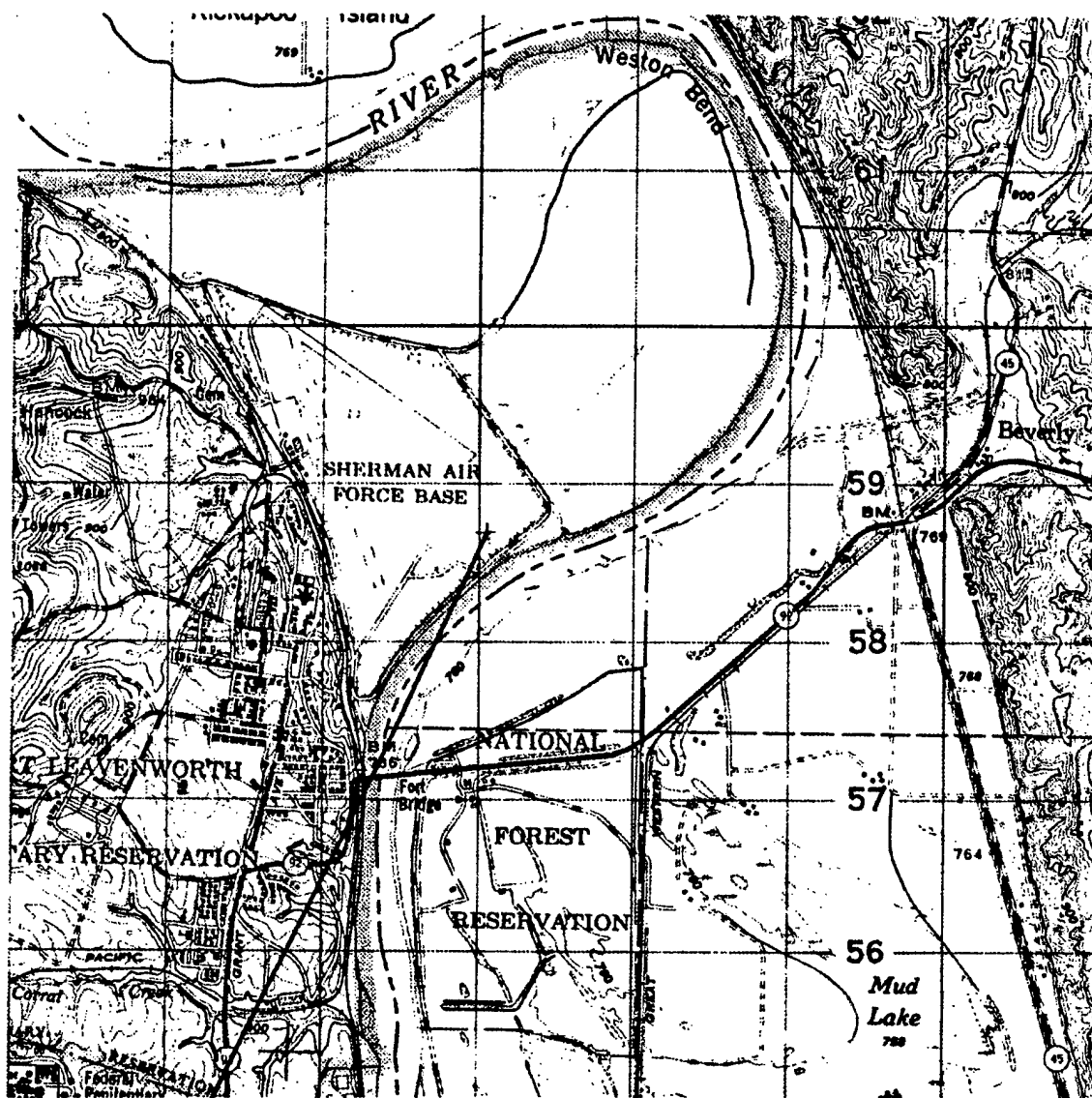
flown at NAP altitudes. These considerations dictated to a certain extent the location of the test sites. They did not, however, impose any attenuation of validity of the tests.

The nine sites selected provided a very good representative sample of the nine possible combinations of landforms and ground cover necessary to achieve a high degree of realism for this experiment. They also satisfied the self-imposed requirement to be removed from the built up areas of the Fort Leavenworth contonment area so as to allow long inbound flights toward the marking systems emplaced at the site location.

Each of the nine sites also met the requirement for sufficient space in which to use all five of the systems tested. The site had to have consistent landform and ground cover over an area large enough to disperse the systems so that when the pilot observed the first marker, he could not immediately focus his attention in that exact area and see all of the rest of them. To emplace all of the markers in such a manner would have seriously affected the validity of the test results.

The next nine pages contain map extracts showing the location of the nine sites used with descriptions of the landforms and cover. All map extracts are from the Army Map Service map LEAVENWORTH KANSAS, 7062IV and are included in the UP 100,000 meter square. Remarks, as appropriate, are included.

EXPERIMENT SITE 1/1



Map 1

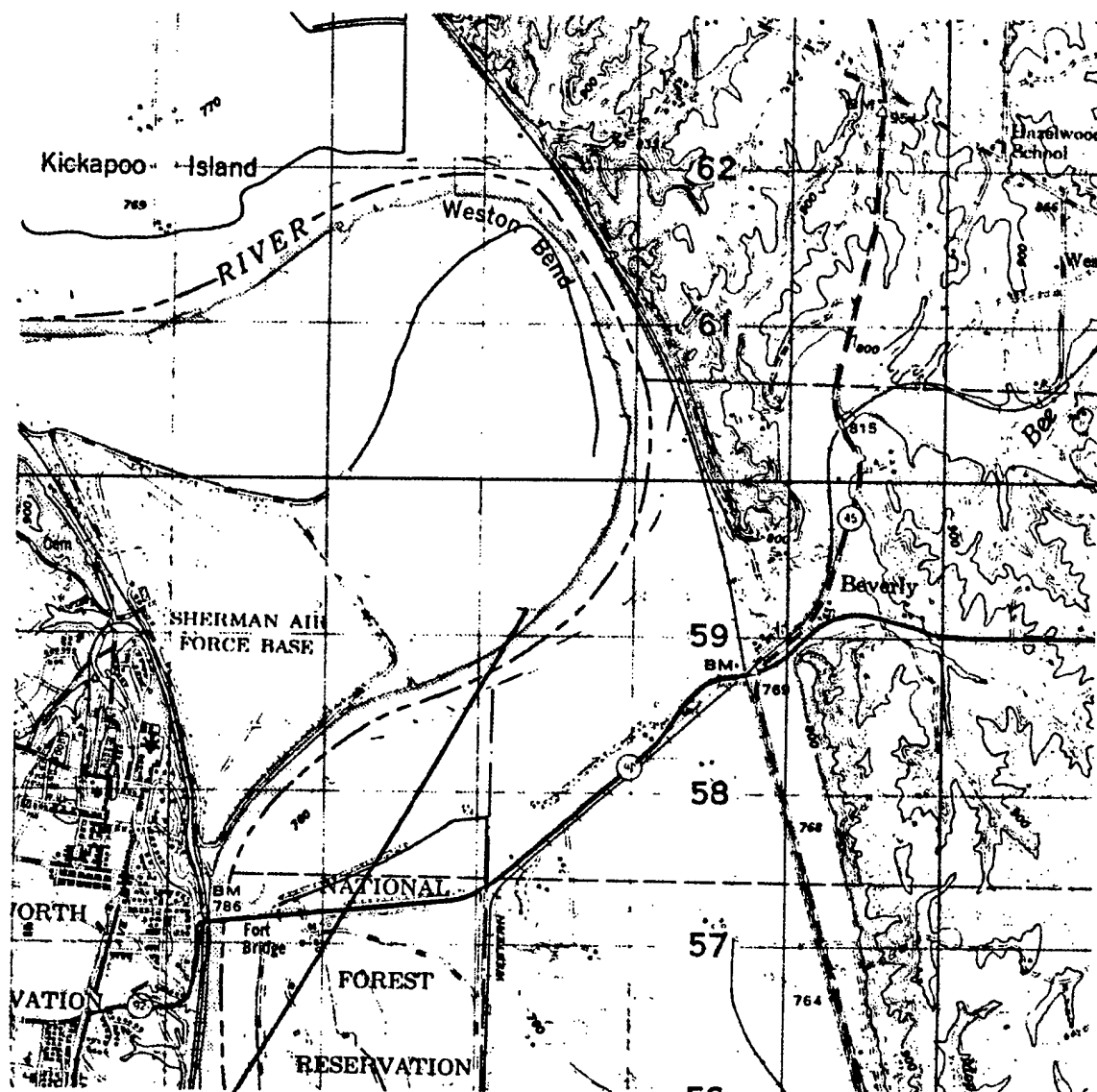
LOCATION: Grid coordinates 361587

LANDFORM: Flat, cultivated field

COVER : Scrub grass

REMARKS : This site is comparable to the rice paddies of the Mekong Delta of Vietnam, the Chorwan Valley of Korea, the Ishakari Plain of Japan and the central plain of Luzon in the Philippines.

EXPERIMENT SITE 1/2



Map 2

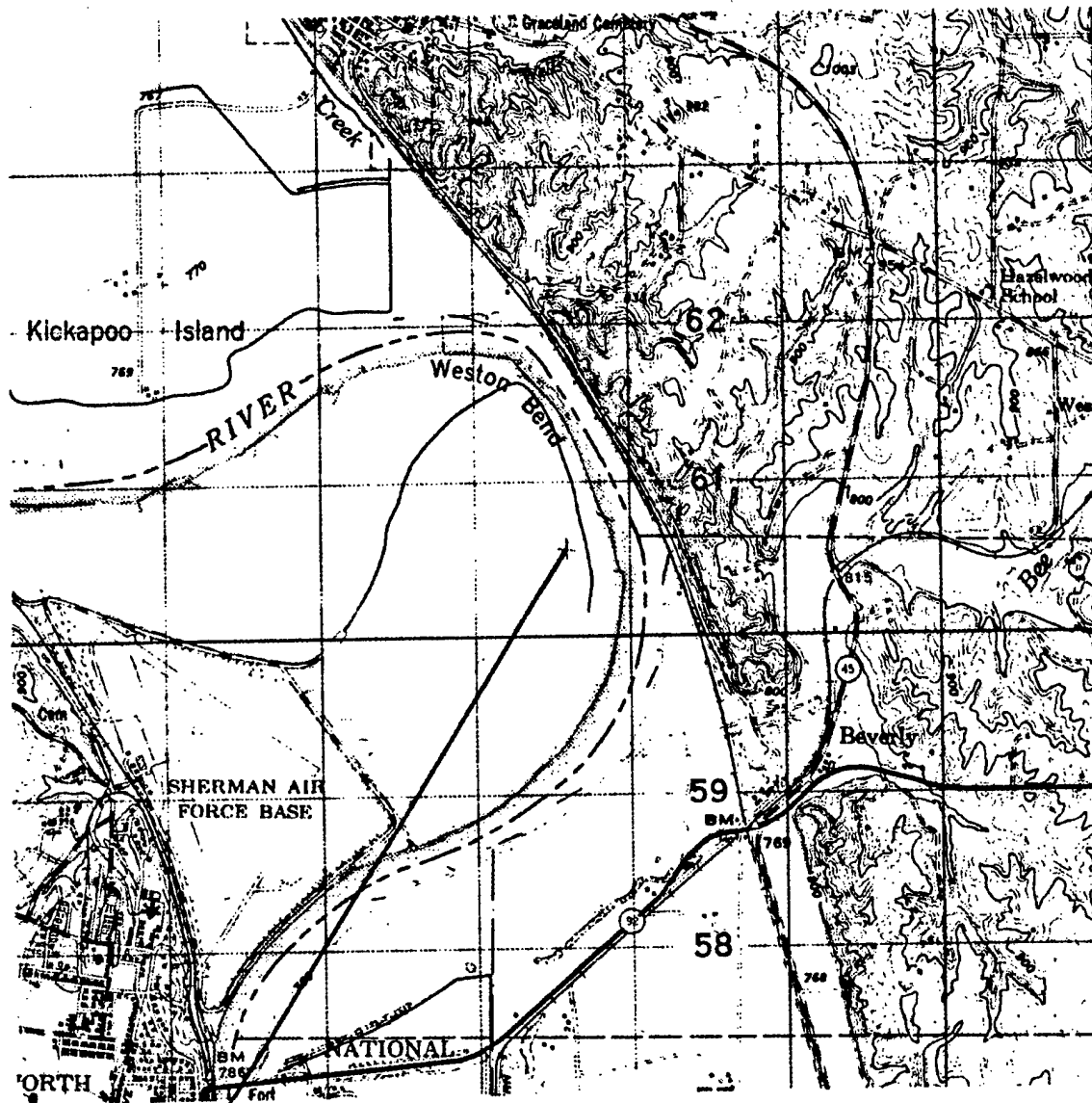
LOCATION: Grid coordinates 373592

LANDFORM: Flat

COVER : Generally open with numerous bushes and small trees not forming a continuous canopy.

REMARKS : An open spot on the ground was selected for the emplacement of the panels and the initiation of the other devices at this location.

EXPERIMENT SITE 1/3



Map 3

LOCATION: Grid coordinates 375606

LANDFORM: Flat

COVER : Jungle type canopy 100-150 feet high with thick underbrush forming a secondary canopy.

REMARKS : The cover in this area closely resembles the jungle cover in many countries of the world.

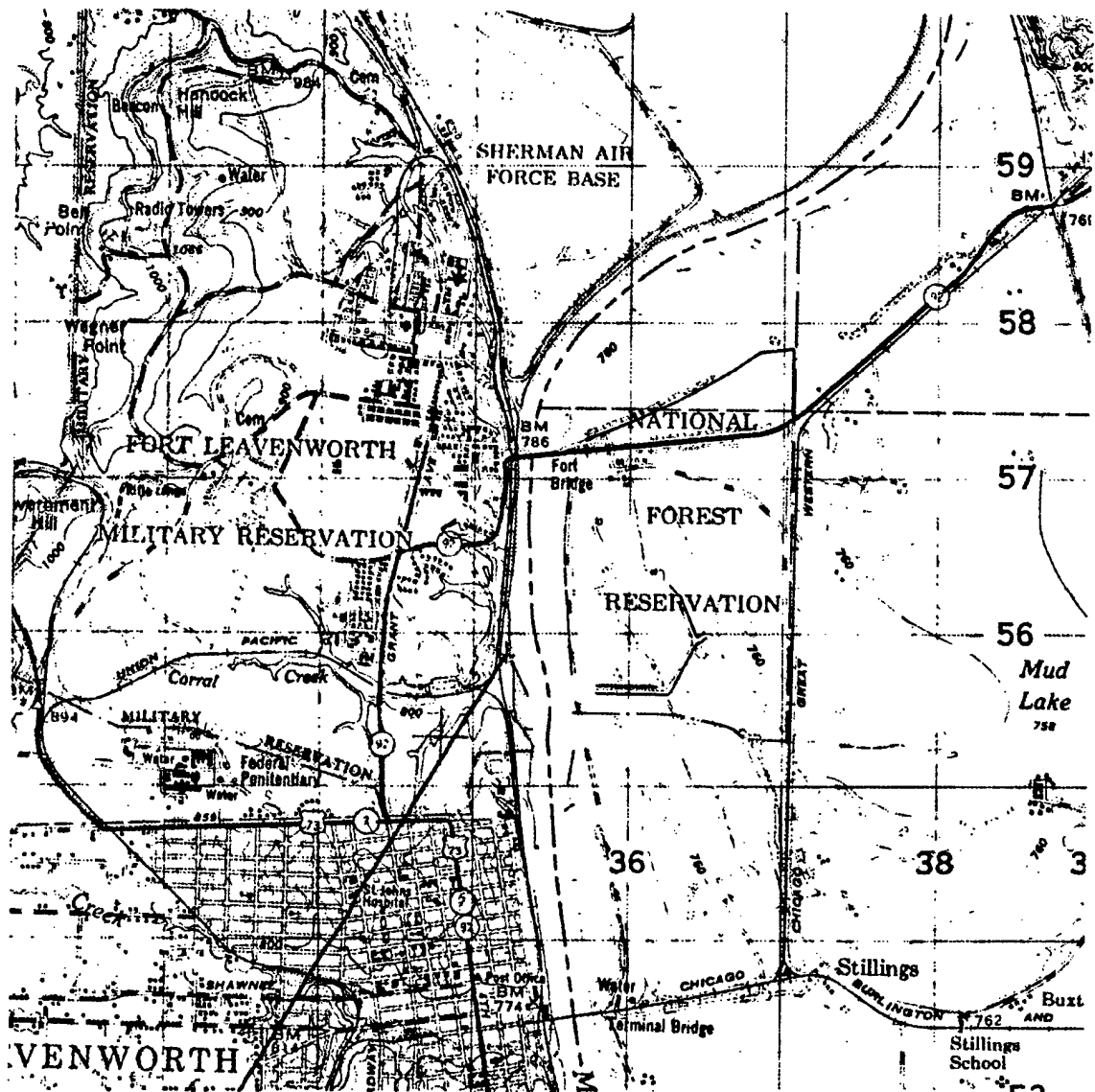
EXPERIMENT SITE 2/1



Map 4

LOCATION: Grid coordinates 324563
 LANDFORM: Rolling
 COVER : Short grass
 REMARKS : This site offers a terrain obstruction to low level observation from the west.

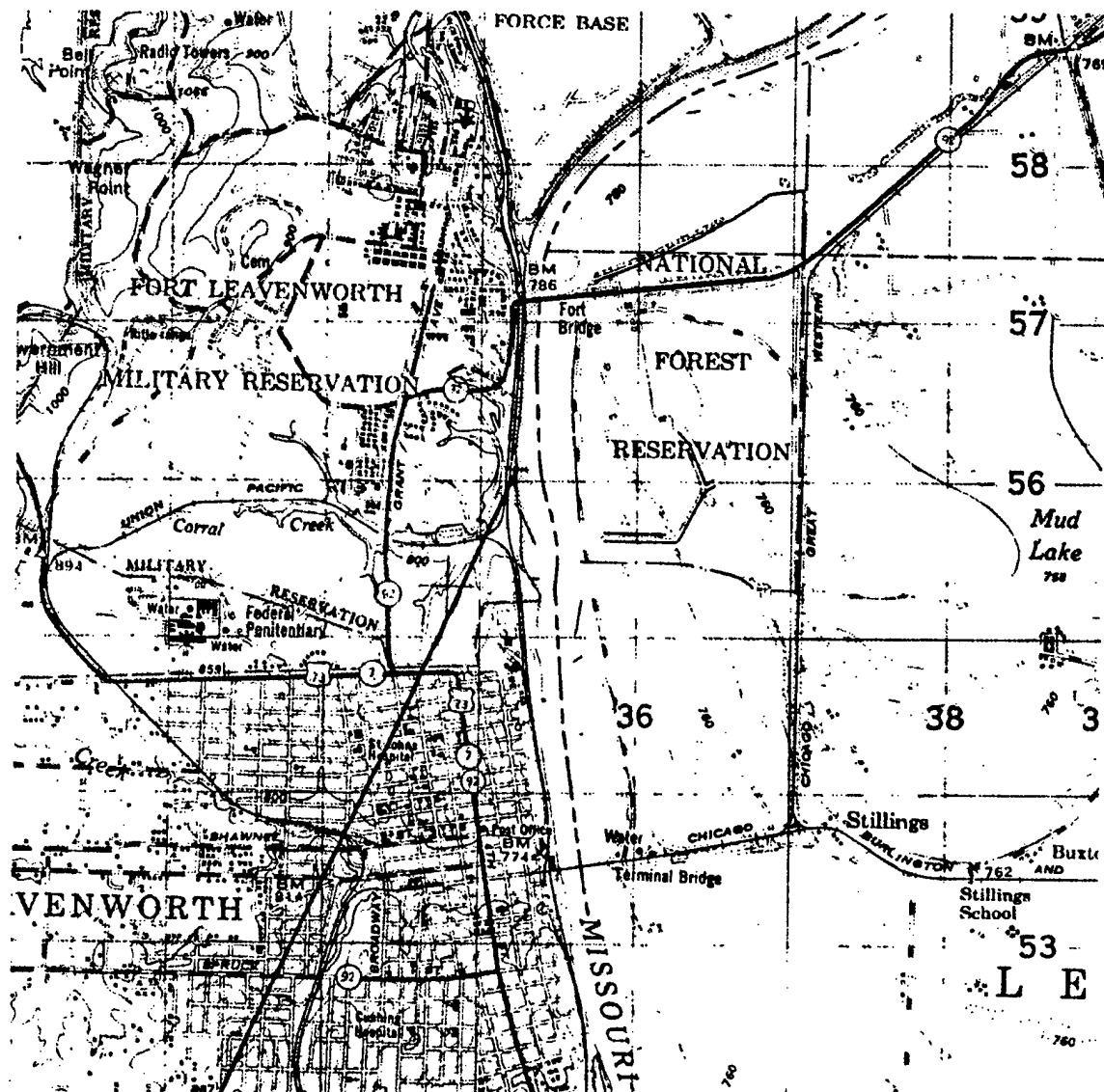
EXPERIMENT SITE 2/2



Map 5

- LOCATION: Grid coordinates 352559
- LANDFORM: Rolling terrain on the edge of a major river
- COVER : Numerous bushes and small trees with a few open areas
- REMARKS : This is a type location which would often be encountered in ground operations in the newly developing countries of the world.

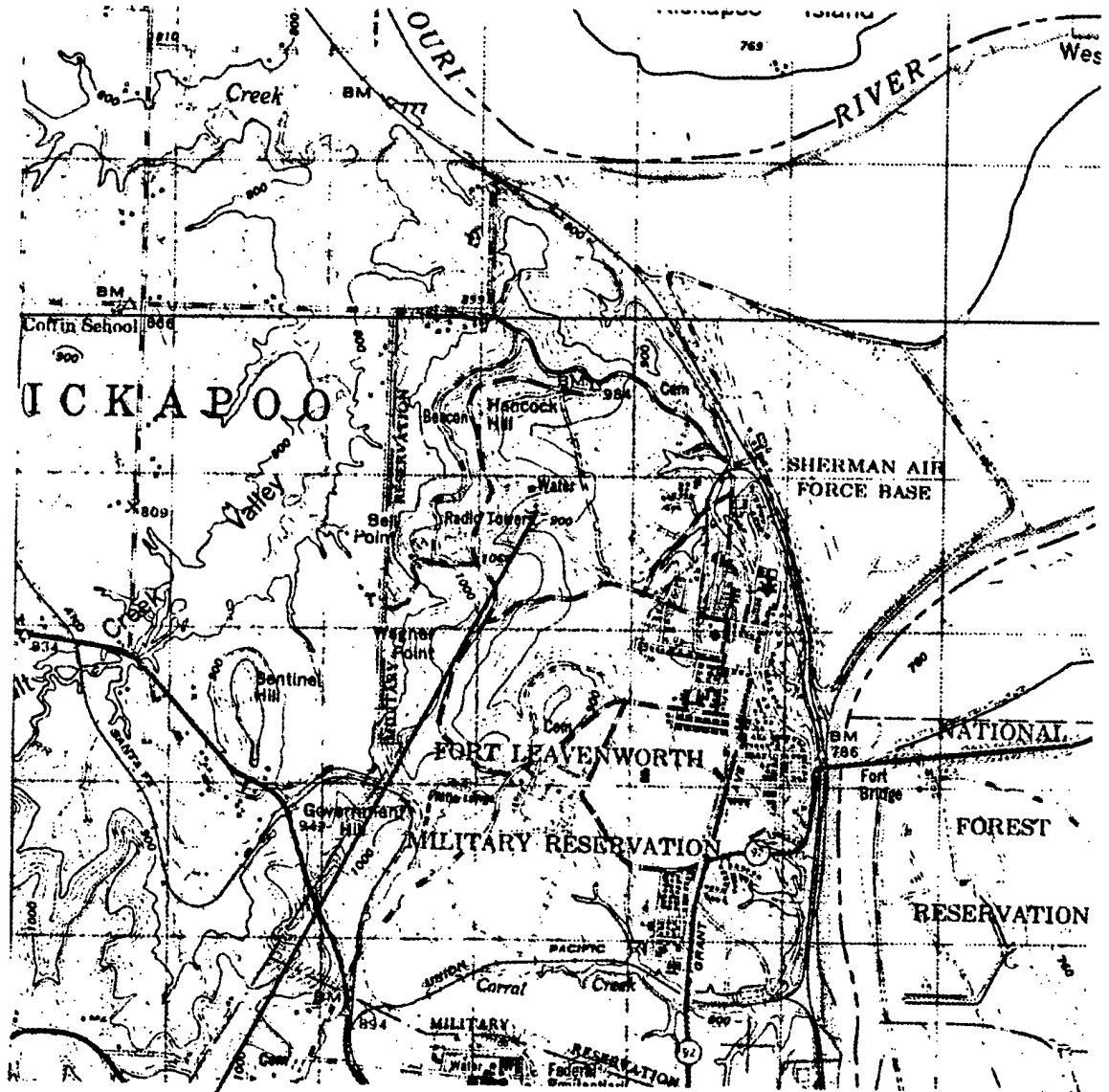
EXPERIMENT SITE 2/3



Map 6

- LOCATION: Grid coordinates 353561
- LANDFORM: Rolling terrain on the edge of a major river
- COVER : Sufficient density of trees to form a continuous canopy.
- REMARKS : Here the different marking systems were used under the canopy as opposed to an open area in site 2/2.

EXPERIMENT SITE 3/1



Map 7

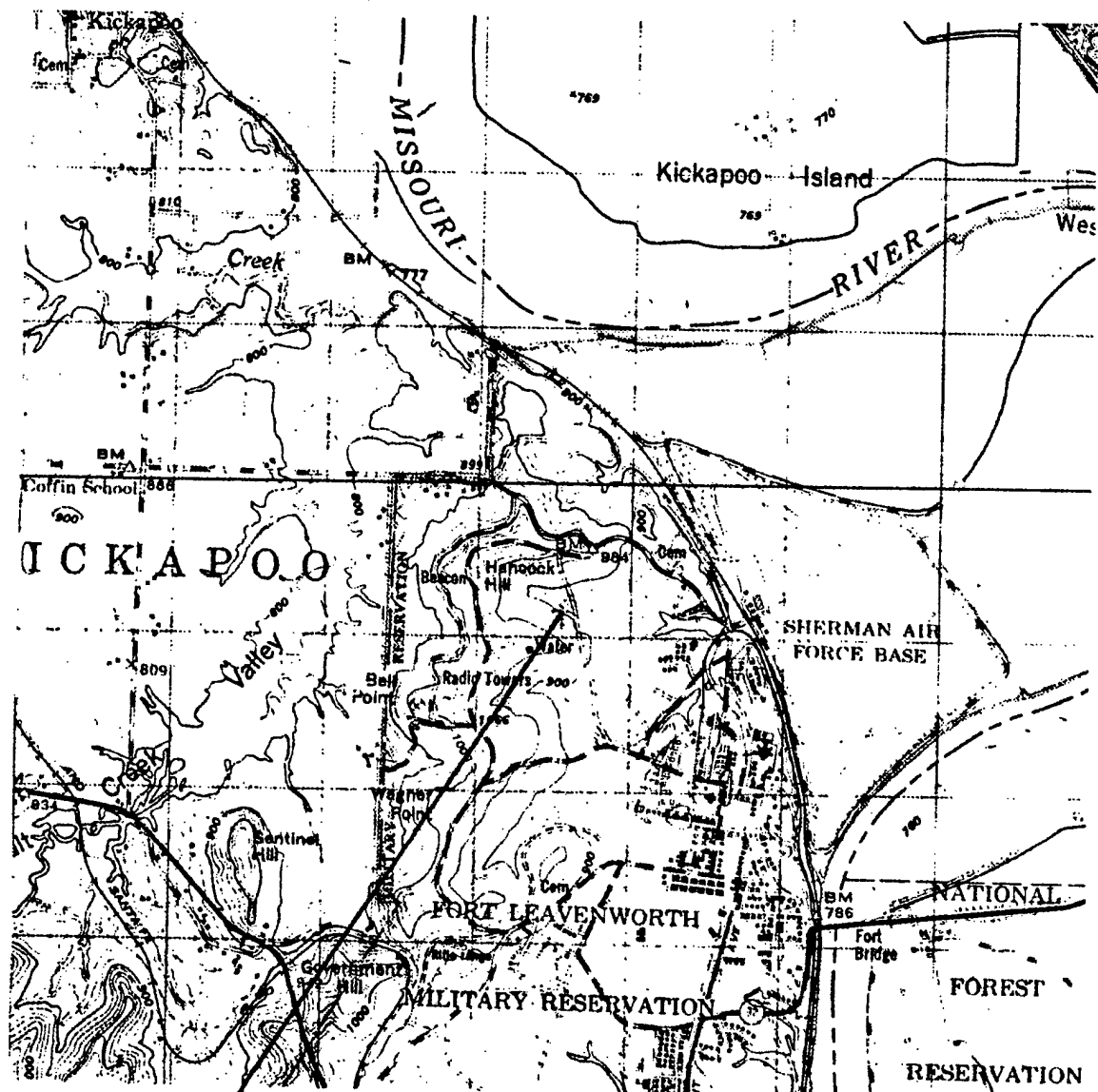
LOCATION: Grid coordinates 336588

LANDFORM: Hilly

COVER : Numerous large trees, cleared of underbrush

REMARKS ; Although there are many large trees in this area, this site was not used until the leaves had all left the trees and therefore qualified as a class 1 cover site.

EXPERIMENT SITE 3/2



Map 8

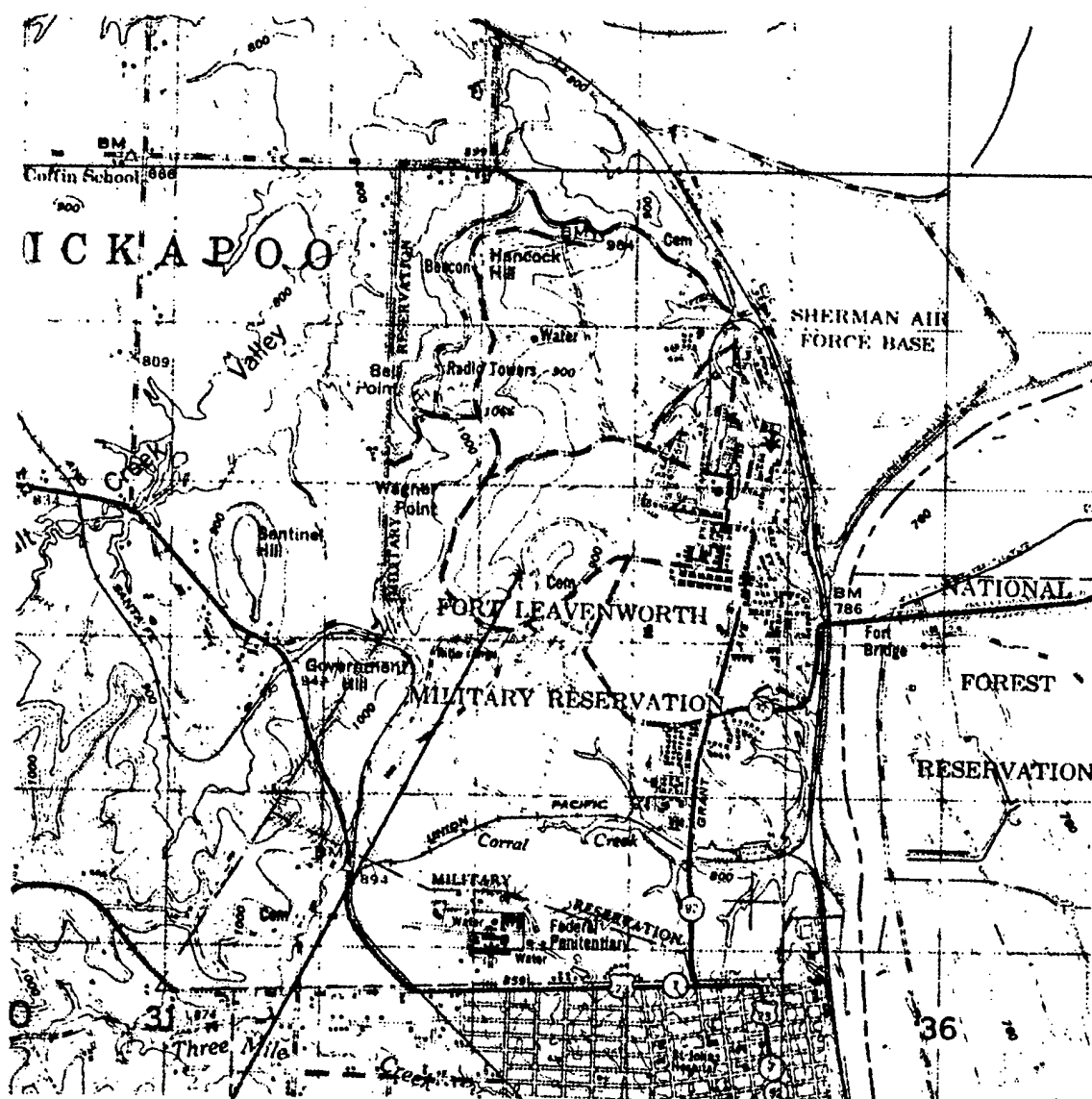
LOCATION: Grid coordinates 336593

LANDFORM: Hilly with a major compartment east to west

COVER : Numerous large trees with some open areas

REMARKS : This site closely resembles many areas such as the central highlands of Vietnam in which itinerant tribes clear small areas in the jungles for farming.

EXPERIMENT SITE 3/3



Map 9

- LOCATION: Grid coordinates 333575
- LANDFORM: Hilly with pronounced relief highly compartmentized
- COVER : High trees forming a primary canopy and secondary growth forming a lower canopy.
- REMARKS : This site encompasses the most difficult combination of landform and cover in which a marking system must work.

Systems Tested

The systems tested were selected for several reasons, the most important of which was that they represent a cross section of the visual systems presently in use and available to the Army. They also represent the two basic approaches of persistency versus non-persistency and ground emplaced versus airborne markers.

As was mentioned in Chapter II, five systems were selected; they were smoke grenades, panels, markers, the balloon system developed by the author, and pyrotechnics. These five represent the spectrum from ground emplaced, static, persistent systems (markers and panels) through the ground emplaced, vaporous, non-persistent (smoke) to the ground launched, airborne, non-persistent (pyrotechnics), and finally to the other extreme of the spectrum, the ground launched, airborne, persistent balloon system.

Three of these, the smoke grenades, marking panels and pyrotechnics are standard Army items which have been in the inventory and available to the field for many years. The red cross marker was a result of the product orientation mentioned in Chapter I and was used during the Air Assault II Test to replace the marking panel for identification of casualties awaiting air medical evacuation. The balloon system, of course, is the author's invention and is used in this experiment as a test vehicle to help determine its value.

The next five pages contain pictures and descriptions of each of the five test systems.

PLATE II



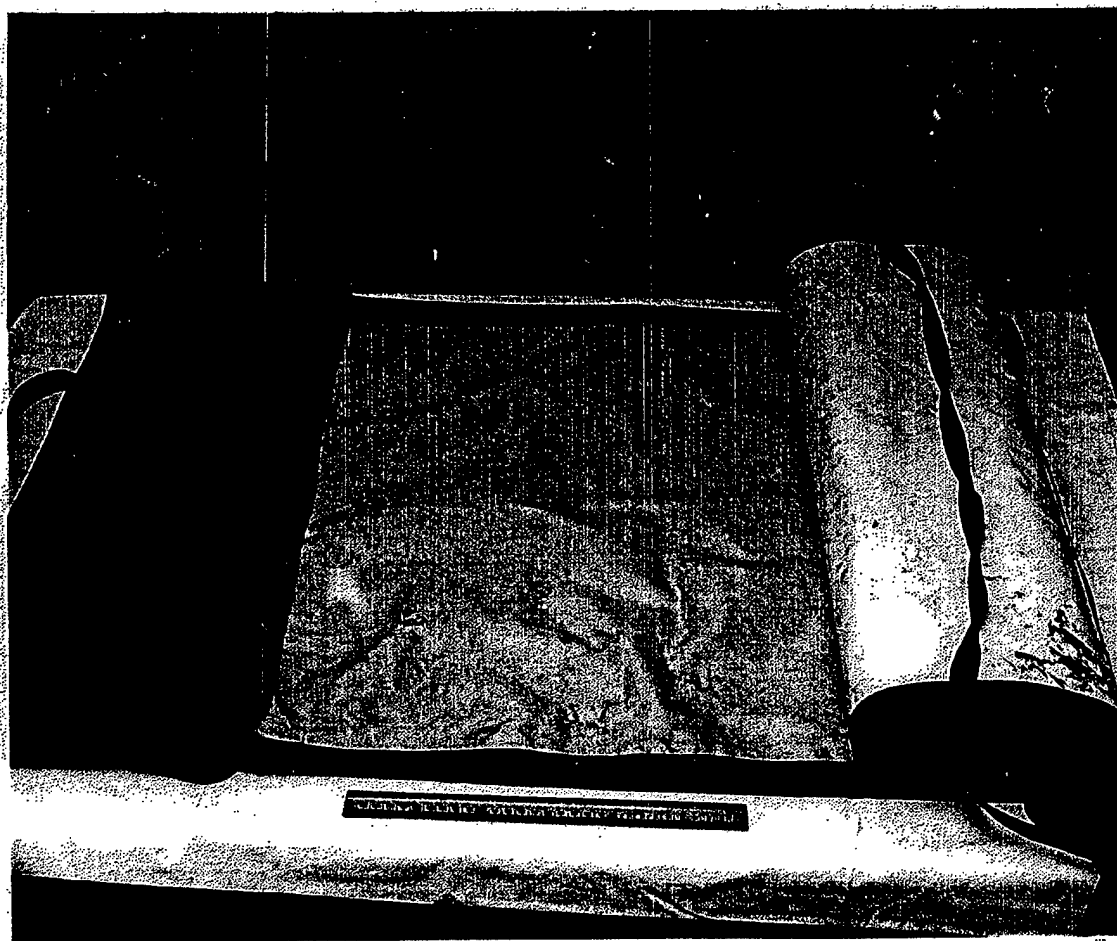
Smoke

DIMENSIONS : Six and one-fourth inches long, three inches in diameter

WEIGHT : One and one-half pounds

CHARACTERISTICS : The grenade, Hand, Colored Smoke M-18 used for this experiment is a burning-type grenade which when used emits a dense smoke. There are four standard colors, red, violet, green and yellow. The burning times and volume and density of smoke emitted varies markedly, however, one minute burning time is a good average.

PLATE III



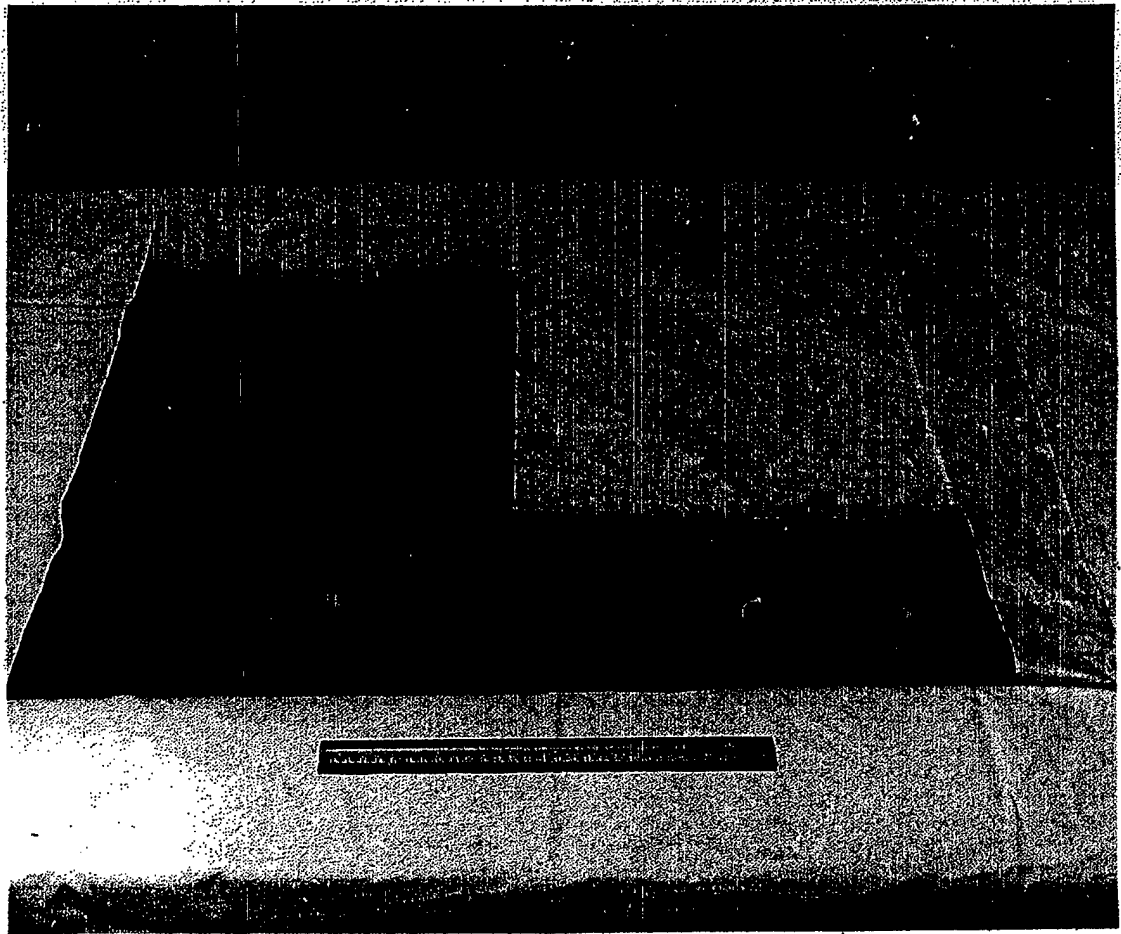
Panel

DIMENSIONS : Rolled-up, thirty-two inches long and five inches in diameter. Deployed ready for use it is twelve feet long by twenty-eight inches wide.

WEIGHT : Five pounds

CHARACTERISTICS : The Panel A1-141-B used in this experiment is made of a plastic material. It is yellow on one side and white on the other. The plastic is susceptible to cracking and during cold weather loses much of its pliability.

PLATE IV

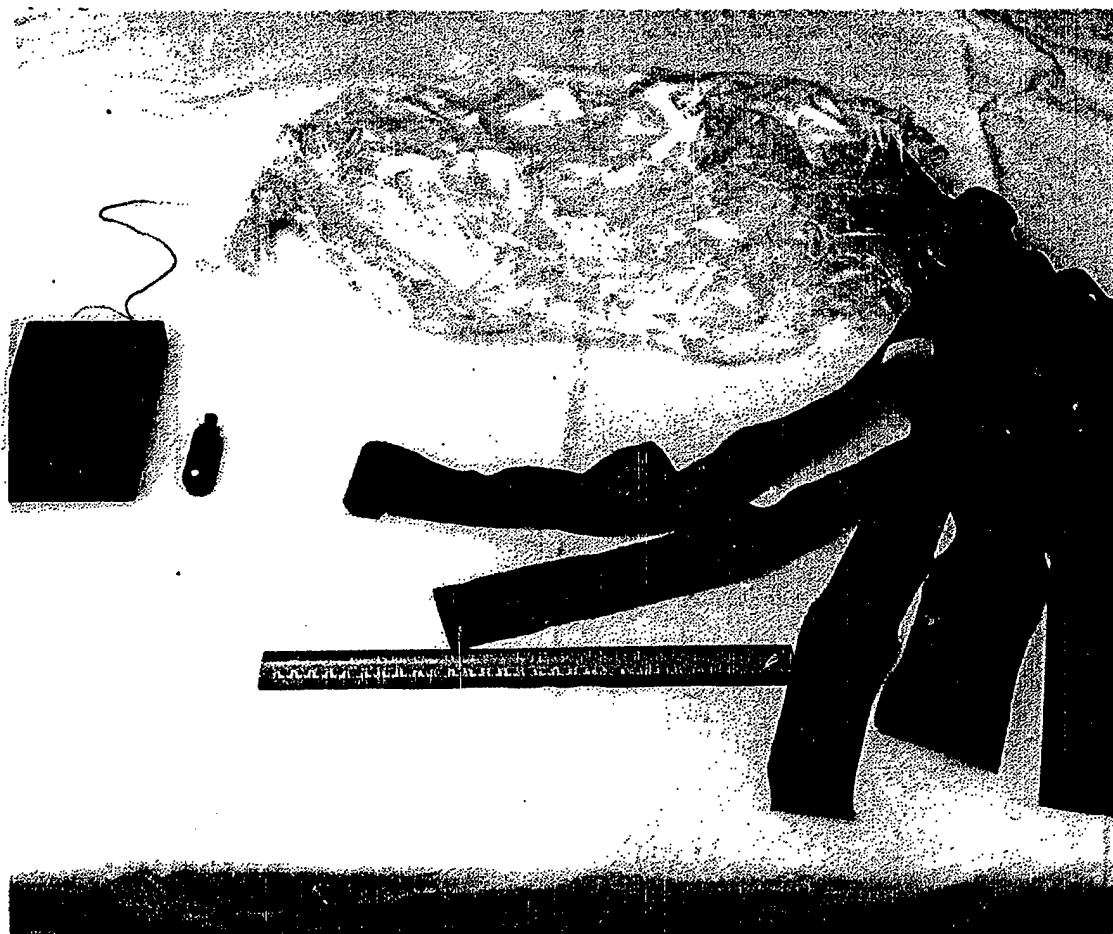


Marker

DIMENSIONS : Deployed fifty inches square; folded for carrying, seven inches long, three and one-half inches wide and one and one-half inches high.

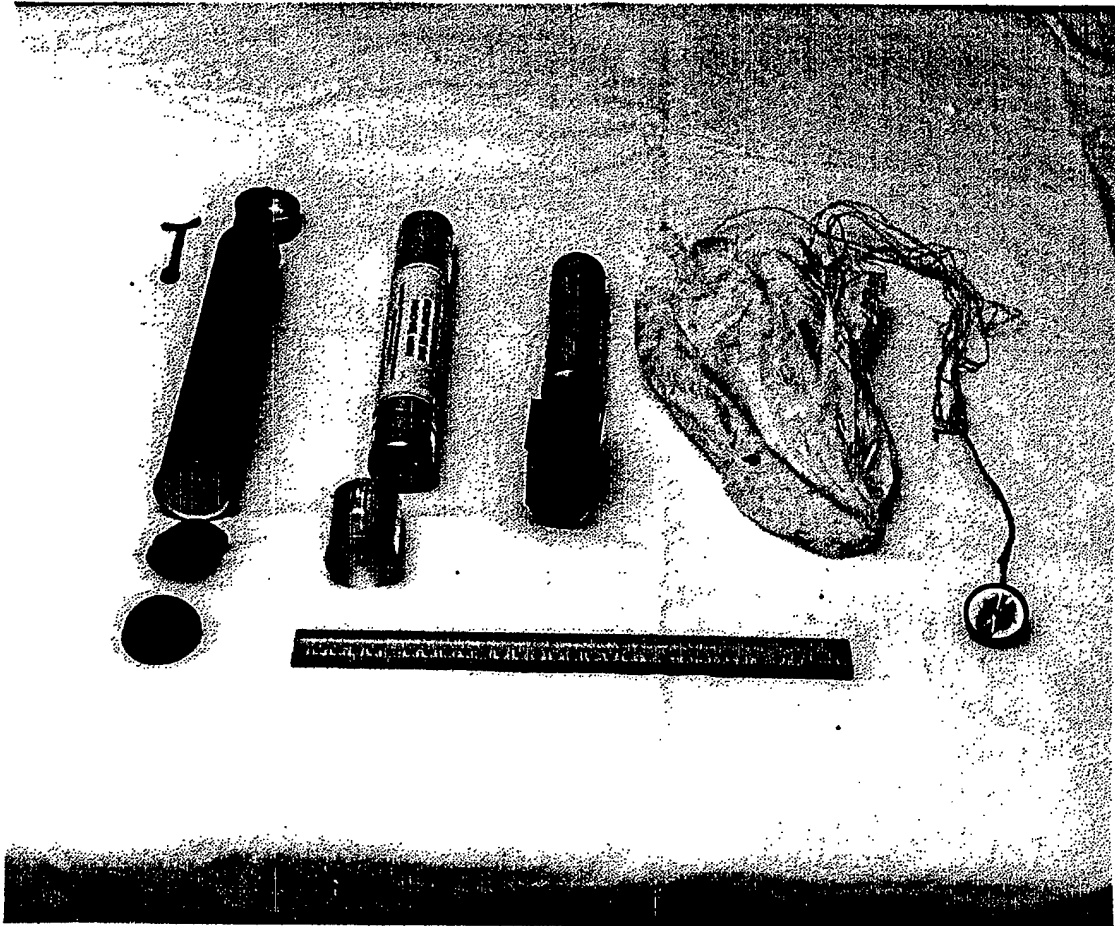
WEIGHT : Six ounces

CHARACTERISTICS : The red cross marker used is made of light weight nylon type material which can be folded or rolled in many different configurations for carrying. It consists of a red cross, the stems of which are fifteen inches wide and forty-three inches long surrounded by a white field.



Balloon System

CHARACTERISTICS: The engineering necessary to make this a self-contained field system has not been done. The prototype developed and used by the author in this experiment was a plastic bag filled with helium which was used to lift a set of streamers above the surrounding vegetation. This arrangement was tethered to the ground by a light weight monofilament fish line. The design for a self-contained system made up of the above elements and charged with a small helium cartridge has been developed by the author, however, in the interest of economy, a large helium bottle was used for the experiment.



Pyrotechnic

DIMENSIONS : Ten and five-eighths inches long, one and three-fourths inches in diameter

WEIGHT : One point twenty-nine pounds

CHARACTERISTICS : Two basic types of ground signals were used in the experiment. They are the Signal Smoke Ground Red (Green), Parachute M129A1 and the Signal Illumination Ground White Star Parachute K127A1. These devices are self-contained fin stabilized ground launched pyrotechnics. When fired, a tube rises to approximately 750 feet where the parachute deploys and the signal element ignites and burns from about four to thirty-six seconds.

Scientific Standards

Every effort was made to adhere to rigid standards of scientific exactness throughout this experiment. The experiment was designed in such a way as to reduce to a minimum the chance of human error invalidating the experiment.

Equipment--The equipment used to assist in the conduct of this experiment was the best that could be obtained. The airplanes were, of course, army, flying regular training missions. These were well maintained and at no time during the experiment was there any difficulty with either an airplane or any of the equipment mounted on it necessary for the conduct of this experiment.

The communication link from aircraft to ground location was over AN/PRC 10 FM radio. A special frequency was obtained from the Fort Leavenworth signal officer. Both radios were kept on channel to insure instantaneous communication.

Each of the test sites was within two and one-half miles of the Sherman Army Airfield weather station so that the bulk of the detailed weather data was secured from that station. Two important weather considerations were recorded at the test site itself. These were ground wind and light intensity at ground level. The ground wind was measured by a ALNOR type 3002 Velometer and the light intensity by a General Electric Model 8DW58V4 exposure meter.

The critically important task of recording observation times, flight times and times at which the aircraft were directly over the ground site was aided by a Vacheron and Con-

stantin timer.

The compass azimuths from the site locations to the principal light source were taken with a U. S. Army M2 compass.

Techniques--Of greatest concern to the author after the experiment had been designed and the sites selected was to insure the accurate collection of the data from the various test runs. To accomplish this task a standard data collection form was designed and used throughout the test series.

This form was set up before the series began so that all that had to be done on the ground was to set off the various devices to be tested and to record the times and other data pertaining to the test run. The author personally performed this task while his assistants set off the smoke grenades on order.

Upon completion of a test series, the data collection form would be checked for any obvious mistakes or conflicts. If none existed the pilot was released. On two occasions the pilot was asked to repeat a particular run to verify the results obtained.

After a statistically significant number of observations had been made or attempted at each site an additional series was run at each of the most difficult sites 1/3, 2/3 and 3/3.

After all of the data had been collected, it was collated and compiled using accepted statistical procedures so that it could be evaluated. The results of this process are reported in Chapter IV.

Summary of Test Series

There were a total of twenty-one test series run. These consisted of two each at sites 1/1, 1/2, 2/1, 2/2, 3/1 and 3/2 and three each at sites 1/3, 2/3, and 3/3. Smoke, the panel and the marker were used for all twenty-one test series. For logistical reasons, the balloon system and the pyrotechnics were used for twelve series each. The total attempted sightings were one hundred and sixty-eight each for smoke, the panel and the marker, and ninety-six each for the balloon system and pyrotechnics or a total of six hundred and ninety-six.

CHAPTER IV

DATA REDUCTION AND EVALUATION

Smoke

Recapitulation--Smoke was used during the field portion of this experiment 168 times. Five of the grenades used were duds which burned, but emitted little or no smoke. The pilot observers actually saw the smoke 99 of the 168 times it was used and failed to observe it 69 times. This computes to 59 percent success for all of the smoke replications. Fifty-nine percent falls within the marginally satisfactory category of the previously established criterion. The data for the use of smoke is arrayed in Table 1 below.

TABLE 1.--Success versus failure as a function of landform and ground cover - smoke

Site	1/1	1/2	1/3	2/1	2/2	2/3	3/1	3/2	3/3
Replications	16	16	24	16	16	24	16	16	24
Success	13	12	15	11	9	12	9	7	11
Failure	3	4	9	5	7	12	7	9	13
% Success	81	75	60	69	55	50	55	44	46

Effect of landforms--The overall performance figures for smoke show a 71.5 percent success figure under the class 1 (flat) landform classifications. When used in the rolling terrain (class 2) it suffered an attenuation of 14.3 percent

to 57.2 percent effectiveness. When used in the hilly terrain (class 3) it lost another 9 percent to 48.2 percent. The total drop in effectiveness from flat to hilly terrain was 23.3 percent which for this landform placed smoke in the unsatisfactory category.

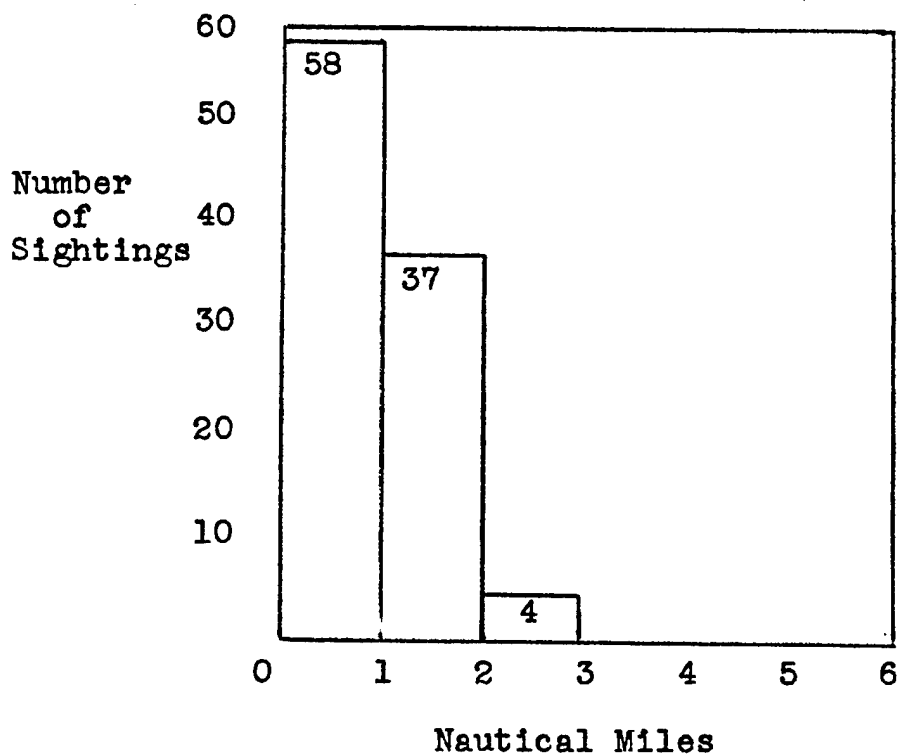
Effect of cover--For class 1 ground cover on all three types of landforms, the percentage success was 68.8. There was a drop of 10.5 percent to an effectiveness of 58.3 percent for class 2 cover and a further drop of 5.5 percent to 52.8 percent for class 3. The total reduction in effectiveness from class 1 to class 3 was 16 percent.

Effect of flight altitude--Of the 99 sightings made, 60 were made at 2000 feet altitude. This represents 71.5 percent of the possible sightings at that altitude. Only 39 or 46.4 percent of the possible sightings were made at nap of the earth altitude - a derogation of 35.1 percent.

Effect of direction of flight--The direction of flight had a profound effect on the degree of success of smoke. Flying with the sun behind the airplane, there were 32 of a possible 42 sightings made. Flying into the sun, there were only 13 of a possible 42, and flying at right angles to the sun-ground site line there were 54 of a possible 84. These percentages are 76.3 flying away from the sun, 64.3 flying at right angles and 31 flying into the sun.

Observation distance--The distribution of all sightings of smoke as a function of distance is presented in Graph 1.

GRAPH 1.--Observation distances - smoke

Panel

Recapitulation--A panel was emplaced for each of the twenty-one test series making possible a total of 168 observations. The panels were detected a total of 67 or 39.8 percent of the time. The panel was not seen once at a class 3 ground cover site. The compiled data for the panel is in Table 2 below.

TABLE 2.--Success versus failure as a function of landform and ground cover - panel

Site	1/1	1/2	1/3	2/1	2/2	2/3	3/1	3/2	3/3
Replications	16	16	24	16	16	24	16	16	24
Success	13	11	0	12	11	0	11	9	0
Failure	3	5	24	4	5	24	5	7	24
% Success	81	69	0	75	69	0	69	55	0

Effect of landforms--At the class 1 landform site, the panel was observed 24 of 56 possible or 42.8 percent of the time. Twenty-three of 56 possible observations were made at the class 2 site or 1.6 percent less than at the class 1 site. At the class 3 site 35.7 percent of the possible 56 observations were satisfactorily made. The total drop in the percentage of observations from flat to hilly terrain was 7.1 percent.

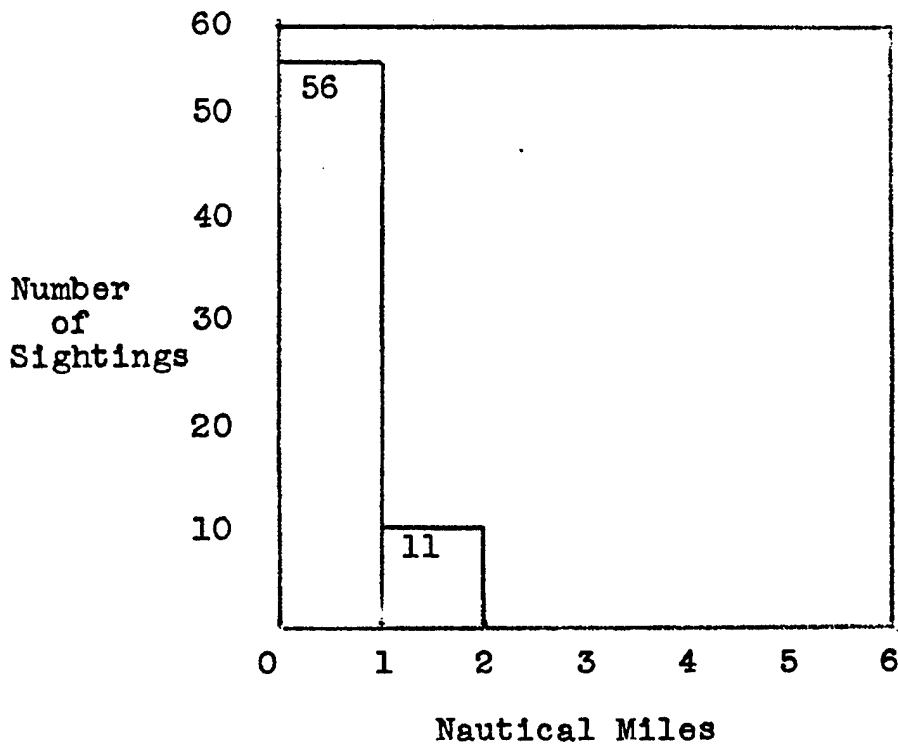
Effect of cover--The percentage of success for the panel on open ground was 75 percent or 36 of 48 possible. The panel at the three class 2 cover sites was observed 31 of 48 possible. Seventy-two sightings were made when the panel was under the continuous canopy at the class 3 sites.

Effect of flight altitude--Of the 67 sightings made, 46 were made from 2000 feet and 21 at nap of the earth altitude. The difference between the 54.8 percent possible at 2000 feet and the 25 percent at nap altitude gives a difference of 29.8 percent.

Effect of direction of flight--Thirty-one or 36.9 percent of the possible sightings were actually made while flying perpendicular to the line from the principal light source to the ground site. Twenty-three of a possible 42 (54.8 per cent) sightings were successfully made while flying away from the sun and 31 percent (13 of 42) flying into the sun.

Observation distance--The distribution of all sightings of panels as a function of distance is presented in Graph 2.

GRAPH 2.--Observation distances - panels



Marker

Recapitulation--The red cross marker was also emplaced for all 168 runs. It was observed by the pilot or his observer 53 times (31.5 percent). It also was not observed at all when emplaced in the areas in which the canopy was continuous. The detailed breakdown of the success and failure of the marker at all nine sites is displayed below.

TABLE 3.--Success versus failure as a function of landform and ground cover - marker

Site	1/1	1/2	1/3	2/1	2/2	2/3	3/1	3/2	3/3
Replications	16	16	24	16	16	24	16	16	24
Success	12	9	0	11	7	0	9	7	0
Failure	4	7	24	5	9	24	7	9	24
% Success	75	55	0	69	44	0	55	44	0

Effect of landforms--On the flat land the marker was seen 21 of a possible 56 times (37.5 percent). At the class 2 sites it was observed 18 of 56 (32.2 percent) and at the class 3 sites, 16 of 56 possible (28.6 percent). The hilly ground caused an attenuation of 8.9 percent.

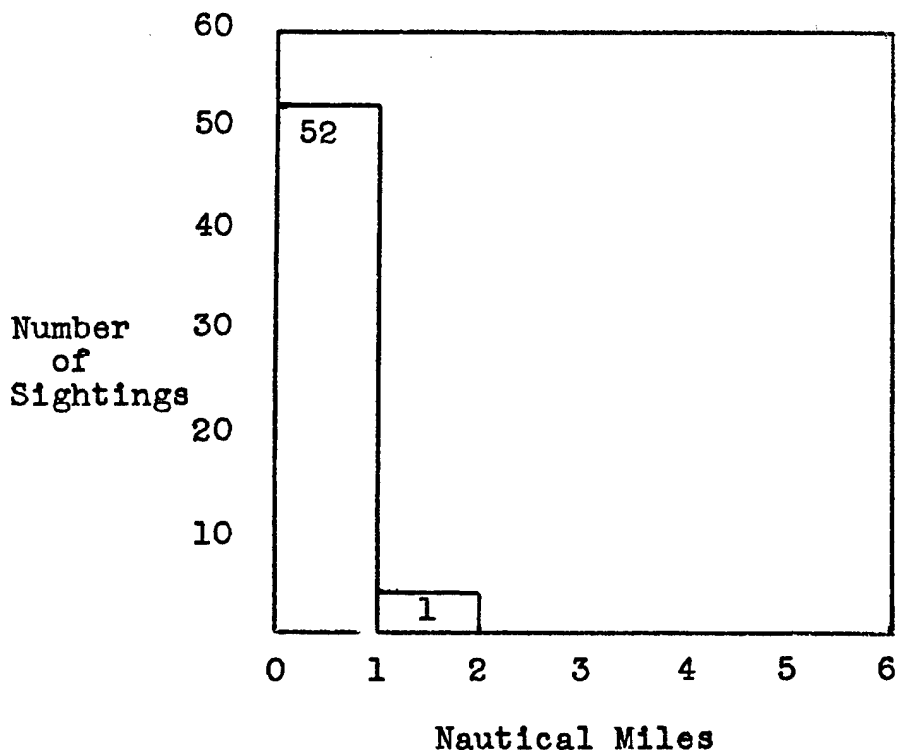
Effect of cover--The degree of ground cover had a profound effect on the marker. In the grass land it was 66.6 percent effective. At the class 2 sites it was 47.9 percent effective and at the class 3 sites it was totally ineffective and was not seen at all.

Effect of flight altitude--The marker was twice as effective at 2000 feet as it was at nap of the earth altitudes. It was observed 36 of a possible 84 times (42.8 percent) at 2000 feet and only 19 times (21.6 percent) at nap of the earth altitudes.

Effect of direction of flight--The sun had much the same effect on the marker as it had on the panel. While flying with the sun to their backs, the pilots observed the marker 45.2 percent of the time (19 of 42). While flying into the sun they only saw it ten of a possible 42 times or 23.8 percent, and while flying at right angles, 27 of 84 possible or 32.2 percent.

Observation distance--The distribution of all sightings of markers as a function of distance is presented in Graph 3.

GRAPH 3.--Observation distances - marker



Balloon

Recapitulation--The balloon system was put together by the author from off the shelf hardware from various local merchants. The first batch of balloons obtained were not large enough or strong enough, and finally plastic clothing bags were used. These worked very well, however, of the twelve series in which the balloon system was used, two were invalidated because the plastic hung up while going through the canopy. The remaining results produced very significant data. Of the 96 possible sightings, 73 were made for a total of 76 percent success. The breakdown by site location is in Table 4.

Effect of landforms--The balloon hung up once at site 1/3 and once at site 3/3 which caused the percentage success figures for the flat and hilly sites to be low. It was 21

of 32 possible (65.6 percent) at the class 1 sites and 23 of 32 possible (71.9 percent) at the class 3 sites. On the other hand, the percentage success for class 2 sites was 90.6 (29 of 32 possible).

TABLE 4.--Success versus failure as a function of landform and ground cover - balloon

Site	1/1	1/2	1/3	2/1	2/2	2/3	3/1	3/2	3/3
Replications	8	8	16	8	8	16	8	8	16
Success	7	7	7	8	8	13	8	7	8
Failure	1	1	9	0	0	3	0	1	8
% Success	88	88	44	100	100	81	100	88	100

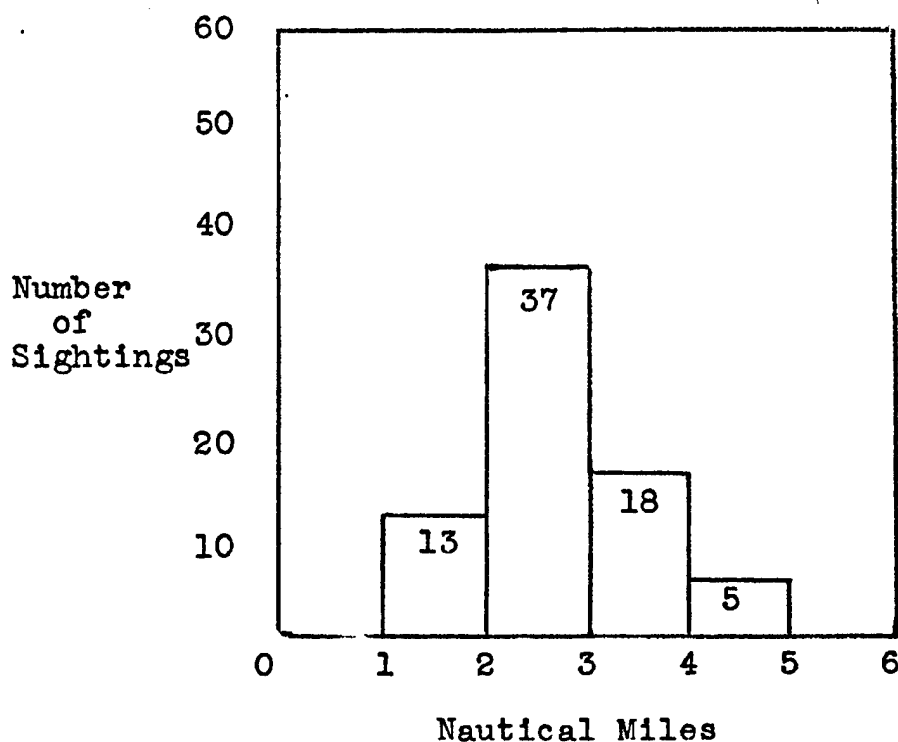
Effect of cover--The balloon system was observed 23 of a possible 24 times (95.8 percent) at the three grass covered sites, 22 of 24 times (91.7 percent) at the class 2 cover sites and 28 or a possible 48 times at the class 3 sites (58.3 percent).

Effect of flight altitude--At 2000 feet the balloon system was sighted 39 out of a possible 48 times or 81.3 percent. At nap of the earth altitude it was observed 33 out of 48 or 68.8 percent of the possible observations.

Effect of direction of flight--Flying away from the sun the balloon was sighted 83.3 percent of the possible times, flying into the sun 58.3 percent and perpendicular 79.2 percent.

Observation distance--The distribution of all sightings of balloons as a function of distance is presented in Graph 4.

GRAPH 4.--Observation distances - balloon



Pyrotechnics

Recapitulation--Pyrotechnics were used a total of 96 times. Of these, 67 were seen by the pilots for 69.8 percent. The data pertaining to success and failure is in Table 5 below.

TABLE 5.--Success versus failure as a function of landform and ground cover - pyrotechnics

Site	1/1	1/2	1/3	2/1	2/2	2/3	3/1	3/2	3/3
Replications	8	8	16	8	8	16	8	8	16
Success	8	7	15	6	5	11	5	4	6
Failure	0	1	1	2	3	5	3	4	10
% Success	100	88	93	75	63	69	63	50	38

Effect of landforms--The pyrotechnics were seen 30 of 32 times used on the flat ground for a percentage of 93.8. They were seen 22 of 32 times at the class 2 sites (68.8

percent), and 15 of 32 times used at the class 3 sites (46.8 percent). The total attenuation from the flat to the hilly ground was 47 percent.

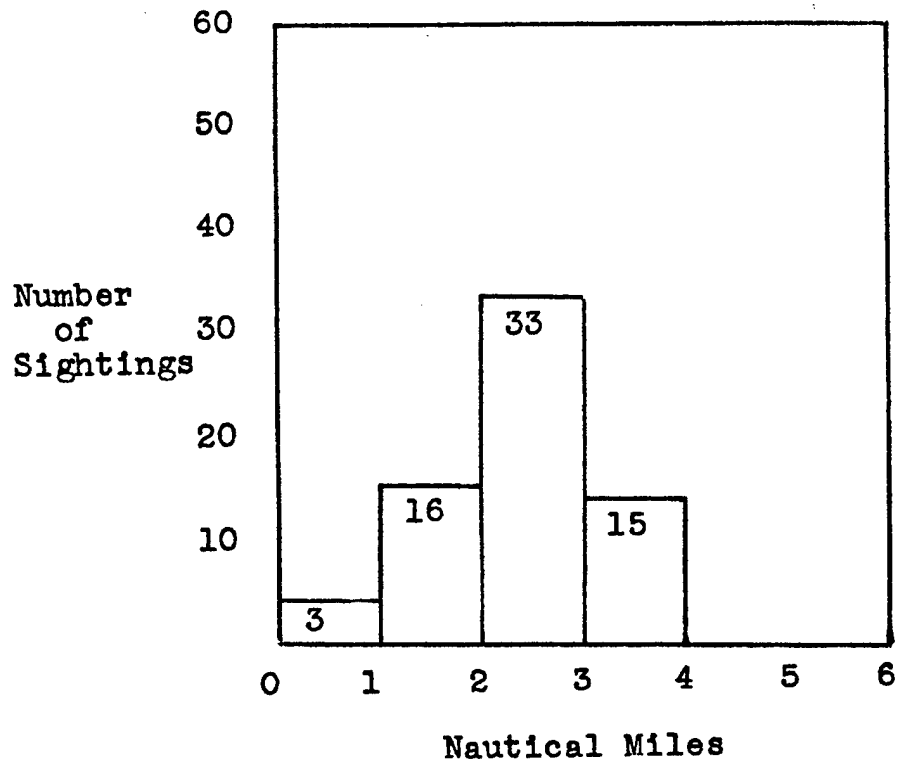
Effect of cover--The pyrotechnics lost quite a bit of their altitude when breaking through the canopy. This can be seen by a comparison of the effectiveness at the different sites. At the class 1 sites, they were observed 78.3 percent of the time (19 out of 24), 66.7 percent (16 out of 24) at the class 2 sites, and 66.7 percent (32 out of 48) at the class 3 sites.

Effect of flight altitude--The pyrotechnics were effective 42 out of 48 times at 2000 feet and 25 out of 48 at nap of the earth altitude - a difference 87.5 percent compared to 52.1 percent.

Effect of direction of flight--The pyrotechnics were observed 23 of the 24 times they were used when the pilot was slying away from the sun and 12 of 24 times when the pilot was flying toward the sun. Of the 48 times that pyrotechnics were used when the pilot was flying perpendicular to the line from the sun to the marker, 32 observations were made.

Observation distance--The distribution of all sightings of pyrotechnics as a function of distance is presented in Graph 5.

GRAPH 5.--Observation distances - pyrotechnics



CHAPTER V

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Smoke

General--Smoke achieved an overall fifty percentile of the possible on the seven criteria evaluated before the field portion of this experiment. This rating placed it right on the line between unsatisfactory and marginally satisfactory for those considerations.

During the conduct of the experiment, it was discovered that smoke was susceptible to derogation of its effectiveness from several factors not evaluated in Chapter IV. These factors were:

1. The smoke grenades were not of uniform quality. Without fail, the yellow grenades burned for a shorter time and produced a less dense cloud than did the green and red.
2. The smoke cloud produced was very susceptible to rapid dissipation from the wind in light ground covered areas.
3. In thickly canopied areas, the bulk of the smoke cloud was dissipated before it ever penetrated the canopy.
4. When there was other smoke present in the area, it was very difficult to distinguish the marker from the

other smoke.

5. Atmospheric conditions exerted a pronounced effect on the persistency of the smoke cloud.

Findings--Assessed against the criteria of versatility, smoke was found to be unsatisfactory, and against the visibility criteria it received a rating of 59 percent effectiveness or marginally satisfactory. Considering all criteria, smoke is unsatisfactory as a general purpose ground to air marking system for use by ground combat units engaged in counterinsurgency operations. It undoubtedly has some specialized applications in the absence of a more effective universal system. Specific findings were:

1. Smoke suffered a 23.2 percent loss of effectiveness from flat land to hilly terrain.
2. It was 15.9 percent less effective in canopy covered areas than it was in the open.
3. Smoke was unsatisfactory for marking locations for aircraft flying at nap of the earth altitudes.
4. Smoke was observed 45.3 percent more often when flying away from the sun than toward it.
5. Smoke was effective only at very short ranges and high altitudes.

Panel

General--The panel scored 71.5 percent of the possible points on the seven preliminary criteria. For this portion of the experiment that was a satisfactory rating. The most significant shortcoming of the panel was that it was not observed

once through the canopy at sites 1/3, 2/3 and 3/3. This would tend to greatly limit its usefulness in any area which has extensive woodlands.

Findings--The panel was found to be unsatisfactory when considered from the standpoint of versatility. It only achieved an effectiveness rating of 39.8 percent which placed it in the overall unsatisfactory category for a ground to air marking system. Specific findings were:

1. The panel was over twice as effective from 2000 feet than it was at nap of the earth altitude.
2. The panel was satisfactory in open flat land as opposed to total uselessness in jungle.
3. The panel was only useful at extremely short range.

Marker

General--The marker was originally intended as a smaller, lighter weight panel with contrasting colors. This was the least effective of those systems used in the experiment. In the preliminary evaluation, the marker scored the second highest rating of all of the systems and only missed being first by two points out of seventy. However, its failure in the field evaluation series indicated its unsuitability for general purpose use.

Findings--From the standpoint of versatility, the marker was unsatisfactory and it achieved the lowest rating of any of the tested systems (31.5 percent effectiveness) on the overall evaluation. Specific findings were:

1. This device was twice as effective (42.8 percent) at 2000 feet than it was at nap of the earth altitude (21.6 percent).

2. It was not observed at all when emplaced under a jungle type canopy.

Balloon

General--The balloon system achieved an 82.8 percent total score when assessed against the preliminary criteria. One major problem detracted from the performance of the light plastic balloon when it hung up twice. This problem was inherent in the type balloon used and can be (and has been in the past) solved by the use of an elongated balloon with a high lift to weight ratio. The author was precluded by the time and funds available from getting or having made the optimum balloon design. However, since the actual engineering of the system was not a part of this experiment, this problem did not detract from the validity of the test results.

What the balloon was used for was to provide a test platform to get a persistent signal up in the air. It performed this mission well.

Findings--The balloon system received a high satisfactory under the versatility criteria. It performed well at all of the sites and against all of the critical variables of the model. In the visibility criteria area, it had the highest rating of 76 percent. This would have been much higher had the two series of eight replications each, when the balloon did not get above the canopy been discounted. Specific find-

ings were:

1. When the balloon got above the canopy, it achieved a visibility factor in excess of 90 percent for all sites.
2. The effect of landform on the system was not as pronounced as on any of the other systems.
3. The balloon was observed at distances of up to five miles.
4. Over fifty percent of the sightings on the balloon were made in excess of two and one-half miles.
5. A high 68.8 percent of the possible nap of the earth sightings were made.

Pyrotechnics

General--Pyrotechnics scored the lowest rating of 44.3 percent on the preliminary criteria evaluation. However, they performed much better during the field portion of the experiment. There were two notable deficiencies documented during the field experiment; the first was that the signal lost much of its altitude (and therefore effectiveness) when shot through a canopy, and second, the signal drifted in the wind. Even the slightest breeze was enough to make accurate pinpoint location impossible; however, the long range capability helped to get an aircraft into the general area.

Findings--Pyrotechnics scored a satisfactory under the requirements of the versatility category and a second high for all systems of 69.8 percent in the visibility category. Specific findings were:

1. Fifty percent of the pyrotechnics sightings were at greater than two mile range.
2. The effect of landform and cover was less than any other system other than the balloon.
3. Pyrotechnics were relatively effective for observation from nap of the earth altitudes and scored a 52.1 percent effectiveness rating at this altitude.

Conclusions

Several valid conclusions were drawn from the results of this experiment:

1. It is possible to apply a systematic approach to the solution of a problem such as the one which is the subject of this experiment.
2. There is not presently in the inventory of visual ground to air marking systems a satisfactorily universal system or device, e.g. one that will assure a high degree of success in the various and varied environments in which it must be used.
3. To be effective for airplanes flying over various types of terrain and ground cover, a system must get above the surrounding cover and should have sufficient persistency to remain there as long as necessary.
4. The ground emplaced systems tested in this experiment were much more effective when viewed from 2000 feet than at nap of the earth altitudes.
5. Of those standard representative systems tested, none provided both the long range observation capa-

bility necessary to get the aircraft to the general location, and also the pinpoint accuracy to get it to the exact location.

6. A system which will work when emplaced on a parade ground will not necessarily work in the other eight basic types of combinations of landform and cover in which it should be able to work.

Recommendations

I recommend that this thesis be forwarded to Combat Developments Command and Army Materiel Command for evaluation and further detailed testing if deemed appropriate.

I also recommend that the balloon suspended streamer system be considered for inclusion in the inventory of ground to air marking systems.

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