QUANTUM ELECTRONICS DIVISION TECHNICAL REPORT

MAGNETIC DETECTION OF CERTAIN LIGHT WEAPONS, MINES, GRENADES AND EQUIPMENT

Don Cameron
Varian
Associates

ABSTRACT

In the most difficult conditions the Varian commercial Portable Search Array Magnetometer (V-4938S) will detect and locate single unloaded rifles (whether submerged in rice paddies, hidden in grass, or buried in shallow holes) at a distance of 8 to 10 feet radius from the searcher.

The same instrument will also detect and locate vehicles and de-activated grenades, mines. ammunition, and other hand carried weapons.

Furthermore the portable magnetometer can detect and locate camouflaged holes (i.e., booby traps) in front of the advancing searcher even if no ferrous material is prese[n]t in the holes.

The portable magnetomete can be used effectively by the average person after Only two hours of instruction.

Z. INTRODUCTION.

The purpose of the tests described in this report was to determine the operational capability of a Varian commercial Model V-49385 Portable Search Array Magnetometer to detect and locate certain weapons, devices, and equipment similar to those being used by the Viet Cong and North Viet Namese forces in South Viet Nam.

The tests were carried out at the simulated Viet Nam Village training site at Ft. Ord, California, on May 9, 1967. Lt. Colonel R. Himmelmann, CDCEC Industrial Liaison Officer at Ft. Ord, made the arrangements for the Varian team to use this site. Lt. Colonel Himmelman also coordinated with Colonel Robert C. Erlenbusch, Commander of the Ord Committee Group who made available to Varian Staff Sergeant Hawks. Sergeant Hawks has had a year of combat experience in the Mekong Delta area of Viet Nam, and provided the equipment and weapons used in the tests. A jeep and an M-14 rifle, were furnished by Lt. Colonel Himmelman of CDCEC.

The Varian team from the Quantum Electronics Division in Palo Alto, California. headed by Sheldon Breiner, a Varian Geophysicist, included Reginald Herbert, Robert Stout, Don Cameron, and Allen Matej. Tests were conducted by both Varian and Army personnel.

The tests established that the Varian Portable Magnetometer, Model V-4938S, will prositively detect and locate a single unloaded M-14 rifle within 10 feet of each side of a searching soldier whether the rifle is camouflaged or submerged in two feet of water in a rice paddy. Correlating the results of this test with data obtained on Viet Cong weapons in earlier tests [1], it can be stated that the V-4938S will detect and locate a single AK-47 rifle (Communist origin) at a distance of 7 to 10 feet
from the searcher. Based on data obtained from Reference 1, it is believed that we can state, conservatively, that the Varian V-4938S will detect and locate any unloaded rifle, being used by the Viet Cong today, when submerged in a rice paddy at a minimum distance of 7 feet from the sensor head.

Tests of other equipment, weapons, and devices indicated that deactivated grenades can be detected and located at a distance of 3 feet, deactivated Claymore mines at feet, deactivated anti-tank mines at 10 to 12 feet, a jeep at 100 feet, a deactivated 81 mu mortar round at 5 feet, and a bobby trap p i t (with Steel, spikes embedded on boards) at 4 feet.

The addition at ammunition, firing mechanisms, or explosives, to the cot that they are magnetic will increase all stated detection ranges.

Furthermore, the addition of mere than one such weapon or device in any

one location w i l l Increase the detect

The equipment used in these tests is described in Section V.

II. TEST SITE

The tests were conducted in the simulated Viet Nam Village located at Ft. Ord. The village proper is situated on a knoll in an isolated area. Near the village, in a low, swampy area, are a series of simulated rice paddies.

The principal part of the village complex is located on the left side of the main road which leads into the area. A booby-trap demonstration area is located to the right of the main road. Both of these areas are enclosed by typical Viet Namese fences. On the right, beyond the booby-trap demonstration area, is a simulated bunker, camouflaged to resemble a stack of hay. Beyond the bunker, and up on a higher knoll is an open cluster of native houses. A series of tunnels have been constructed in the main village compound and in the open compound. An escape tunnel connects to the tunnel network and leads away from each of the compounds and down into a valley to the rear of the village.

These tunnels are approximately 2' x 2' in cross-section, with the center of the tunnels from 3' to 5' below the surface. They were constructed by trenching, shoring the tunnels with prefab plywood sections, and then refilling the trenches. The entrances to the

the native shacks which **are situated** at random around the compound, and in the well which is located in the center of the compound.

Numerous trees, native to the area, are situated throughout the training site. Short grasses, weeds, and bushes are abundant.

The surrounding areas are relatively magnetically "clean", in that there are no power transmission lines or electrical motors or generators in the vicinity. However, the local soil is contaminated with small ferrous objects such as nails and pieces of iron wire which produce typical magnetic anomalies (similar to sharpnel).

Photographs of the area are presented in Exhibits A through C.

II. EQUIPMENT DETECTED

The military equipment, weapons and devices which were tested represented those being used in Viet Nam and were available at Ft. Ord. These items were:

1. M-14 Automatic Rifle (U.S.)
2. AK-47 Rifle (Viet Gong)
3. 7.62 mm Light Machine Gun (belt fed) (Viet Cong)
4. Claymore Anti-personnel Mine (U.S.)
5. M-12 Anti-tank Mine (U.S.)

6. M-21 Anti-tank Mine (U.S.)

7. M-606 Fuse Mine (U. S.)

8. M-26 Hand Grenade (U.S.)

9. "Pineapple" Hand Grenade (U.S.)

10. A-2 Jeep (U.S.)

11. 81 mm Mortar Round (in tree) (U.S.)

12. Booby-trap Pit (15" x 30" x 24" deep) The trap consists of two boards in which steel barbed spikes have been embedded. The boards are mounted on rods such that the spikes face inward and pierce a man's leg when he steps into the center of the pit.

13. Two tunnel complexes.

IV. DESCRIPTION OF TESTS

The prime purpose of the tests and experiments was to determine if the Varian Model V-4938S, Portable Search Array Magnetometer could detect a rifle, or comparable weapon, which had been submerged in the water in a rice paddy.

The other tests were secondary in importance, but were conducted to take full advantage of the time the village training site was made available for use. The magnetic moment data obtained on all of the military equipment tested will be useful in determining the overall capability of the Varian magnetometers to military applications. It will also aid in determining the changes in, or improvements to, Varian's equipment which might be required in order to more completely meet the military tactical requirements.

The tests are described below.

1. M-14 **Submerged in Rice Paddy**

The M-14 rifle was submerged in two feet of water and 10 feet out from the edge of the dike, about 15 yards from the nearest end of the dike. The two rice paddies are about 50 yards wide by about 100 yards long.

The location of the weapon was not known to Sheldon Breiner, Varian Geophysicist, who conducted the search. After the weapon had settled, and the water was calm, Sheldon Breiner commenced a traverse of the paddy adjacent to the left side of the dike. As he approached the location of the weapon, the frequency of the audio readout changed noticeably. He stopped, then conducted a search of the local area, and "zeroed" in on the weapon, locating it exactly in 30 seconds from the time he started the search. The change in the frequency of the audio readout, when the sensor was 10 feet from the weapon, was sufficient for a novice to detect. After locating the weapon anomaly, Breiner continued his search of the dike, going to the end of the dike (50 yards) and searching back along the right side of the dike. He completed the search and returned to the location of the weapon in 4 minutes from the time he started.

Anomalies produced by random magnetic materials in the area, both on the dike and in the water, were quickly discarded as not being the suspect weapon.

As a further test, Staff Sergeant Hawks, was given a 3 minute training course on the use of the V-4938S. While he was being instructed in the use of the instrument, the M-14 rifle was relocated to the right side, and near the far end of the dike. This time the weapon was tossed out into the paddy 12 - 15 feet from the dike.

As soon as the weapon had settled and any evidence of disturbance had disappeared, Sergeant Hawks commenced to search the left side of the dike. After completing the search on the left side, he then moved over to the right side and continued to search. He detected the rifle as soon as the sensor head was in line with the weapon. He then "zeroed" in on the weapon, waded out into the water and retrieved it. He had removed the weapon from the water 3.5 minutes from the time he started the search.

The tests proved a man can search an area as fast as he can walk. The exact location of a suspect anomaly requires less than one minute of "zero in" time.

Effective use of the magnetometer for locating weapons submerged in a rice paddy requires only a brief training period of a few minutes.

2. Mines and Grenades

The mines and grenades were tested by placing them, one at time, on the ground in a comparatively magnetically "clean" area. The Model V-4938S Portable Search Array Magnetometer was used as a search instrument and was moved on a line by the object, at progressively closer intervals until a noticeable frequency change occurred in the audio readout. This procedure was followed on four sides of each object being tested. The distance at which the objects could be detected is shown below for each item.

Claymore Anti-personnel Mine	-	4 feet
M-12 Anti-tank Mine	-	10 feet
M-21 Anti-tank Mine	-	12 feet
M-606 Fuse Mine	-	10 feet
M-26 Hand Grenade	-	3 feet
"Pineapple" Hand Grenade	-	3 feet

All tests were made of unarmed weapons and devices. The addition of firing mechanisms or explosives, to the extent that they are magnetic, will increase all stated detection ranges.

Where a grenade is used as the explosive for a booby-trap, it is possible that additional ferrous material may be present in the device. In this case, the booby-trap could be detected at a distance greater than 3 feet, This can be determined only by testing an actual booby-trap.

3, 81 mm. Mortar Round

This ammunition was located in a tree in the booby-trap demonstration area to simulate a booby trap over a t r a i l . By elevating the magnetometer sensor towards the 81 mm motor round, it was determined that the round could be detected at a distance of 5 feet..

4. Booby-Trap Pit

This booby-trap is located in the demonstration area where all types of typical traps are on display. It was found that a pit, such as this one, could be detected at a distance of 4 feet. Should a soldier be walking down a trail where a pit trap has been located in the trail, the sensor will detect the trap when it is 4 feet from the trap. With the sensor head at least 3 feet in front of the soldier's feet, the trap will be detected when the soldier is 7 feet from the trap.

It has been demonstrated in tunnel detection tests that the magnetometer will readily detect voids and open pits in the earth. Therefore, a pit trap without magnetic material, for instance, one with punji stakes can be detected.

5. A-2 Jeep

The jeep was driven along a line which was perpendicular to the direction to the magnetometer sensor and 100' from the sensor. The particular jeep under test produced an anomaly of I gamma at 100' which is detectable with the V-4938S.

This test was conducted to obtain magnetic moment data for another program. Therefore, the detailed data will be presented in another report to be issued at a later date.

6. Tunnel Complexes

Detectability tests had been conducted over the tunnel complexes on May 5, 1967, while training an Air Force Master Sergeant to use the Model V-4938S Portable magnetometer for tunnel detection.

The tests conducted on May 9, 1967, consisted of traversing a grid pattern over the main tunnel complex. The grid pattern covered an area 48' x 48', with readings taken every 3 feet along parallel lines which were spaced 3 feet apart. Total field readings were recorded for each data point.

The collected data will be reduced and evaluated to determine the requirements for a portable magnetometer designed specifically fur tunnel detection. In addition, the reduced data will be included in contractual report to Warfare Laboratory at Aberdeen Proving Ground in connection with a tunnel study program being conducted by Varian.

V. DETECTION EQUIPMENT DESCRIPTION

Varian V-4938S Portable Search Array Magnetometer

The V-4938S consists of the following sub-systems:

1. 49-546 Cesium Portable Sensor with either a collapsible or stiff-staff and sensor electronics

2. 49-425 Battery Belt Pack with shoulder harness

3. 49-115 An Audio Indicating Magnetometer Readout with earphones
4. Carrying case of aluminum 25' x 17" x 7-1/2" for the collapsible unit or, an oblong transit case for the stiff-staff unit approximately 70" x 12" x 12". Both cases hold a complete V-4938S system.

Sub-system Discussion:

1. 49-546. The basic principle used in the 49-546 Cesium Portable sensor employs the physics phenomena of optical pumping 2.

Utilization of a cesium alkali vapor optically pumped and monitored sensor provides for high sensitivity to changes or perturbations imposed on the earth's total magnetic field by the target (an anomaly) as the sensor passes near the target or vice versa. Actual values of perturbations as found in rifles have been described in Ref.1 and represent the use of a station magnetometer readout 3 of much higher sensitivity than

Physical information:

a. length 68"

b. weight 6.1 pounds

c. balance point 28" from the electronics end of the staff

2. 49-115A. The Audio Indicating Magnetometer Readout provides an adjustable frequency which when mixed or single heterodyned with the Larmor frequency coming from the Cesium Sensor 49-546, results in a difference frequency in the audio range, once the adjustment has been made by the operator. The 49-115A operates over three ranges of total magnetic field. They are 30,090 to 40,000 gammas, 40,000 to 50,000 gammas, and 50,000 to 60,000 gammas. The range selection is made by changing jumper wires on one of the printed circuit cards within the audio readout. Generally speaking, the three ranges cover magnetic latitudes over most parts of the world.

The resultant audio frequency difference generated within the 49-115A is supplied to a speaker within the unit itself or, to earphones (Which use a jack that disables the speaker).

The output audio frequency is squared and distorted on its leading edge such that frequency changes down to 1 cps can be detected by the human ear. This provides a resolving capability limited only by the users mental time elapsed sensing capability to determine the rate change which has occurred up or down in frequency as an anomaly is passed. Generally speaking the frequency tuner on the 49-115A (a ten turn micro dial) is set at a 10-12 cycle rate and locked in that position, variations in the rate act as the signal. They indicate achange in the total field caused by an anomaly as the sensor passes by.

Physical Information:

a. Weight 2.1 pounds and the unit is clipped on the same belt to which the battery pack is attached

rear including connectors and controls 5-1/2 inches,

c, Width across the front panel is 5-1/4 inches d.

Thickness 2 inches

Controls on the 49-115A are all located on the front panel and are as follows:

a. ON - OFF, Volume Control.

b. A 32v and a 28v push to test light indicating condition of the battery pack,

c. A ten turn micro dial calibrated to indicate absolute total field measurements for the particular 10,000 gamma range selector.

3. 49-425. The battery pack, with shoulder harness, provides a nominal 30 volts with a capabity of 7.5 to 8 ampere hours. The V-4938S system has an average power consumption of 650 milliamps following initial warm-up. This provides 11 to 12 hours of operation from a fully charged battery pack. The shoulder harness is adjustable and the batteries themselves are fitted to a military webb belt with heat shrinkable heavy duty polyvinyl chloride tubing.

The entire V-4938S system is interconnected through the 49-115A Readout. The phone jack for inserting the earphones to the system is also located on the rear of the readout along with the system fuse.

The batteries employed are a lead acid type using a new technique which provides a jellied electrolyte. The batteries are completely sealed, non-spillable, with built-in gas vent releases. Each pack contains five battery units of 6 volts each, made up of 3 two-volt cells. The batteries themselves are interconnected in series within the heat skrinkable tubing.

METHOD OF OPERATION

Two major methods are employed with the V-4938S. The first method could be entitled, "Broad Search" in that many users, especially military, will be using combat boots with steel arches which would be detected by the sensor. It has been found, for this reason and for extended search techniques, that when traversing a large area in a parallel and anti-parallel pattern, the best position for the sensor is at right angles to the user. This method allows for rapid traverse, a constant distance maintenance of the sensor off the ground, and the searcher can look ahead to follow the prescribed search pattern. Once an anomaly signature has been detected, the user will shift into the second method, the " Localizing Mode". In this mode, the searcher sweeps the sensor through a horizontal arc from one side to the other side of his body in order to indicate the direction of increase in the total field signature caused by the anomaly. From this standing position, he can locate the strongest point of the magnetic anomaly. Then with the sensor extended straight ahead and sweeping from side to side slowly, he can approach the anomaly until a maximum signal pitch is obtained or he can pass the anomaly until the maximum-minimum range has been detected.

Battery charging is accomplished with the use of a standard commercial constant voltage, taper current power supply, similar to a Trygon Model T-50-750 power supply. Charging is accomplished in two different methods.

In the first method, a long term low current charge of 400 mills is used to assure gassing of the battery cells. This cycle should be run every 12 to 15 discharge cycles in order to assure a return of the batteries to their full 100% capacity. The second method employs the use, over a shorter period of time, approximately ten hours, 750 mills with a constant voltage setting to provide a return to 90% of initial capacity of the batteries.

Warm-up Time:

Present requirements call for the gas cell employed in the sensor head to reach 56°C for optimum performance. This generally will require a twenty minute warm-up time of the system. Current developments at Varian indicate that the time can be reduced substantially in follow-on units for military applications.

VI. CONCLUSIONS

Based upon the results of the tests described above, it can be stated with assurance that the Varian Model V-4938S Portable Search Array Magnetometer will detect:

1. An M-14 rifle submerged in 2 feet of water in a rice paddy when the rifle is as much as 10 feet from the sensor.
2. Any rifle being used by the Viet Cong when submerged in 2 feet of water in a rice paddy and when 7 feet from the sensor head.
3. A grenade at a distance of 3 feet.
4. An anti-tank mine at a distance of 10 to 12 feet.
5. A Claymore mine at a distance of 4 feet.
6. An A-2 jeep at a distance of 100 feet.
7. An 81 mm mortar round at a distance of 5 feet.
8. A booby-trap pit, in which iron spikes have been emplaced, at a distance of 4 feet.
9. Tunnel complexes, when the center of the tunnel is between 5 to 5 feet from the surface.

All tests were made of unarmed weapons and explosive devices. The addition of ammunition, firing mechanisms or explosives, to the extent that they include ferrous material, will increase all stated detection ranges.

All items were tested individually, separate from any other arms or munitions. The placing of two, or more, of the same items (or items with similar magnetic moments) together in one location will increase the detection range.

These tests further demonstrated that the average non-commissioned officer, or a technician in the military service, can be trained in a short period of time to use the V-4938S to detect and locate hidden weapons.

Should military requirements warrant, the Varian V-4938S can be improved to provide higher resolutions, or sensitivity, for an increased detection range. In addition, it is recognized that certain design changes may be required to meet military specifications and make it more suitable for military use. The present design meets the requirement as described in Reference 3.

REFERENCES

1. Varian Associates, Quantum Electronics Division Technical Report - "Magnetic Measurement of Light Weapons of U.S. and Communist Block origin, January 20, 1967", Sheldon Breiner

2. Varian Associates, Quantum Electronics Division, Geophysics Technical Memorandum #25 - "Avalanche Victim Detection - The Magnetic Method 1964-1965", Lee Langan

3. Varian Associates, Quantum Electronics Division, Rubidium Magnetometer V-4938 Data Sheet August 1963.

VI. EXHIBITS

Exhibits A through C are photographs of the Vietnam village training area at Fort Ord.

Exhibits D through F are photographs showing the detection of a rifle in the rice paddy.

Exhibits G through I show the method of determining the distance at which the mines and grenades could be detected.

Exhibits J through L show the booby traps.

Exhibits M through 0 show the Varian Model V-4938S Portable Magnetometer.

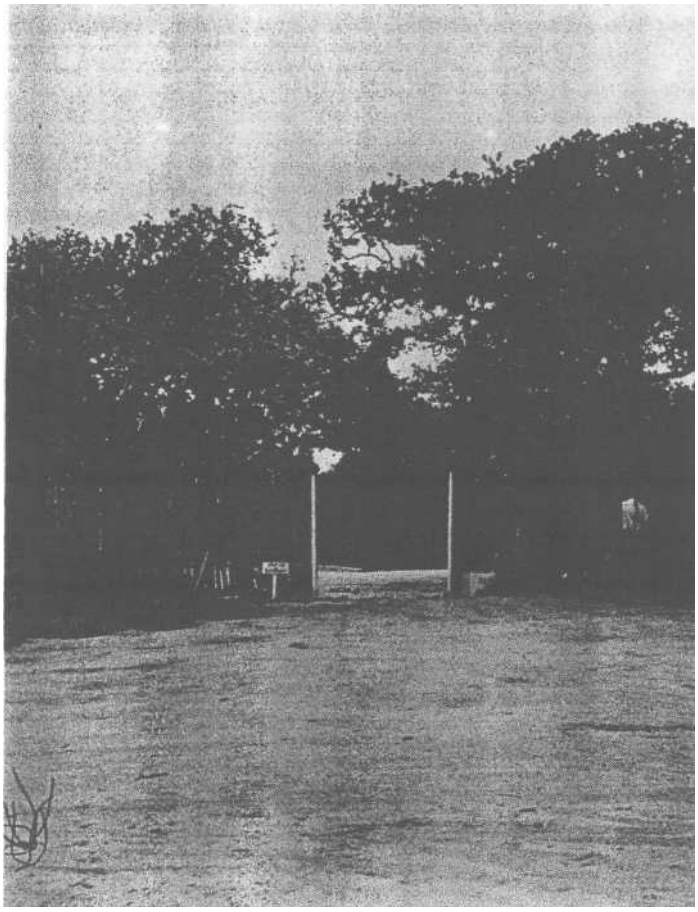

EXHIBIT A - Entrance to Vietnam Village Training Area

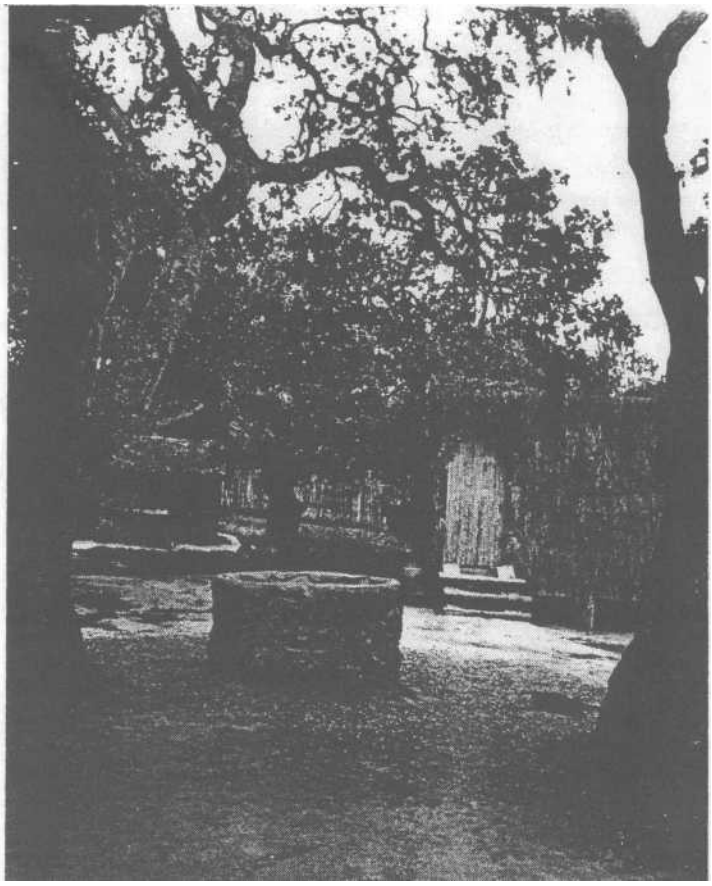

EXHIBIT B - Interior of Vietnam Village Training Area. A tunnel entrance was found in the well located in the foreground.

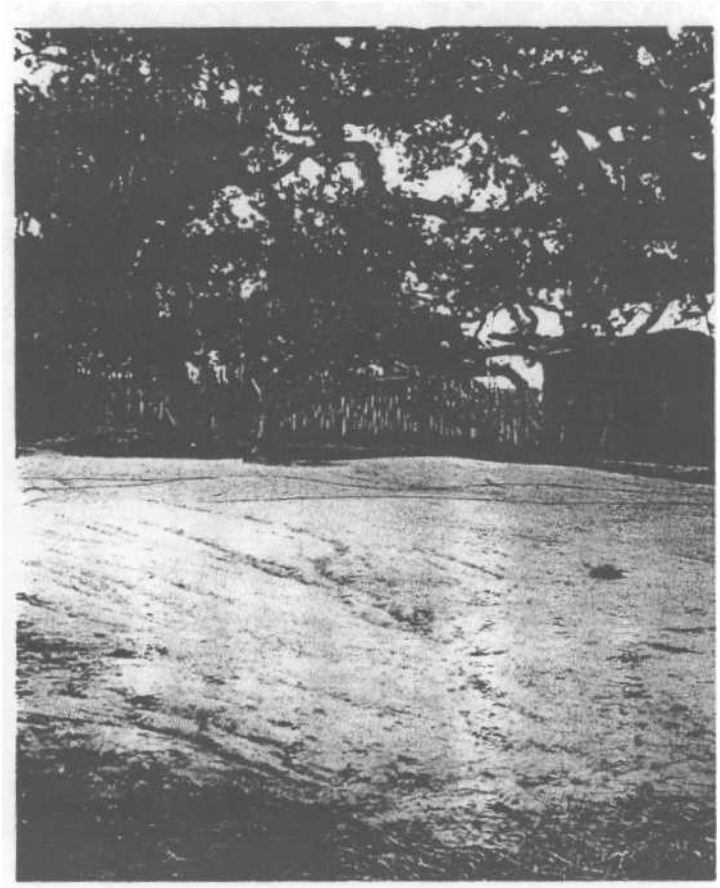

EXHIBIT C - Interior of Vietnam Village, showing the surface over the main tunnel complex. One tunnel entrance was found in the hut at the right. A large room is located under the surface in the near foreground.

EXHIBIT D - Army Staff Sergeant searching a rice paddy for a submerged rifle, using the Varian Model V-4938S Portable Magnetometer.

EXHIBIT E - The M-14 rifle, which is encased in a waterproof bag, is shown directly under the magnetometer sensor. The magnetometer sensor was enclosed in a plastic bag to protect the sensor from the rain.

EXHIBIT F - This photograph shows the relative position of the rice paddy dike, the magnetometer, the rice paddy and the location of the weapon.

EXHIBIT G - Sheldon Breiner conducting traverse with the V-4938S Portable Magnetometer to determine distance at which the M-12 Antitank Mine can be detected.

EXHIBIT H - Sheldon Breiner conducting reverse traverse to determine detection range. Note that the magnetometer sensor has been moved to the operator's right side so that it is on the target side of the operator.

EXHIBIT I - Sheldon Breiner traversing past anti-personnel mine to determine the maximum distance at which the mine could be detected.

EXHIBIT J - Booby trap with iron spikes embedded in boards. This trap was detected at a distance of four feet.

EXHIBIT K - Searching for 81 mm mortar round booby trap in tree. Part of the mortar round can be seen at the top of the picture. The booby trap was detected at five feet.

EXHIBIT L - Locating a Punji stake booby trap in the grass beneath the sensor, which was detected at a three feet distance.

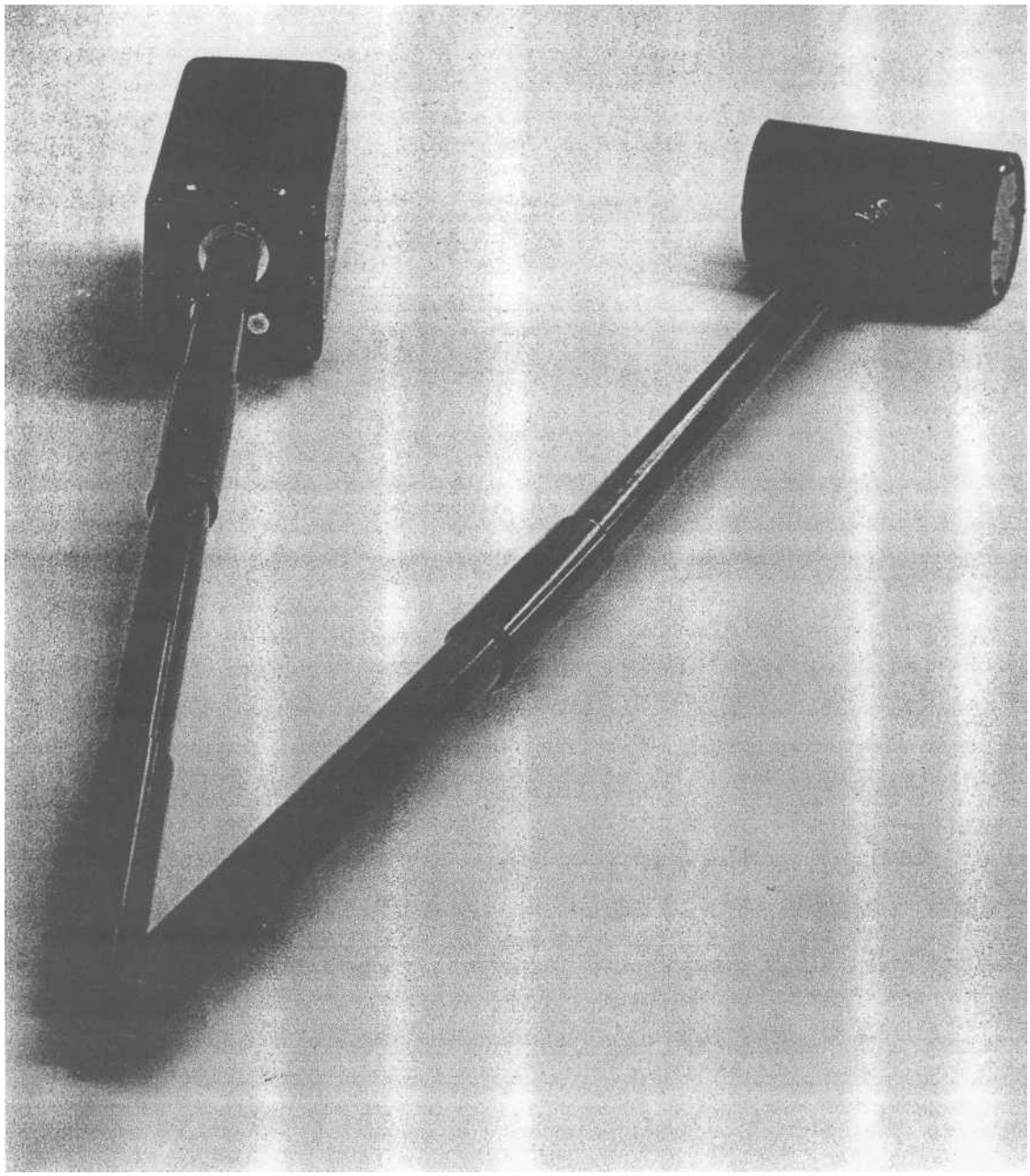

EXHIBIT M - Varian Model V-4938S Portable Search Magnetometer with the staff folded back to show method of folding.

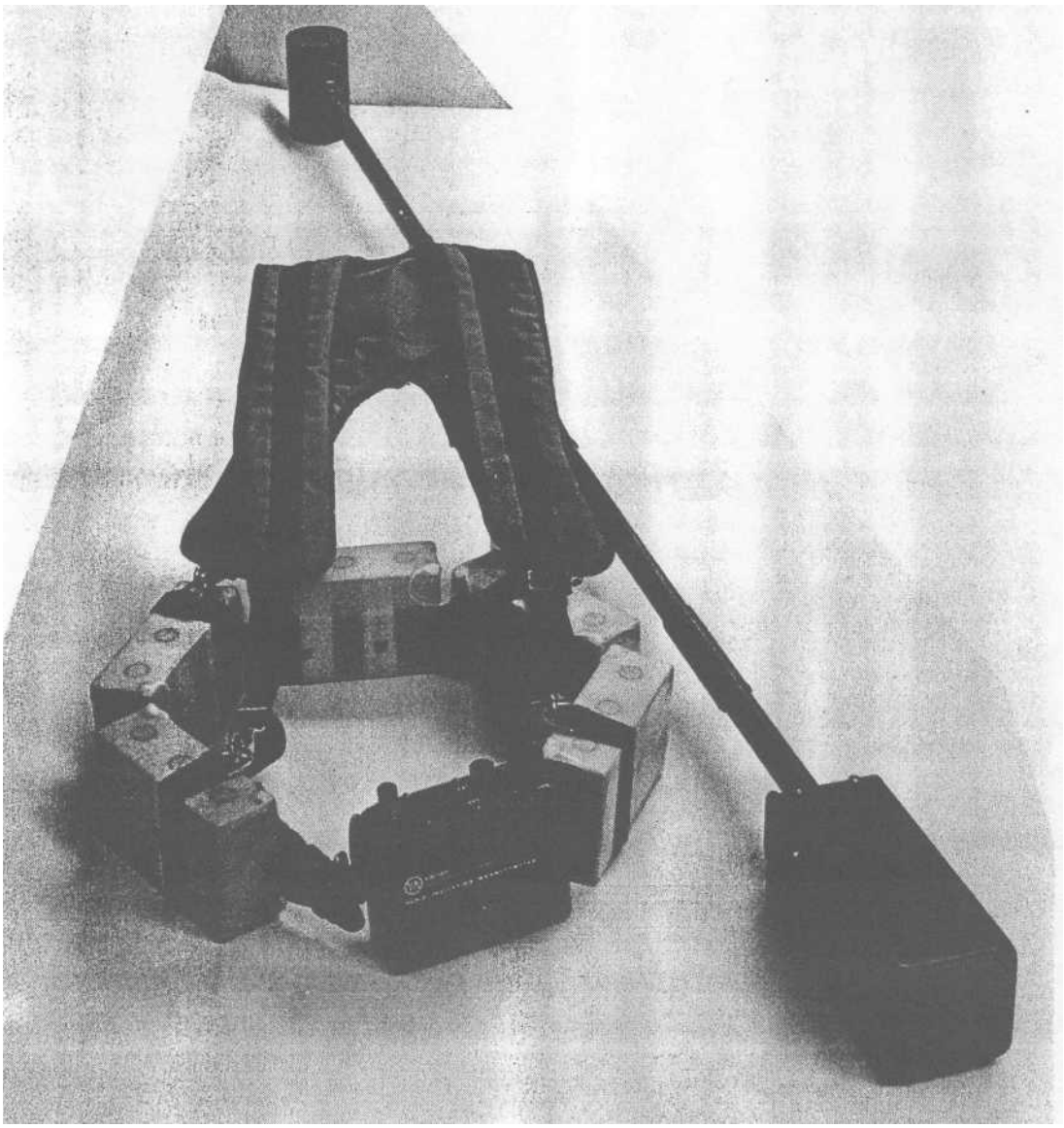

EXHIBIT N - The Varian Model V-4938S Portable Search Magnetometer, complete with audio readout unit and the battery pack and carrying harness.

EXHIBIT 0 - The Varian Model V-4938S Portable Search Magnetometer, complete with the carrying case.