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May 1993

Technical Urban Search and Rescue, System to Locate Survivors (STOLS) Units, Operator's Manual

Prepared for Earthquake Preparedness Center of Expertise

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Technical Urban Search and Resue, System to Locate Survivors (STOLS) Units, Operator's Manual

by U.S. Army Corps of Engineers
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Final report

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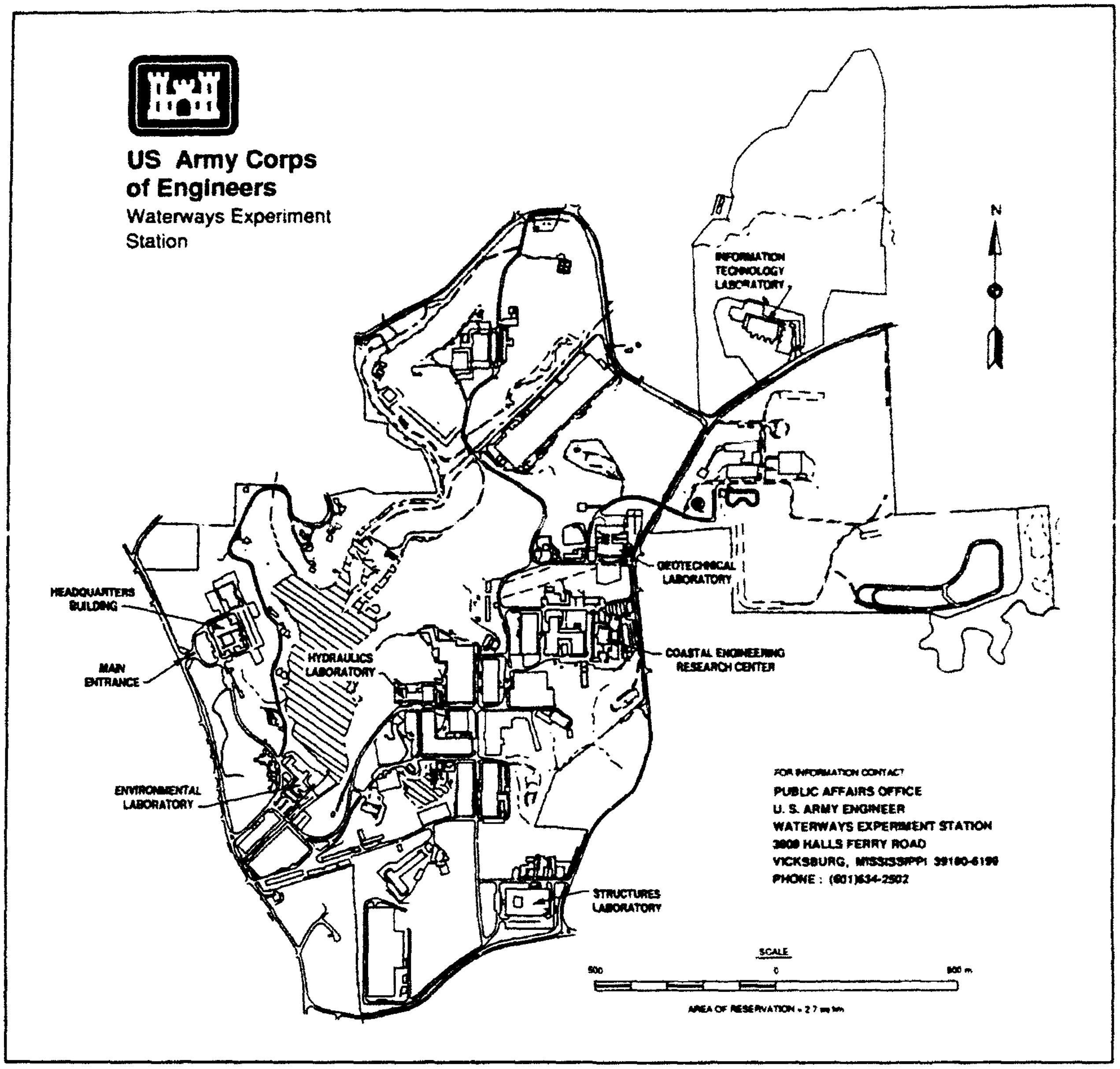

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PREFACE

Under the Federal Response Plan, (Public Law 93-288, as amended) the U.S. Army Corps of Engineers has been designated by the Department of Defense (DoD) as its operating agent for planning, preparedness, and response under Emergency Support Function (ESF) #3 - Public Works Engineering. Under this plan, the Corps also provides support to the DoD for Emergency Support Function #9 - Urban Search and Rescue (US&R).

In December 1990, the Corps was formally tasked by U.S. Forces Command (FORSCOM), who serves as Executive Agent for DoD regarding their support for domestic natural disasters, to provide specialized (structural) engineers and technical support for Urban Search and Rescue (US&R) operations. The Corps as identified in the Federal Response Plan has agreed to carry out its assigned mission.

Under ESF #9 the Corps as a support agency to DoD is required to provide as requested: structural or civil engineers capable of advising on structure stability and shoring techniques, available victim detection equipment and operators, and contract support for the leasing of heavy equipment.

Also, under the National Security Emergency Preparedness (NSEP) Program, reference USACE ER 500-1-25 or Army Regulation 500-60 Military Assistance to Disaster Relief, the Corps may be requested to provide disaster assistance for victim detection equipment and operators.

In an effort to fulfill these requirements, the newly established Earthquake Preparedness Center of Expertise (EQPCE) in conjunction with the Waterways Experiment Station (WES) developed the Systems To Locate Survivors (STOLS) units, a geophysical instrument system designed to detect and determine the location of persons trapped under debris.

Overall direction at WES was provided by Dr. A. G. Franklin, Chief, WESGH, and Dr. W.F. Marcuson III, Director, GL. At the time of publication of this report, the Director of WES was Dr. Robert W. Whalin, the Commander of WES was COL Leonard G. Hassell,EN. Overall direction at EQPCE was provided by Ms. Theresa A. Mendoza, Chief, EQPCE. The Commander of SPD was BG Roger F. Yankoupe.

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PART I: INTRODUCTION

Purpose and Scope

1. The US Army Corps of Engineers disaster response can be classified into three phases: (1) Initial, (2) Sustained, and (3) Recovery. The Initial phase is described as the Corps' response in the first 72 hours after the disaster. The Sustained phase may continue for days to weeks depending upon the severity and location of the disaster. The Recovery and final effort continues until the completion of the task. The technical urban search effort for survivors by the Corps of Engineers is categorized in the Initial phase. For effective survivor location, it is necessary to mobilize, deploy, and initialize the search effort in less than 24 hours. It is also necessary for technical search teams to be in a constant state of readiness for this mission.

Urban Search and the Incident Commander

2. The search for, location, and rescue of survivors is one of the highest priority items for local, state, and federal governments after a catastrophic event. Assets typically converging onto the disaster area include: medical response groups, communications and logistical specialists, public utilities personnel, structural engineering and shoring crews, Urban Search and Rescue (US&R) search dogs and handlers, heavy rescue equipment and personnel, and technical search teams.

National volunteer relief, search and rescue, and other nonpayed professional organizations respond to the disaster to offer logistical support, humanitarian relief, professional assistance, medical care, or to assist in the location and extraction of survivors. The recovery effort is coordinated and organized through local, state, and federal government emergency management agencies. The overall search and rescue effort is directed and lead by the local Incident Commander. The authority level of this person varies from site to site and disaster to disaster but may be a local or state emergency manager, national guard officer, police or fire official, etc. Whom ever the local Incident Commander is, it is traditional among urban search and rescue personnel that all activities are coordinated through this individual or their designated alternate or assistant.

Survivor Mortality Rates

3. A limited number of investigations have been conducted concerning the number of persons who survive a structural collapse. After the collapse of a reinforced concrete building, generally 20 to 80 % of the persons within the building are still alive. Interviews with persons who have survived and were the sole person rescued from an area, report hearing multiple persons asking for assistance in the first few hours after the collapse. As time progressed, fewer and fewer voices were heard. It is evident that a substantial number of persons endure beyond the initial collapse. The majority of survivors however are either quickly rescued or expire from trauma injuries before any heavy search and rescue assets reach the site. Three classifications of survivor rescue are recognized: (1) Self Rescue or Colleague Rescue. The person is able to free themselves from the debris, or fellow workers, family members, etc. are able to find, uncover, and remove the trapped person(s). (2) Light Rescue. First responder organizations such as fire or police departments are able with specialized tools and some heavy equipment to find and rescue trapped persons. (3) Heavy Rescue. Persons are deeply trapped in the rubble. Specialized teams with US&R search dogs

or seismic acoustical "listening" devices are used to locate survivors. These persons are rescued by highly trained and equipped experts who with specialized implements, tunnel or cut into the area where the survivor is located. Trained medical personnel then assist in the removal of the survivor.

4. Survivor mortality is clearly a race against time. The number of survivors rescued decreases rapidly every day after the main shock and the fatality rate of rescued persons also rapidly increases in relation with the number of entrapment days. Evidence suggests the first two days (48 hours) are the most critical. Effects of exposure, dehydration, shock, and numerous other factors take an increasing toll each hour. Beyond the first two days after the catastrophic event the number of survivors decreases dramatically. However, documented cases exist where persons have been detected and rescued more than a week after the structural collapse.

System TO Locate Survivors (STOLS)

5. STOLS units and operators are part of the technical search arena for survivors trapped in debris after a catastrophic event when federal assistance is requested. This technology is developed and designed to locate persons trapped relatively deep within collapsed buildings or other structures who otherwise cannot be detected or located. The STOLS is a portable seismic/acoustic monitoring and recording system. The unit is designed to aid rescue personnel in locating survivors trapped in collapsed structures by detecting taps or cries for assistance emanating from the structure. To facilitate the rapid deployment of the STOLS, all of the equipment necessary to operate the system is contained in a single transit case. The unit is supplied with special, highly sensitive geophones and a single miniature condenser microphone. A stereo cassette tape recorder is provided to retain significant signals for further analysis. Extension cables, additional headsets, adapters, and other

peripherals are also included to make the STOLS unit more versatile.

6. The search for trapped survivors deep in collapse structures has focused on two techniques: (1) Dog teams. Handlers with trained canines search, smell and indicate the possibility of a trapped person in the structure. (2) Elastic and acoustic wave monitoring devices. These devices locate the trapped person(s) who indicate their presence with shouts or taps. Studies have shown that acoustic wave responses (cries, shouts, claps, etc.) do not travel well through the debris, and often can only be heard a few to ten feet from the trapped person. This is a result of the long and contorted path that the sound must travel through the air filled voids in the debris. Elastic waves are vibrations which travel through solid material (such as debris) rather than through the surrounding air. In principle this type of wave generally travels further and is significantly easier to detect than acoustic waves. Elastic waves are generated when a person taps with a solid object, stomps with the heel of a shoe, scrapes with a belt buckle, squirms around, etc. The elastic waves generated by these activities can be detected to various distances depending upon the field conditions. Activities such as light tapping with a bit of hard debris on something solid can be monitored in quiet surroundings to a distance of 60 to 80 feet. The harder the person strikes or taps, the greater the range to which they may be detected. Persons able to tap on relatively intact steel or cast iron plumbing, such as typically found in building basements, can be detected for significantly greater distances.

7. STOLS units were developed by the US Army Corps of Engineers at the Waterways Experiment Station. A planned series of field tests were conducted to research the most effective way to find trapped persons by technical means. Various types of tapping devices and speakers were placed in armored boxes and installed in a multi-story reinforced concrete building of column and slab construction. The building was then forced to collapse

and the signaling boxes were individually activated. Multiple types of elastic and acoustic wave transducers were used to monitor the signals from these boxes in order to establish an optimum sensor(s) for the STOLS system. All data were recorded and used to configure a simple to operate, yet very portable and effective signal amplification and processing unit.

PART II: SET UP AND OPERATION OF STOLS UNITS

Set Up of STOLS Units

8. The STOLS units can be effectively operated after a short instruction period. The units are fabricated from relatively easy-to-locate electronic parts, allowing for expedient field repair if necessary. Each unit conatins (see Figure 1):

A	2 Geophone Transducers w/ 10 feet Cables (Mark Products L1-B's)
B	2 Shorting or Shunting Plugs for the Geophones
C	1 Extension Cable, 20 feet, for Geophones or a Microphone
D	2 Brass Geophone Bottom Weights
E	2 Aluminum Geophone Soil Spikes
F	1 Miniature Microphone and Pre-Amplifier with Battery
G	1 Adapter Jack to Plug Miniature Microphone into Extension Cable
H	1 Large Speaker Headset
I	1 Small Speaker Headset
J	1 Battery Charger
K	1 Two Channel Portable Tape Recorder w/ Operation Instructions
L	1 Iron Oxide Cassette Tape
M	1 Jel Cell Battery, 6 Volt
N	1 XENOTRONIX 24 Volt Fast/Float Battery Charger
NOT SHOWN	4 Extra AA Alkaline Batteries for the Tape Drive 2 Extra 1.5 Volt Batteries for the Microphone

The STOLS unit is designed to operate for 24 hours continuously on one battery charging. If the unit is switched off when not in use, several days of operation can be expected. The STOLS battery can be recharged by plugging the charger into any 110 V 60 Hz single phase wall outlet and then plugging the charger output terminal to either of the ports on the STOLS battery. Any standard small appliance electrical converter used for international travel e.g. 208 V, 50 Hz to 110 V, 60 Hz, can be attached to the transformer and then used to charge the STOLS battery. Full cycle battery charging takes 8 to 10 hrs. Two other battery operated devices are in the STOLS system. One is the tape recorder that operates on 4 AA alkaline batteries. Four

Figure 1. STOLS Components

hours of continuous operation can be expected with one set of new alkaline batteries. It is also possible to directly power the tape recorder from the STOLS battery. When configured in this manner, the battery adapter cable is plugged into the "AUX TAPE POWER" port on the STOLS unit and then plugged into the "DC in 6 V" jack on the tape recorder. The other battery powered device is the miniature microphone. This unit uses a standard 1.5 Volt miniature battery available at most electronic supply houses. Twenty hours of continuous operation is possible with this unit. Toggle the switch on the pre-amplifier box (the small case before the microphone) to the "OFF" position when not in use.

9. The STOLS units are specifically designed to be air transported as "carry-on" baggage. It is not recommended to check the units as baggage without additional packaging. If a unit needs to be shipped, it should be packed in a durable freight box with proper padding such as bubble wrap, or styrofoam.

Turning On STOLS Units

10. The STOLS unit is turned on by first plugging the jack on the cable coming from the panel below the words "STOLS SEARCH UNIT" to either port on the STOLS battery. Switch the toggle on the panel marked "POWER" to "ON", (see Figure 2). The battery indicator light should be green "OK" or red "LOW". If the battery is low, it needs to be charged. When the power toggle is "ON", push the red "BATTERY CHECK" button. The needles on both VU meters should go way to the right past the red portion of the dial if the STOLS battery is fully charged. If the VU meter needle remains in the black portion of the dial the battery requires charging. The STOLS 6 Volt jel cell battery should be charged for 24 hours once every 30 days to maintain the battery shelf life and keep the unit in a ready-to-operate mode. When the STOLS unit is not in use, the cable connecting the battery to the operating panel should be disconnected.

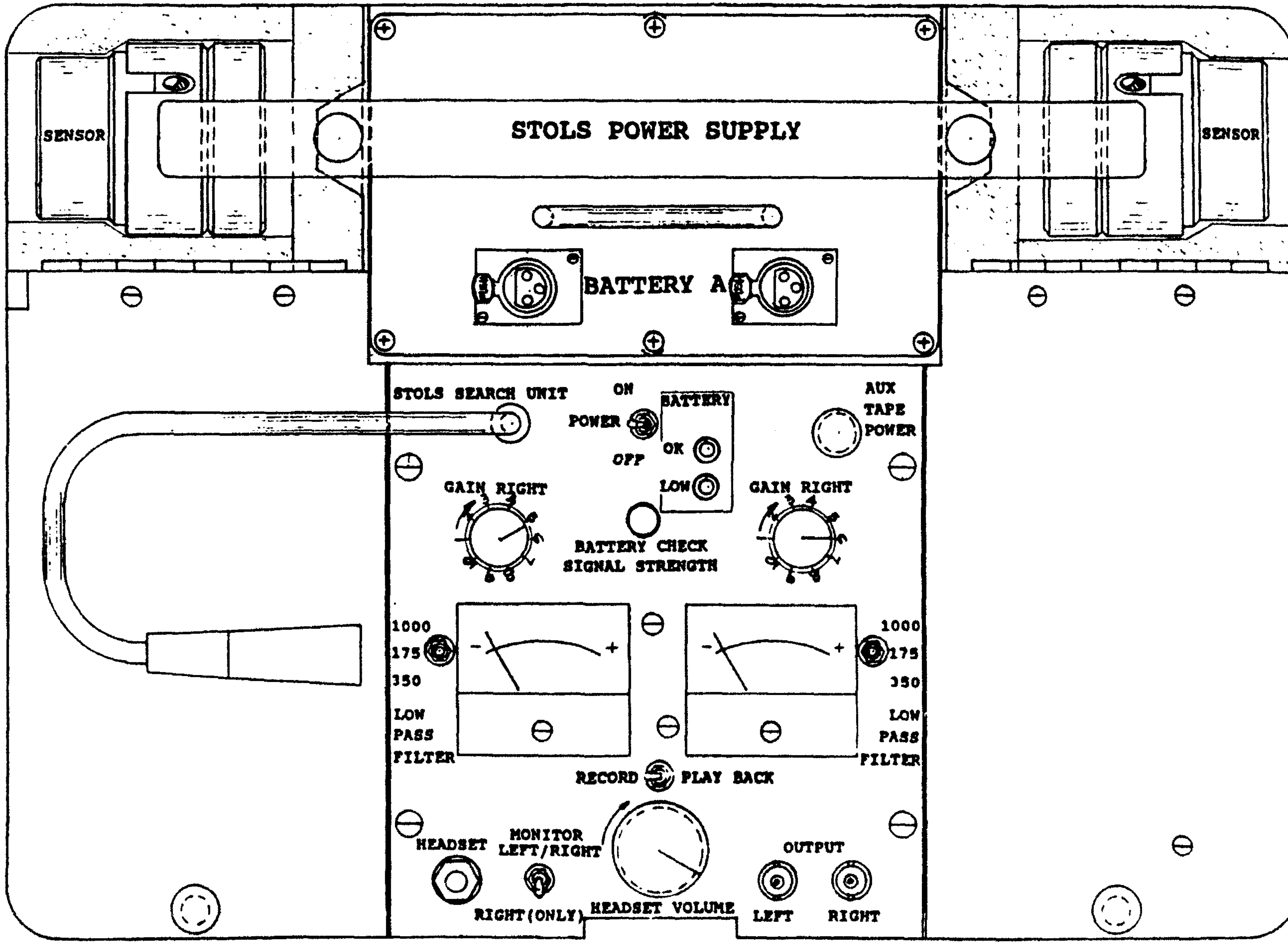

Figure 2. The STOLS Panel

Geophone Sensors

11. Two specially manufactured geophones are provided with each STOLS unit. These instruments are used to monitor elastic waves. CAUTION: The special geophones supplied with the STOLS have been determined by special studies to be the best sensor for the task of finding survivors in debris. They are delicate and therefore must be handled with some care. The following rules MUST be strictly observed.

a. Never drop or shake a geophone.
b. Always ensure that the shorting or shunting plug is connected to the end of the cable before moving the sensor. It is also acceptable to move a geophone if it is plugged into a STOLS unit.
c. Always carry the geophone sideways, i.e. with its long axis perpendicular to the ground.

Remove the two geophones from either the padded compartments on opposite side of the STOLS battery and unwrap the cable. Note that the end of the cable has a cap or plug. THIS IS IMPORTANT ! This cap serves to "shunt" or to short the geophone. When the cap is on the end of the cable, it keeps the internal mechanism in the geophone "braked" or fixed into position. Do not move, carry, or handle the geophones unless this cap is on the end of the cable or the geophone is plugged into the STOLS unit. To do otherwise may damage or break this very sensitive instrument. KEEP THE CABLE CAPS ON AT ALL TIMES WHEN THE GEOPHONES ARE NOT PLUGGED INTO THE STOLS UNITS. Remove the shunt cable caps when the geophones are not being handled or jostled and plug the cables into the right and left sockets on the sides of the STOLS unit marked "INPUT RIGHT" and "INPUT LEFT". When the STOLS is functioning with both geophones, signals from the right geophone will be monitored with the right side of the head set and vice versa. When using the headset, speakers marked "RIGHT" and "LEFT" should be placed over the right and left ear. Insert the headset plug into the receptacle marked "HEADSET". Locate the geophones in a position that will be used to monitor for survivor responses. These sensors need to be placed upright for best sensitivity and signal response. The more the sensor tilts from a vertical axis the lesser the response and sensitivity of the instrument. An off-vertical tilt of less than 10 degrees is satisfactory, and "eyeball" leveling is sufficient. When operating on rubble, the brass geophone base should be snugly attached to the bottom of the geophone. If the instrument is to be utilized on soil or sands, the spikes should be screwed onto the geophone bottom in place of the brass plates. If more cabling is required for a geophone, attach the 20 foot extension cable between the STOLS unit and the sensor. Up to three extension cables may be connected together without a significant loss of signal.

Microphone

12. The miniature microphone may be used in place of either geophone if it is desired to monitor acoustic waves. When utilizing the microphone, be sure that: (1) The battery terminals are clean (rub with an eraser). (2) The battery is properly inserted in the pre-amplifier. (3) The exterior switch is in the "ON" position. To plug the microphone into the STOLS unit or into the extension cord, use the adapter jack provided. When the STOLS is in field use, it is useful to tie string, etc. to the adapter jacks and other small parts to prevent them from "falling through cracks" in the debris pile. The microphone may also be used to place messages on the cassette tape by the STOLS operator or inserted into a debris pile to listen for verbal responses from survivors. A typical insertion system is to tape the microphone and cable onto long flexible pole such as a fiber glass rod or 1/2" PVC pipe. Protect the microphone by not placing it directly on the tip or end of the pole. As with the geophones, several extension cables may be linked together to give a long reach into hard to search places. In addition the microphone is not water proof, a sacrifice made to increase its sensitivity.

Using Only One Channel

13. It is advantageous in certain instances to use only one rather than both channels on the STOLS system. A toggle switch on the panel marked "LEFT ONLY / RIGHT ONLY" and "BOTH" allows this to be done. This switch allows both left and right sensors to be simultaneous monitored or only one sensor at a time with the other sensor switched off. If only one microphone or geophone is to be monitored, plug the cable into the right side of the STOLS unit and toggle to "RIGHT ONLY". If the left channel VU appears to be moving but no sound is reaching the left headset, it may be due to the fact the toggle was inadvertently placed in the wrong position.

Acoustical and Elastic Wave Frequencies

14. Rescue experience and field tests have shown that voices or taps from trapped persons are of specific spectral frequencies. With this in mind, it is possible to electronically separate or filter out many unwanted noises or interfering signals. Elastic wave signals from persons tapping are generally in the 25 to 50 Hz range. This is near the lower range of human hearing and often elastic waves from vigorous pounding in the debris pile will be identified as strong but low pitched thumps. To monitor elastic wave taps with the geophones, place the right and left channel toggle switch at 175 (a 175 Hz low pass filter). This greatly reduces unwanted noises above 175 Hz. Tests and experience have shown that voices do not travel well from debris piles. However acoustic responses below 350 Hz appear to propagate much better than those above 350 Hz. Hardly any voice generated acoustic waves above 1000 Hz propagate well from debris or rubble, but if the void space in the debris is fairly large and continuous from the victim to the STOLS microphone, a voice response in the range 350 to 1000 Hz should be detectable. Thus when monitoring with microphones have the frequency toggles set at 350 or 1000. Remember that more interfering signals will be heard with the 1000 Hz filter than the 350 Hz filter. Both filter switches must be set to the same cutoff frequency to

preserved matched phase response from each channel. When using the STOLS geophones start monitoring with the filters set at 175 Hz. The normal setting for the microphone is 1000 Hz. The 350 setting is used with the microphone in the presence of interfering noises.

Adjusting the Amplification or Gain

15. The amplification or electronic gain of left and/or right channel(s) must be set or adjusted. With the power on, the filters set and sensors placed and connected, increase the electronic gain by turning the left and right knobs marked "GAIN" to greater numerical numbers. Monitor the increasing amplification level on the appropriate VU meter. The needle should move back and forth but should for the majority of the time remain in the black colored portion of the dial. If the needle remains in the red portion of the VU meter, the gain is too great and needs to be reduced. Plug the headset into either the jack marked "HEADSET" on the panel or into the external headset jack adjacent the STOLS carrying handle. Two headsets can be used simultaneously if desired. Adjust the sound volume to a comfortable level by increasing the secondary amplification with the knob marked "HEADSET VOLUME". Test the system now by very lightly tapping on either the geophones or the microphone. When this is done, the VU meters should deflect and an audible sound should be heard in the headset. If this is not the case, retrace the set-up procedure to identify the cause.

Using the Cassette Recorder

16. Each STOLS unit has a built in stereo cassette recorder. Collection of signals by tape recording is an important task for the STOLS operator. Sometimes a signal or noise may be heard which cannot be identified but should be re examined by a more seasoned operator. Many times uncertain sounds which were recorded can be scrutinized using more sophisticated data processing equipment and clearly identified as to their source. Data collected on disaster sites can be used to train other STOLS operators. Once the STOLS amplifier levels have been set so that

the VU needles remain in the black colored portion of the dial most of the time, the STOLS unit can be used with the recorder. Adjusting the amplifiers by monitoring the VU meters sends nearly the optimum voltage level of signal from the STOLS to the tape recorder. This greatly enhances the capability of post processing weak and uncertain signals and sounds. Adjust the toggle on the STOLS panel which reads "RECORD/PLAYBACK" to the "RECORD" position. Open the box on the right side of the control panel which contains the tape recorder. Insert the plug on the black cable from the STOLS unit into the jack on the tape recorder marked "INPUT". Turn on the tape recorder in the RECORD mode. Instructions on the use of the tape recorder will not be addressed here, as these are covered in the operational guide provided by the manufacturer and included in the STOLS unit. To check if the signal is being recorded, the smaller head set can be plugged into the tape drive or the varying signal intensity lights on the recorder can be visually monitored. To play back a tape through the operating STOLS unit, adjust the "RECORD/PLAYBACK" toggle on the STOLS unit to the "PLAYBACK" position. Insert the plug on the black cable from the STOLS unit into the jack on the tape recorder marked "OUTPUT". The tape can be monitored through the headset and the signal volume adjusted to an optimum level by turning the "HEADSET VOLUME" knob on the STOLS panel. If signals are not recorded or cannot be played back with the tape recorder, retrace the adjusting and connecting steps with the STOLS units and the operation of the tape recorder until the problem is identified. Always use normal or iron oxide cassette tapes with the STOLS recording unit. These are generally the least expensive type of cassette tape and have superior frequency range below 100 Hz when compared to chrome oxide or other types of recording tapes.

Repositioning the STOLS Unit

17. When the STOLS unit is ready to be relocated, first UNPLUG THE GEOPHONES FROM THE STOLS UNIT AND REPLACE THE SHUNT CAPS ON THE CABLE ENDS BEFORE THE GEOPHONES ARE HANDLED OR MOVED.

Turn all power switches to the "OFF" position and pick up the gear.

Site Operation of STOLS Teams

18. STOLS teams are organized with each STOLS units. Two to four persons are normally formed into a team and assigned to each STOLS unit. This allows a nearly continuous operation at the disaster site with the STOLS unit handed off from one section of the team to the other. The teams are trained to work together, with the "off-duty" team members assisting the "on-duty" team in tasks such as securing of rations and potable drinking water, watching personal belongings, maintenance of team gear, and administrative tasks. In addition STOLS team members at the disaster site watch out for each other, remembering that excessive physical and mental fatigue can lead to mistakes and injuries. Safety is a critical part of STOLS operation. Watch out for your buddy and realize teamwork is the key to the success of survivor detection and location.

Disaster Site Operations

19. Disaster sites generally are confusing but not impossible affairs. It is important to work along side and in concert with the efforts of the Incident Commander at the disaster location. He or she will designate a location for the STOLS teams to stage their efforts which is relatively close to the collapse structures. This may be a school room, spot in an armory, or a tent in a park. The Incident Commander will then provide a reporting procedure as to who in the agency to furnish a daily report and with whom the STOLS teams should coordinate. In past technical search operations acoustic / seismic listening teams have worked closely and in coordination with US&R dog teams and medical personnel. It is important that a designated person from the STOLS teams coordinate with the dog team leader(s) concerning areas searched, possible live survivor indications, and methods of field markings. It has been standard practice at

past disasters that locations in debris where dogs have indicated a possibility of a survivor are checked by technical search teams for any indication of the presence of a trapped person.

STOLS Teams Operating in Groups

20. STOLS teams generally operate best in groups. Often there is a temptation to disperse the teams over a wide area to apparently increase the number of sites investigated. However, by placing only one or perhaps two STOLS units and operators per building, large areas of the collapsed structure are not effectively monitored for survivor response. As the STOLS team work their way over the structure, survivors can be effectively "worn out" and unable to give a strong or loud response when a STOLS team eventually places the sensors within effective listening range. It is therefore imperative that a sufficient number of STOLS teams are assigned to monitor a collapsed structure so that a reasonable survivor response is detected soon after the STOLS teams are set up and begin listening.

Controlling Noise Pollution and Types of Interfering Noise

21. The STOLS units have extremely sensitive sensors which respond well to frequencies associated with taps from survivors in rubble. In a disaster area, many other acoustic and seismic noises will be present. Some such as background noise, produced by wind are natural in occurrence. Most others at the disaster site will be the result of cultural activity. These include: (1) Construction equipment, such as cranes, bulldozers, jackhammers, pumps, air compressors, generators, etc. (2) Fixed and rotor wing aircraft overhead. (3) Sirens from various emergency vehicles. (4) Heavy road traffic. Noise levels at an operation site may reach an order of magnitude greater than those in normal day activities. Although the STOLS units are designed to remove and filter as much of these interfering noises as possible, noise pollution control for a city block or more around the searched area is generally necessary. In addition, the air space above the searched area needs to be controlled and restricted for 10 nautical miles around the disaster site. Generally, local law

enforcement and disaster response agencies will aid in ground noise pollution control at coordinated times. The Federal Aviation Agency under the US Department of Transportation has upon request, traditionally restricted airspace to aid disaster operations. Invariably, the overall noise level from cultural sources greatly abates after sunset and does not increase again until sunrise. Nighttime is therefore the most effective time for STOLS unit operation and should be designated as the primary time for the technical search effort. Although the technical search for survivors should take place on a 24 hour basis, night time efforts have proved to be more effective. During such quiet time operations, footfalls can be easily detected and it may be necessary to request persons on the site to be seated still while the monitoring is being conducted.

Common Collapse Patterns and Voids

22. Buildings of differing construction collapse in a variety of ways. It is important to be able to recognize various types of these structures and their collapse patterns. An understanding of these failure patterns will assist the STOLS operators in determining likely areas where survivors may be trapped. Voids are created in most collapses into which survivors either have been able to move, or where some may have been located when the building failed. In many instances, buildings have been described to have disintegrated "in slow motion" during an earthquake. Generally the more prolonged the destruction of a building the greater the likelihood for voids to be present and hence the increased chance for survivors. Particular areas of interest are regions where a building has strong structural elements such as stairways and elevator shafts. The walls of basements also represent a solid member and large voids are often found adjacent to these. Typical failure patterns which create voids are in indicated in Figure 3. These general types of collapses are: (1) The Lean-To. One side of a floor falls and the other side may be partially supported.

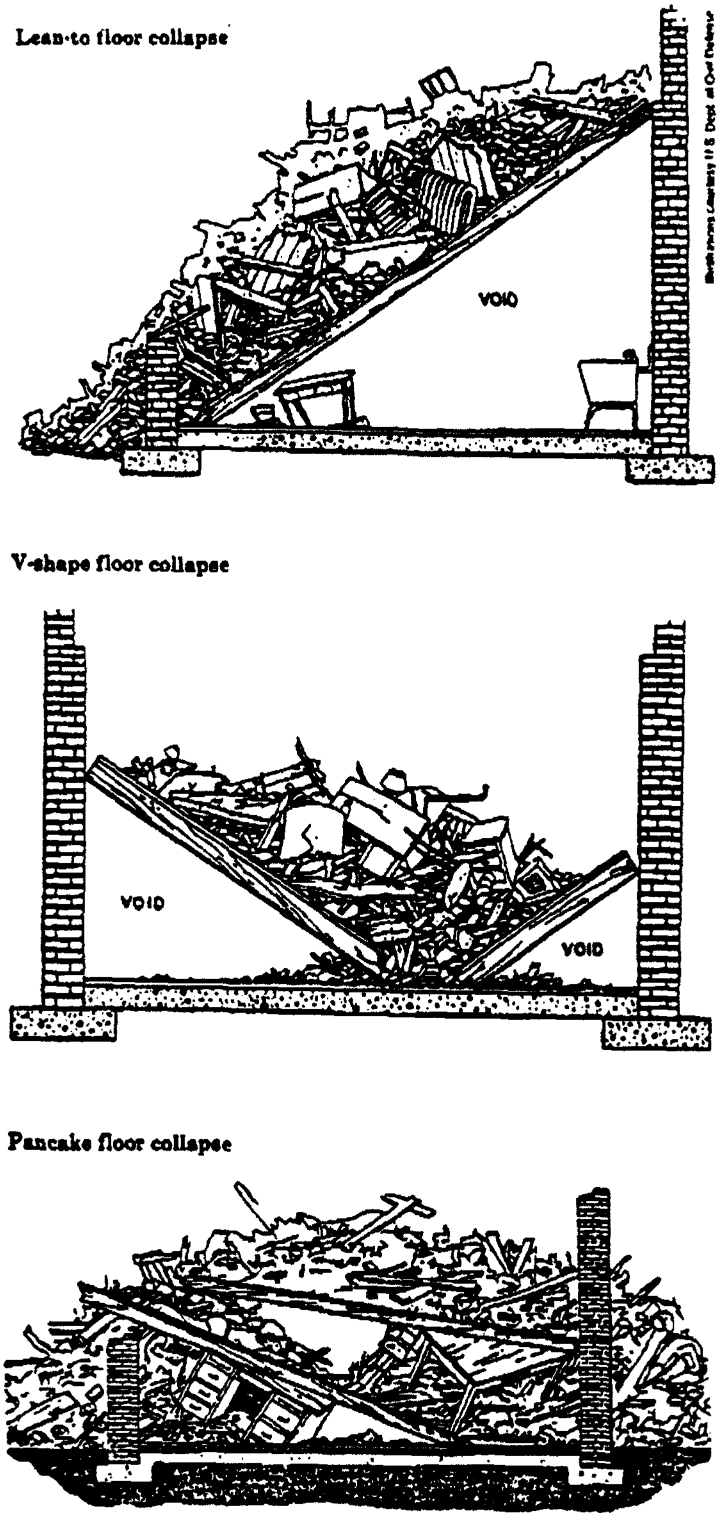

Figure 3. Typical Building Failure Classification

(2) The V-Type. The floor buckles somewhere near the center. (3) The Cantilever, (Not shown). A wall pulls away leaving the floor only partially supported. (4) The Pancake. The supporting floor columns fail, leaving multiple stories stacked upon one another. In each general collapse case, the building still contains numerous voids within the failed structure that may contain trapped persons.

23. Heavy wall collapse patterns are shown in Figure 4. Typically these structures are unreinforced masonry (URM) with massive brick or concrete block exterior walls. These walls may split as one layer falls off and other layers stay on in a weakened state. Often a entire wall will fall into rubble, leaving large angular voids since large sections of the floor and roof commonly stay together as a plane.

24. Concrete buildings have several typical collapse patterns as seen in Figure 5 and 6. Most typical of these are torsional effects or column/joint failure. This later case produces the common "pancake" pattern, with the floors of multiple stories stacked a few feet apart. Survivors are often trapped between these layers where voids are created by heavy cffice equipment or other debris which can partially support the floor above.

25. The typical precast concrete failure pattern is seen in Figure 7. With this type of structure, failure patterns are varied and difficult to predict. However, the resulting configuration involves a jumble of heavy unconnected building slabs, beams, and columns. The prediction of void locations in this type of collapse is often more difficult.

<u>Placement of Geophones on Collapsed Structure and Debris</u>

25. Placement of the STOLS geophones for survivor detection is a critical task. Different locations of geophones on different portions of the collapse will result in a large variation of the signal response or background noise. The STOLS group leader should survey the structure and direct the teams to general locations for set up in the survivor detection effort.

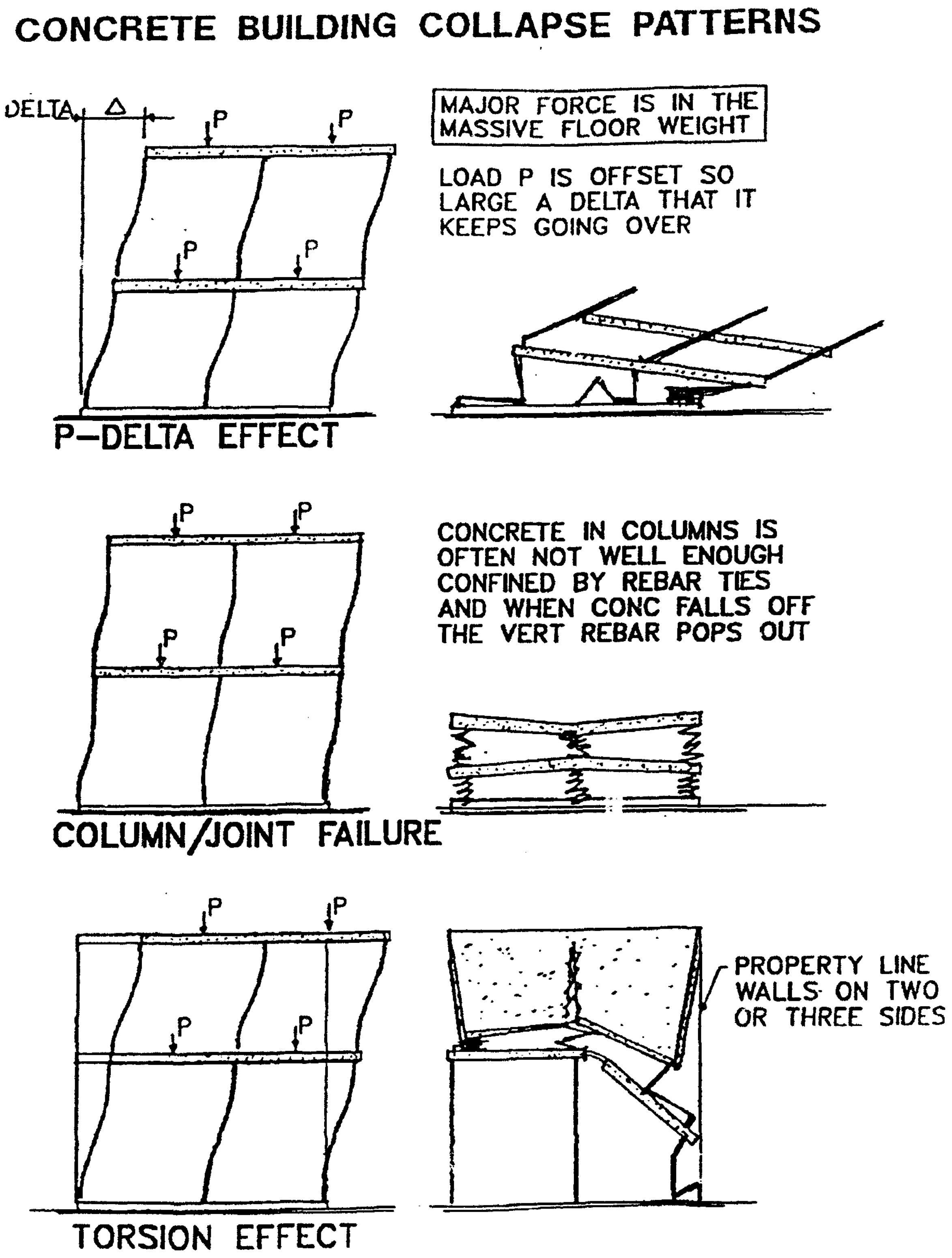

Figure 4. Typical Heavy Floor Building Failure Patterns

PRECAST CONCRETE FAILURE PATTERN

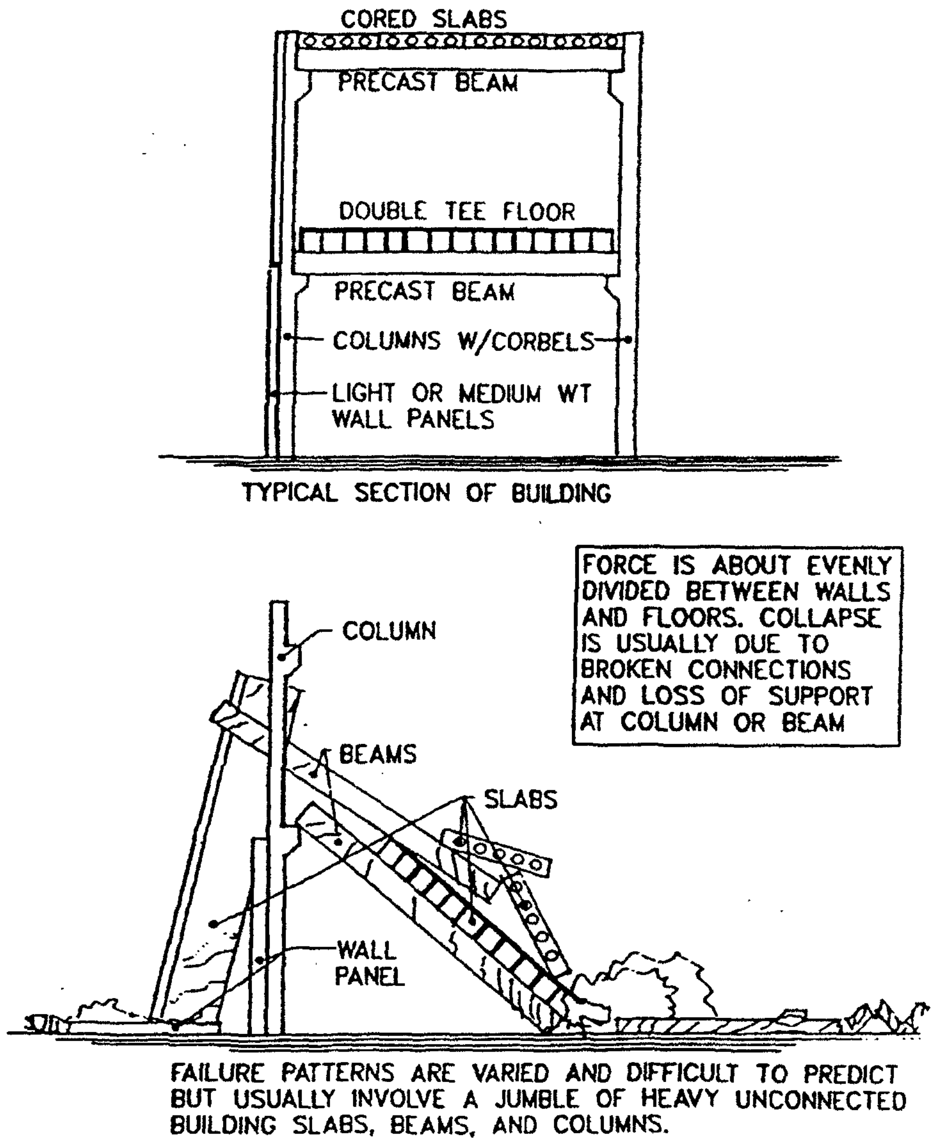

Figure 5. Typical Precast Concrete Building Failure Pattern

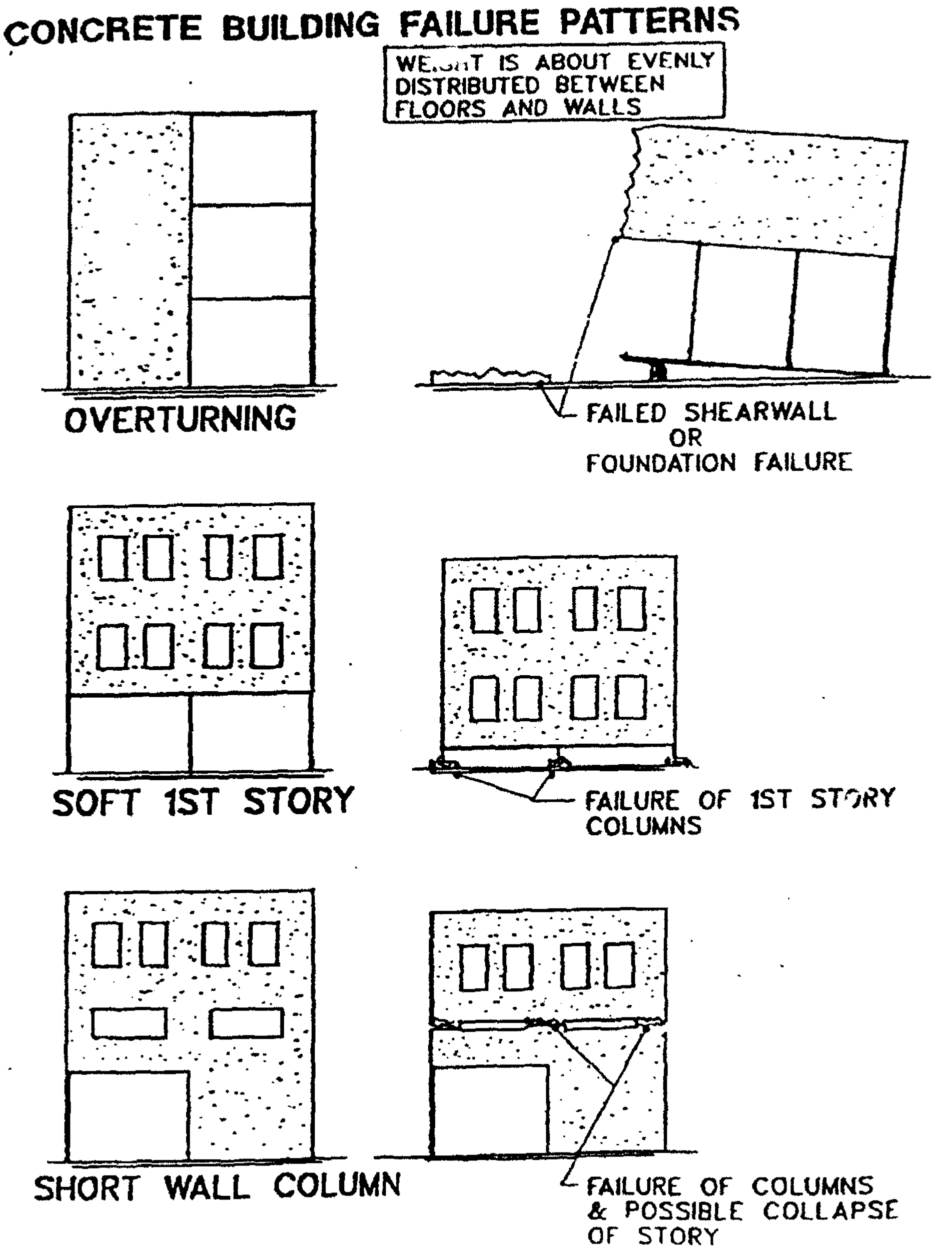

Figure 6. Additional Concrete Building Failure Patterns

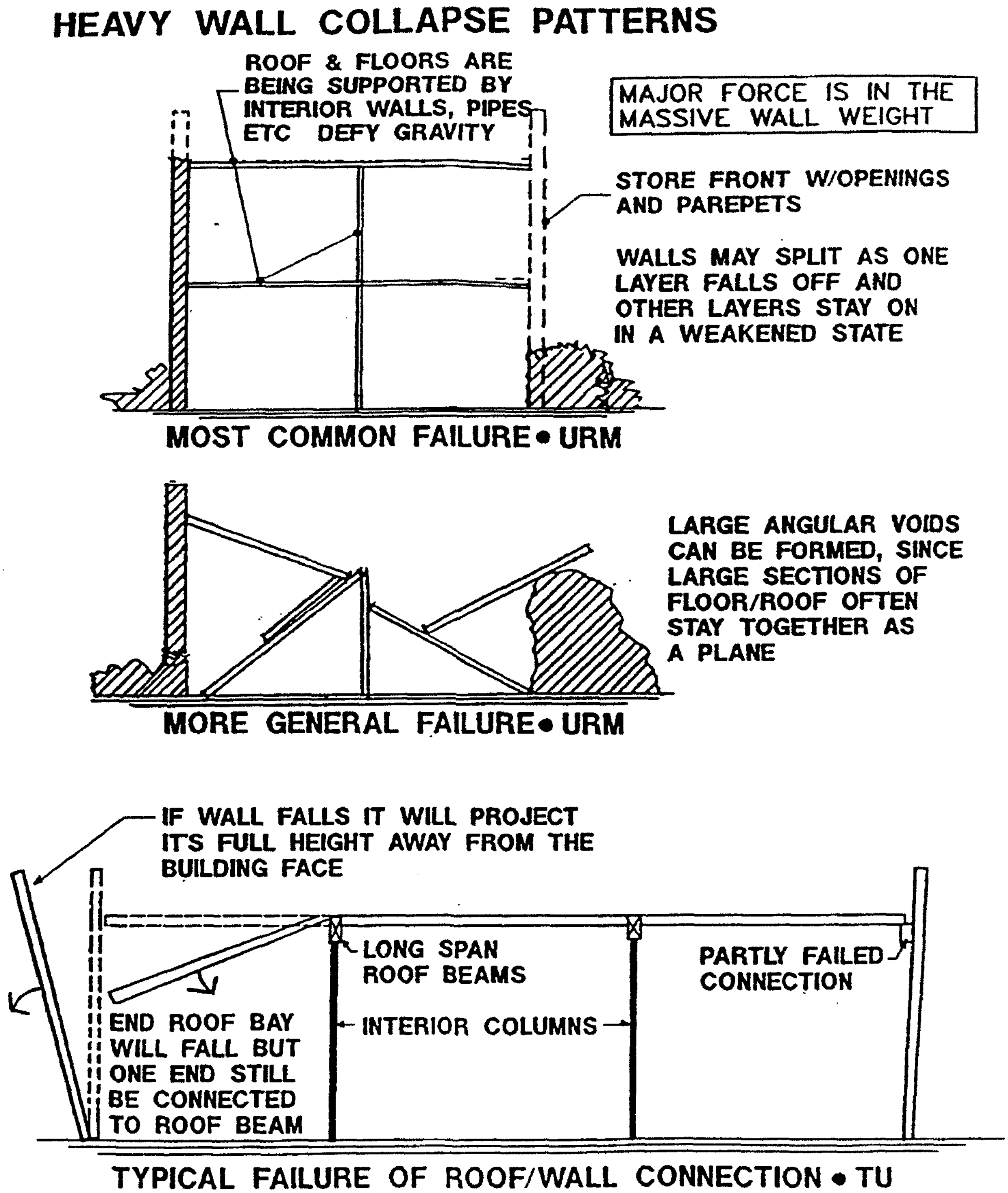

Figure 7. Typical Heavy Wall Building Failure Patterns

It is usually desirable to place the geophones well up onto the debris pile. This involves careful climbing on the debris pile. The larger the building member or piece of debris the sensor is placed upon, the greater the probability that a weaker tap will be heard. An ideal placement of a sensor would be: (1) Placing it in a nearly level orientation, i.e., not tilting in any direction. (2) Having it located on a large horizontal structural member of the collapsed building. (3) Isolating it by situating it in an acoustically protected niche or hole in the debris pile. Figure 8 shows typical geophone placement locations on collapsed buildings. Although all of these criteria cannot always be met, it is important that these espec lly sensitive type geophones be orientated nearly vertical for optimum sensitivity, i.e. plus or minus 10 degrees. The brass base or bottom of the sensor needs to be in contact with as much of the debris material as possible. Rather than wedge the geophone into a level position with a small bit of debris, it is a far better practice to adjust a large piece of debris so that it has a portion of the surface in an orientation allowing proper orientation of the geophone. If necessary, the geophones may be affixed to vertical members such as columns or pipes with tape. When this is done on unsupported free standing building members, the noise level may be excessively high due to the natural noise amplification of an inverted pendulum. It is not desirable to place the geophone on the top of walls or still standing vertical members of a building, as these are seismically very noisy places. A large horizontal piece of debris which is acoustically isolated is the best location for a geophone. The geophones may also be lowered into pits or holes, and an effort should be made to orientate the sensor in a near vertical manner when this is done. This can be accomplished with the expedient use of local materials and duct tape. The geophones are not submergible in liquids, and should not be placed in standing water or in tanks. If necessary the brass plates may be removed from the geophone and replaced with the spikes. The geophone may then be inserted

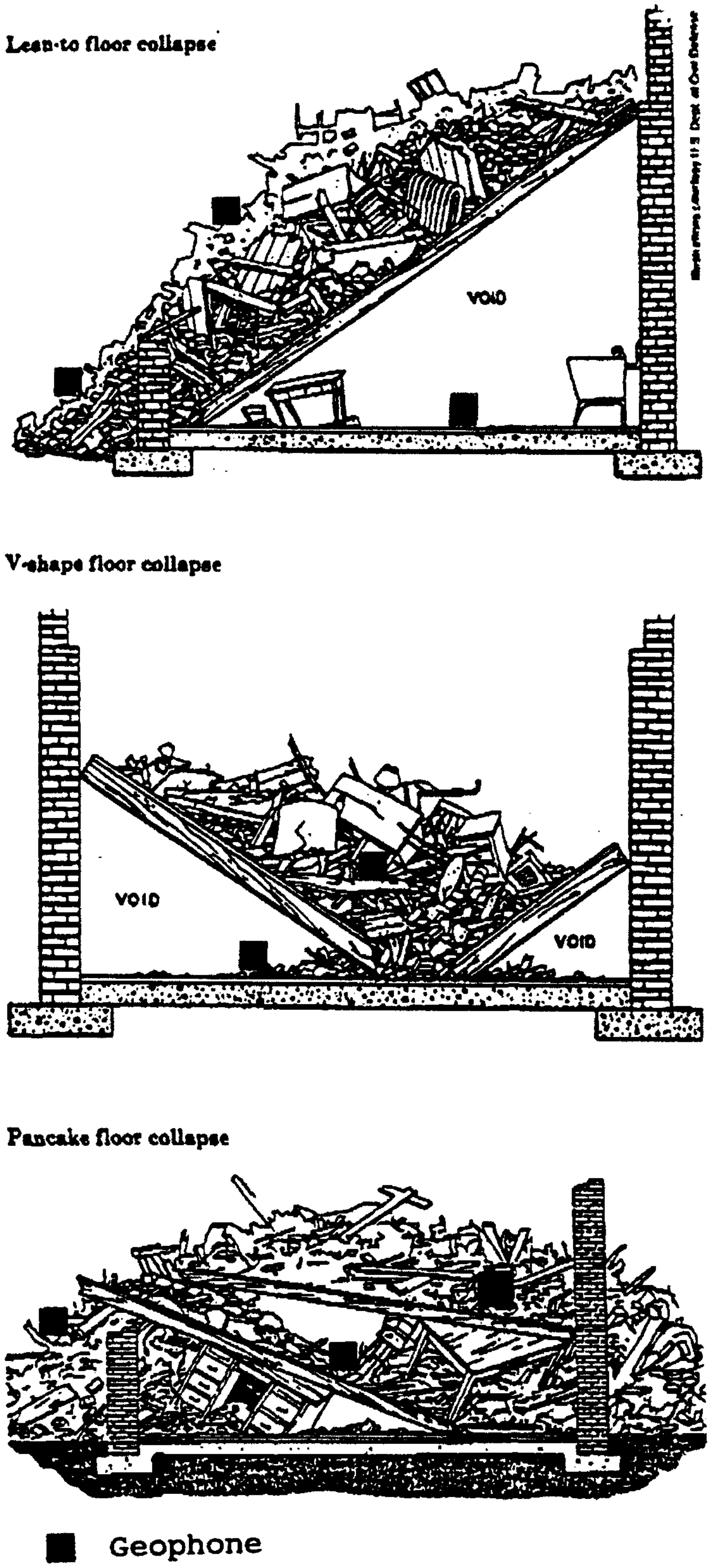

Figure 8. Geophone Placement Locations on Collapsed Structures

into soil or wedged into cracks or joints.

STOLS Team and Geophone Spacing

26. The separation and spacing of the STOLS teams and hence the geophones over and around a collapsed or damaged structure needs to be chosen so the resulting response of a trapped person may be identified. Under quiet conditions such as found at night or with careful daytime noise pollution control a reasonably good tap can be normally detected with the STOLS unit for a range of approximately 75 feet. Often taps can be detected for even greater ranges, but the certainty of identification decreases with distance. The maximum range that any tap may be monitored is in the range of 150 to 175 feet. To be conservative the geophones should be place approximately 25 to 40 feet apart. Conditions vary considerably from site to site and a tap test should be conducted at each location to determine the effective distance a reasonably strong tap may be detected. This test is generally conducted by tapping with a piece of debris on the ground. A tap test also assures the operator that the STOLS units are functional and properly adjusted. Once the effective range for tap detection is established for the site and conditions, the STOLS teams may be effectively spaced so that no gaps occur in the coverage. Field tests demonstrate that sound travels fairly well into the debris pile but poorly out of it. The range that a trapped person may be able to hear a request from a megaphone for a tap can be greater than the distance to which the tap is detectable. Therefore the collapsed structure needs to be adequately covered with STOLS teams and sensors.

Challenging the Trapped Person to Tap

27. It is necessary to challenge the trapped person to respond once the STOLS teams have been deployed on the structure. Field tests have demonstrated that taps rather than voice responses are detectable significantly greater distances through the debris pile. Two current schools of thought describe the best way to request a person to tap. One technique is to use a tapping rod. A series of five quick taps followed by two slower

taps is performed at the surface. This will alert the person(s) in the debris to answer with taps. Arguments against using this method are that if the debris pile is large, persons located more than a few tens of feet from the tapping rod may not hear the request. Another school of thought is to use a megahorn and request for taps. It is necessary to challenge the trapped person their native language. Arguments against using a voice challenge are that persons trapped may hear a distorted voice through the debris pile and not understand the directions. They may then try to respond by voice rather than by taps. Until one technique clearly displays itself as greatly superior to another, it is advisable to use both techniques, first the tapping rod and then the megaphone. It is important to try to have the trapped person respond with taps rather than shouts if they are able. Field tests conclusively demonstrate that a good tap from a person well into the debris pile can be detected a significantly greater distance than a voice response. In addition, tests and rescued survivor interviews indicate that a person trapped well into a collapse structure can generally hear a voice challenge through megahorns or other voice amplification devices.

28. The length of time a building site should be monitored before the STOLS teams move onto another location is uncertain, Generally, once the teams have been place and have been actively listening for survivors for 10 minutes or so it is advisable to move to another site. Before moving to a new vicinity it is often advisable to have the STOLS teams shift to new positions on the same debris pile and relocate the geophones. Queries should be repeated for survivors to tap. Once a collapsed building or area has been monitored by the STOLS teams it should be placed on a priority list for a later return. In many instances survivors have been detected and located after a second or even third return to a collapse site. Many of these persons were unaware of earlier search and rescue efforts.

Use of Microphones to Listen for Voice Responses

29. Not all survivors in debris have the means to produce taps. Infants, totally pinned persons, or completely exhausted individuals do not or may not have the means to tap. Although it is recognized that voices do not travel well through debris, a cry for help may be the only means these persons have to request assistance. To recognize and locate these cases the STOLS units contain a miniature microphone which may be used on either channel. Microphones and extension cables from other STOLS units may be used in conjunction to form one or more dedicated units just for acoustical search. The most practical way for monitoring survivor's cries for assistance has been found to tape the microphone and extension cable(s) onto a long flexible pole and insert this pole into gaps in the rubble as far as possible. Field expedient insertion devices may be fabricated from such sources as PVC pipe, cane fishing poles, fiber glass surf fishing rods or connectable flexible poles used by chimney sweeps. Note: It is not recommended to use metal poles unless it is certain that all electrical power sources are disconnected. In past search efforts it has been found possible to drive a cast iron or steel pipe through a portion of the debris into a void and insert the miniature microphone through the pipe. Other microphones, in addition to the miniature device supplied with the STOLS units may be effectively used. The only restriction is that the microphone have a standard impedance.

Located Survivor

30. A positive response from a survivor should be authenticated at once. This can be accomplished by playing back the recorded channels on the tape drive and having other persons verify the signal. Several steps then need to be taken: (1) The Incident Commander must be notified a possible survivor has been located. (2) The supporting rescue and medical teams need to be alerted. (3) Techniques need to be taken to locate the trapped person as accurately as possible. However, note that buildings containing one survivor often contain more. Do not focus the

entire search effort on the response of one person, the rest of the area must be searched for additional survivors. All STOLS units should recheck their tape recorded efforts to insure that the same or another survivor's response has not been overlooked. STOLS units receiving a positive indication of a trapped person should temporarily stay in place. At least one geophone definitely receiving a response from a trapped person should remain in the same position. Those not receiving a signal or obtaining only having a weak reply should move to a location which would appear to be more favorable. All STOLS units tracking a responsive survivor should be adjusted to the same gain or amplification level and the same filter settings whereever it is practical. In this manner the strength of the signal from the trapped persons response may be used to spatially locate the person(s) within the debris. Generally the stronger the signal, the closer the person would be to a geophone location. The relative strength of the signal when the gain levels are the same can be easily determined by how great the needle deflects on the VU meter. It is important not to tie up all the technical search effort for a great deal of time at a single site where a survivor is located. Once someone has responded and has been located as accurately as possible, a STOLS unit(s) should stay to monitor the survivor(s) and to assist the rescue teams in identifying the location of the survivor(s). The remainder of the group should move to the next site and continue the search. It is critical that the STOLS personnel NOT attempt to immediately uncover any trapped person. Individuals covered by debris for any length of time and uncovered without on site medical assistance may develop acute renal failure as a cause of traumatic rhabdomyolysis or crush syndrome. Survivors should only be uncovered in the presence or after treatment by trained medical personnel. Many trapped persons have expired after being uncovered or removed due to the lack of needed medical assistance during the extraction effort.

31. A typical search procedure with a STOLS unit containing four geophones would be as follows. The geophone sensors would be placed in a square pattern at favorable locations on the site with a 25 to 40 foot spacing between sensors. Survivors would be challenged to respond with a tapping rod and megahorn. Two sensors at a time would be monitored. The signal strength of a answer from a trapped survivor would be compared between channels. The geophone having the strongest response will remain in place and the other geophones moved to new locations to "zero-in" the location of greatest signal level. Two or more STOLS teams hearing the same person respond would work toward each other until a final peak response location is achieved.

Record Keeping

32. Each STOLS group leader has the responsibility of keeping a work diary. Information should include as a minimum: the names of the STOLS operators, time of day, street addresses or locations, building or business names if known, sketch map of the site with the STOLS monitoring locations, indications of any survivors, and any other observations that the group leader feels necessary to record. The STOLS teams, if working independently need to maintain similar records. In addition each STOLS operator has a responsibility to voice record information onto the STOLS tape recorder such as: the location, time of day, site conditions, amplifier gain levels, and any information the operator feels to be significant.

Marking the Site

33. Many search and rescue efforts are comprised of local, state, national and international assets which operate under the local incident commander. Due to the wide diversity of effort, standard site markings have been established which are spray painted at each building site. These hieroglyphics have been developed by agreement among the search and rescue community. This system is found in Appendix A. It is important that this or any other marking system at the disaster site be understood and used by the STOLS operators. It is critical that if additional

or different marking systems are used by other search teams, local search and rescue organizations, or international groups, that these systems be recognized and interpretable. It is important that the markings by the STOLS teams be placed on the buildings so that they represent a fairly permanent record and are easily seen by other organizations. Painted symbols on sheets of plywood or other debris which can be easily erased, moved, hidden, or altered are discouraged. Attempt to leave a tamper-resistant indication of the technical search effort preformed by the STOLS teams. At past disasters persons have erased search team markings in order to encourage additional monitoring of a collapsed structure.

Maintenance and Repair of the STOLS UNITS

34. The STOLS units have been developed to be transportable and operable in a wide variety temperatures and climatic conditions. Standard and reasonable care and maintenance will keep the units in good working condition. All dry cell batteries should be replaced twice a year. The two jel cell batteries which are the main power source for the STOLS unit should be charged monthly. These power units should be replaced every two years. After charging the STOLS unit, it should be set up and all functions and accessories checked for good performance. This includes checking the geophones, microphone, tape recorder, filter functions, indication lights, and accessories. If a unit needs to be repaired or serviced, it should be shipped to the Earthquake Engineering and Geoscience Division, US Army Corps of Engineers Waterways Experiment Station, 3909 Halls Ferry Rd, Vicksburg, MS, 39180. Emergency field servicing is possible, and circuit diagrams, board layout, and part lists are included in Appendix B.

Safety

35. Safety is a continual concern at all disasters. Live electrical wires may be present. Natural gas lines may be broken with fire or an explosion a possibility. Unstable and damage structures may collapse or shed debris during an aftershock.

Debris piles may shift during climbing operations. Always consider safety when operating STOLS units. The buddy system is used to check on the physical and mental well being of STOLS team members.

Personal Gear and Equipment

36. STOLS team members need to be ready to go on very short notice. It is necessary to keep a minimum amount of equipment ready for rapid deployment. The following is the recommended basic equipment for operation.

List of Required Equipment for STOLS teams

a. Boots (Mountaineering) for Talus Slope Climbing
b. Durable Flashlight w/ Additional Batteries and Bulb
d. Chemical Light Sticks
e. Canteen w/ Water Purification Tablets
f. 2-Way FM Radio (with proper frequency)
g. Surgical Mask (2)
h. Identification Bracelet/Tag
i. Pocket Notebook, 100% Rag Paper e.g. Survey Notebook
j. Waterproof Ink Pens
k. 6 - 8 MRE's (Meal, Ready to Eat)
l. 1 Roll Grey and Duct Tape
m. Building Markers i.e. spray paint, lumber crayons, surveyor tape
n. Safety goggles
o. First Aid Kit
p. Megaphone

Suggested Personal Gear and Equipment

q. Socks
r. Seasonal Clothing, two changes
s. Utility Tool, eg Swiss Army Knife
t. Helmet w/ Mountable Light
u. Leather Gloves (2 Pair)
v. Extra Safety Eye Glasses
w. Compass
x. Foul Weather Gear
y. Sleeping Bag
z. Personal Hygiene Accessories
aa. Insect Repellent
bb. Sun Screen
cc. Mosquito Netting (According to Location)
dd. Wrist Watch
ee. Credit Cards and Telephone Calling Cards
gg. Government Identification Card
ff. Cash
hh. Pack or Duffle Bag

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APPENDIX A

SITE MARKING SYMBOLS

ASSESSMENT & MARKING SYSTEM

TASK FORCE MARKING SYSTEMS

Search Assessment Marking

Search personnel shall use international orange-colored spray paint to mark the exact location of a victim alert. In addition, surveyor's tape may be used as a flag to denote the appropriate area, in conjunction with the spray paint marking.

As with the Structure/Hazards Evaluation, it is important that markings are made specific to each area of entry or separate part of the building. If an area is searched and no victims are found, it must be noted with an X. It is also important that situation updates be noted as they are available, to reduce needless duplication of search efforts. Previous search markings would be crossed out and a new marking would be placed next to it with the most recent information.

Personnel using the marking system will be inundated with additional information relative to the incident. Extemporaneous information needs to be acknowledged and appropriately disseminated - in most cases this information would not be noted on the structure marking.

Generally, the Search Team Manager will be in a position to pass additional information received on to the appropriate element - rescue, command, medical, technical, etc.

NOTE: It is important to clearly identify each separate structure within an area when important information is being disseminated to other operational entities. The primary method of identification should be the existing street name and building number, if known. Obviously, such identification is not always possible due to site conditions. In these situations, it is important that the task force supervisory personnel establish a workable identification method for each specific structure.

ASSESSMENT & MARKING SYSTEM

TASK FORCE MARKING SYSTEMS

Structure/Hazards Evaluation Marking

It should be noted that marking boxes would also be placed in each of the specific areas within the structure (i.e., rooms, hallways, stairwells, etc.) to indicate conditions in separate parts of the building.

Search Assessment Marking

A separate and distinct marking system is necessary to conspicuously denote information relating the victim location determinations in the areas searched. This separate Search Assessment marking system is designed to be used in conjunction with the Structure/Hazards Evaluation marking system. The Canine Search Specialists, Technical Search Specialists, and/or Search Team Manager (or any other task force member performing the search function) will draw an "X" that is 2' X 2' in size with International Orange color spray paint. This X will be constructed in two operations - one slash drawn upon entry into the structure (or room, hallway, etc.) and a second crossing slash drawn upon exit.

/	Single slash drawn upon entry to a structure or area indicates search operations are currently in progress.
X	Crossing slash drawn upon search personnel exit from the structure or area.

ASSESSMENT & MARKING SYSTEM

TASK FORCE MARKING SYSTEMS

Search Assessment Marking

Distinct markings will be made inside the four quadrants of the X to clearly denote the search status and findings at the time of this assessment. The marks will be made with carpenter chalk or lumber crayon. The following illustrations define the Search Assessment marks:

OR-TF1 X

LEFT QUADRANT - FEMA US&R task force identifier

7/15/91
1400 hr
X

TOP QUADRANT - Time and date that the task force personnel left the structure.

X RATS

RIGHT QUADRANT - Personal hazards.

X
2 - LIVE
3 - DEAD

BOTTOM QUADRANT - Number of live and dead victims still inside the structure. ["X" = no victims]

APPENDIX B

STOLS MODEL 91 ELECTRONIC COMPONENTS

1. Features and Specifications

Geophone Transducers

Two MARK PRODUCTS Model L1-B instrument quality geophones

* Natural Frequency: 4.5 Hz
* Damping: 60 % critical damped
* Sensitivity: 2.58 Volts/ips
* Coil resistance: 1480 Ohm
* Cable: 10 foot shielded cable molded to geophone

Microphone

Miniature electric condenser microphone

* Frequency response: 50 Hz to 15 Khz
* Impedance: 800 Ohms
* Sensitivity: -72dB +/- 4 dB
* Cable: 8.8 feet

Signal Conditioning Circuit

A combination of electronic circuits consisting of filters, drivers, amplifiers, and monitor devices that were specifically designed for the STOLS.

* Channels: 2, Phased matched
* Input stage: AD512 precision instrumentation amplifier has differential input, low noise, full input protection and high common mode rejection.
* Gain: 34 to 94 dB (50 - 50,000 X) in 10 precision gain steps.
* Filter: Two pole low pass Butterworth with switchable cut off frequencies set for 175, 350, and 1000 Hz
* Output: The signals from the precision amplifier/filter stage are routed to the:
    1. External monitor BNC's
    2. Front panel VU meters
    3. Internal SONY tape drive
    4. Stereo headset jacks via the audio volume control

Power Supply

System power is supplied by two 12 Volt batteries contained in the internal, Quick Change power pack.

* Battery: Rechargeable sealed lead acid, 12 Volt, 1.9 AH
* Consumption: 110 ma from the 12 Volt battery.
* Output: Regulated output for auxiliary tape power.
* Monitor: LED and Panel meter

Recorder

* SONY Model WM-D6C stereo professional cassette recorder
* Tape Head: 4-track, 2 channel
* Speed Control: Quartz Lock Servo
* Filter: Dolby B & C
* Line: Output and input
* Monitor: LED level meter
* Power: 6 Volts, 4 AA dry cells
* Frequency Response: 30 Hz to 10 KHz

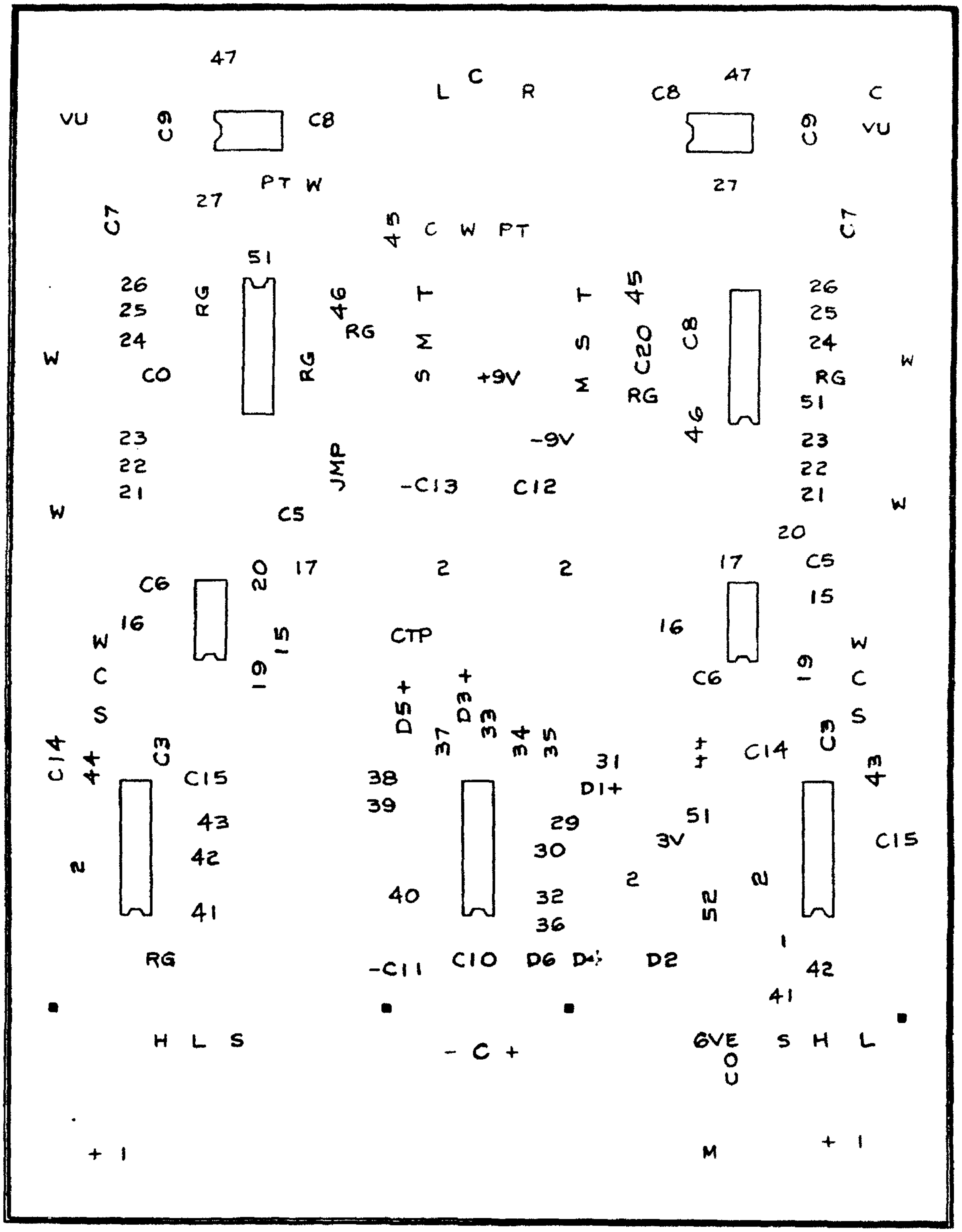
Case

Deep drawn GUARDIAN aluminum suitcase functions as both a transit case and instrument housing.

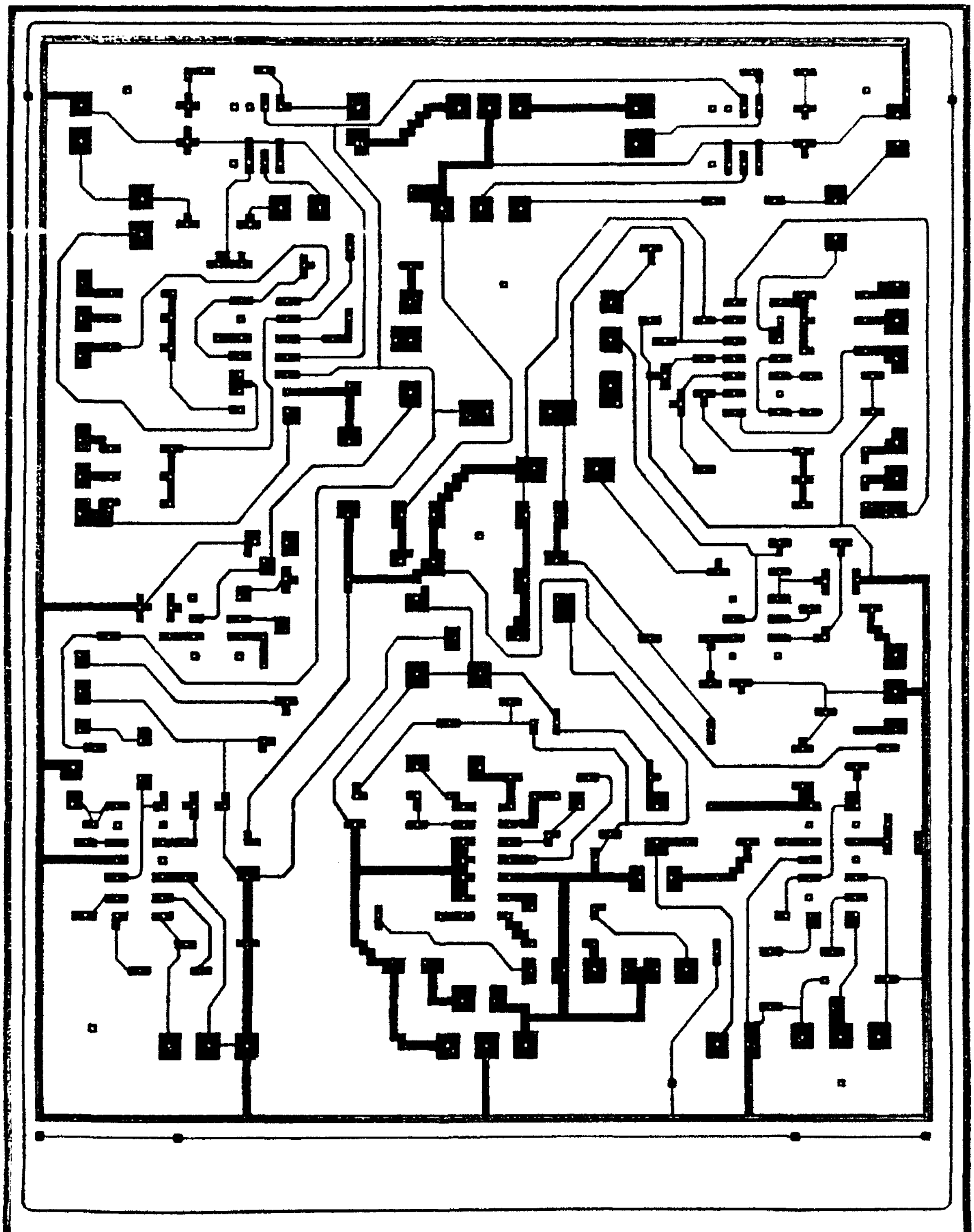
* Size: 18.22" X 13.14" X 6.00"
* Weight: 32 lbs. fully loaded
* Lock: 3 digit Combination

Accessories

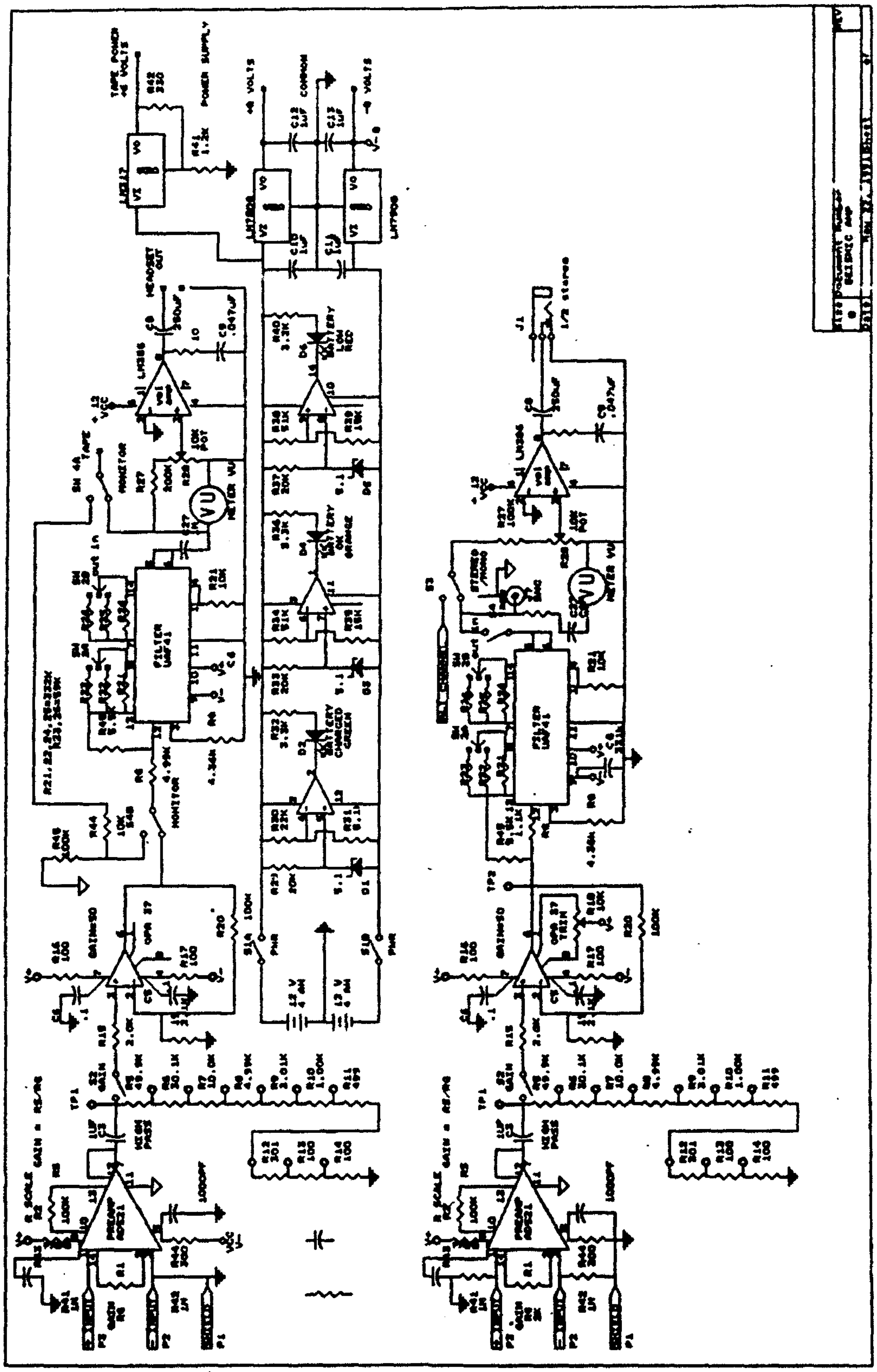
* Two Quick Change power packs
* Two quality stereo headsets
* Two transducer extension cables (20 feet each)
* XENOTRONIX battery charger
* Two each, Brass Weights and Spike geophone couplers
* Two geophone shorting plugs to protect the geophones during transit
* Tape Recorder Adapter



STOLS Amplifier Board Components



STOLS Amplifier Board



STOLS Amplifier Schematic

APPENDIX C

OPERATORS CHECKLIST AND TROUBLE SHOOTING

TROUBLESHOOTING THE STOLS

1.0 Operators can expect few problems from the STOLS as long as the equipment is operated properly and handled carefully. Since unexpected problems can occur, users must be cognizant of basic troubleshooting techniques.

1.1 Equipment problems can be categorized into four basic groups:

A. Operator Problems

Operator problems occur when the STOLS is incorrectly set up or operated improperly. Even the most experienced operators must be ever vigilant for these type of problems.

Operator errors can only be reduced with adequate training and a good understanding of the STOLS capabilities and limitations.

Troubleshooters should first eliminate the possibility of operator errors before they proceed with an investigation of hardware problems.

B. Mechanical Problems

Since mechanical problems are often difficult if not impossible to repair in the field, they must be avoided.

The STOLS must be properly packaged for shipment and handled carefully while in use. The STOLS suitcase was not designed to be shipped or checked as baggage without additional protective packing.

The geophones are the most fragile part of the STOLS. They must be handled with great care; broken geophones can not be repaired in the field.

C. Power Problems

Separate batteries are required to operate the STOLS amplifiers, tape recorder and microphone. A low or bad battery can cause a variety of confusing symptoms. A check of the STOLS battery should be the first operational and troubleshooting step.

The main battery pack contains two 12 volt, 1.9 amp hour rechargeable Gell-Cell batteries. A single battery pack will provide enough energy to power the STOLS for approximately 12 hours of continuous operation. Power problems can be minimized by proper care of the battery:

1. Check the battery before operating the STOLS and before taking the equipment to the field.
2. Recharge the battery after every use and at least every 6 months when the STOLS is in storage.
3. Store batteries fully charged in a cool place.
4. Never discharge the battery pack below 10.5 volts
5. Replace the batteries every 3 years.
6. Keep ample supplies of tape and mic batteries
7. The STOLS can be damaged if it is connected to a faulty battery.

D. Electronic Problems

Electronic problems include bad circuit components and connections.

The STOLS circuits are composed of integrated circuit micro chips and associated discrete electronic components. Troubleshooting these circuits will normally require a electronic technician and special test equipment.

Electronic problems can usually be isolated by injecting a oscillator signal into the amplifier input stage and tracing the signal through the circuits until the faulty stage is identified. The active IC circuits are socket mounted for easy replacement.

2.0 TROUBLESHOOTING TIPS

2.1 Take advantage of the symmetrical design and redundancy of the STOLS to isolate and identify problem areas.

Compare the operation of the identical amplifier channels for indications of a problem.

Switch transducers between channels to isolate problems to the amplifier or transducer

Use the VU panel meters and stereo headset to monitor proper channel operation

Use battery check feature to monitor the battery pack

Exchange battery packs, transducers, headsets etc. as required to isolate problem areas

2.2 A systematic approach is required for efficient troubleshooting:

A. Return controls to the Set-Up condition (FIG.2).
B. Check battery
C. Confirm that the problem is not operator error
D. Start with the lowest (input) stage (microphone or geohone) and proceed to the last (output) stage, (headset)
E. Use the techniques suggested in paragraph 2.1 to isolate and identify the problem area.

2.3 A simple example will help illustrate how to approach a typical STOLS troubleshooting situation.

What to do if a geophone channel is not working:

1. Return the STOLS to the SET-UP (para.3.0) configuration
2. Increase channel GAIN while exciting the input transducer ie.. gently tap on geophone or speak into microphone.
3. Does signal on VU and Headset increase with gain? If no then go to step 3A.
4. Monitor the signal while selecting different filter cut off frequencies. Does the signal respond correctly to a change in the low pass filter setting? If no then go to step 4A.
5. Does the headset volume increase as the Volume control is turned counterclockwise? If no then go to step 5A
6. Does the audio signal sound mechanical or distorted? If yes then go to step 6A.

3A. Select a different transducer and repeat the gain check to determine if the amplifier or transducer is bad.
4A. The filter chip may be bad. Check the response with the transducer connected to the other channel.
5A. The headset driver chip may be bad. Check the response of the other channel.

3.0 INITIAL STOLS SETUP

POWER PACK	Batteries charged and connected
TRANSDUCER	Connected to input
POWER SWITCH	On, Battery OK LED on
GAIN SWITCH L/R	Position 1, minimum gain
FILTER SWITCH	Set to 1000
RECORD/PLAYBACK	Record
MONITOR	Left/Right
HEADSET VOLUME	1/4 Turn clockwise
HEADSET	Fully plugged in
TAPE	Off and Disconnected
MICROPHONE (if used)	Preamp on, battery installed

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13. ABSTRACT *(Maximum 200 words)*

The technical search for survivors in debris after catastrophic events is now a Department of Army mission area. The System to Locate Survivors (STOLS) units was developed and fabricated to help fulfill the equipment need for this new tasking. This instructional report discusses the operation, deployment maintenance of the STOLS units in the urban search for survivors environment.

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