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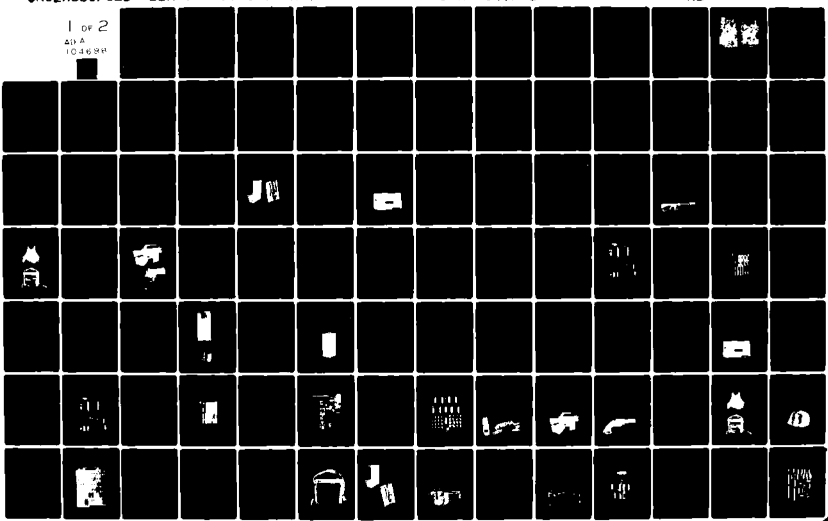

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# THEATER NUCLEAR FORCE SURVIVABILITY, SECURITY AND SAFETY INSTRUMENTATION

## Volume I—Engineering Development Phase—Fiscal Year 1980

The BDM Corporation
P.O. Box 9274
Albuquerque, New Mexico 87119

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the status of the engineering development phase of the TNFS3 Instrumentation Development effort. Evaluation of TNFS3 technologies, hardware, and concepts required field testing in both controlled test environments and simulated tactical environments. Free-play, force-on-force testing, and real-time casualty assessment provide the two-sided, free-flowing operational scenarios necessary to determine successfully the resolution of the majority of the TNFS3 issues.

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## PREFACE

This report was prepared by The BDM Corporation, Technology Applications Center, 1801 Randolph Road S.E., Albuquerque, New Mexico 87106 under the Defense Nuclear Agency contract DNA001-80-C-0083. Captain S. W. Achromowicz is the Contracting Officer's Representative.

This report presents the status of the Engineering Development phase for the TNFS3 Instrumentation Development effort. This instrumentation is needed to satisfy the test analysis and evaluation requirements on force-on-force, free-play testing of the TNFS3 using real-time casualty assessment. The instrumentation design philosophy centered around a system that is to be modular, flexible, and expandable. The instrumentation will be portable, will not require extensive field support, and in some cases will be secure from outside monitoring. Existing, off-the-shelf technology is being used to minimize development risk.

The instrumentation system consists of three basic elements. The master station performs the operations and maintenance, calibration, test control, and data quick-look tasks. The RF communications system allows for two-way communications from the master station via repeaters to the players, and will evolve into an accurate transponder position location subsystem. The player instrumentation contains a microcomputer and will be capable of totally decentralized operations. It will perform the functions of position location, weapon simulation (weapon and target sensors), player cueing, data logging, RF communications with the master station, and the computation of real-time casualty assessments.



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## EXECUTIVE SUMMARY

### 1-1 INTRODUCTION.

The Theater Nuclear Force Survivability, Security, and Safety (TNFS3) Program instrumentation system consists of several subsystems working together in a coordinated way to accomplish the real-time data acquisition and processing task essential to the successful operation of the TNFS3 testing program. For the first time, an instrumentation system exists which utilizes the concept of distributed processing to vastly simplify both the hardware and the software and at the same time meet the stringent operational requirements of small-force close-in engagements.

The system elements which make-up the instrumentation are

1. The player pack and its associated subsystems are lightweight and transparent to the human, providing realistic free-play force-on-force scenarios.
2. The master station which provides the test set-up, command and control, real-time monitoring, quick-look data evaluation, and an operations and maintenance base for the field test.
3. The repeater/transponder network which, if utilized, provides a bidirectional data link between the master station and the individual player packs and allows the player packs to determine their location within the test area.
4. The umpire or test monitor, an adaptation of the basic player, allows for real-time recording of events by expert observers.

#### 1-1.1 The Key Element is the Player Pack.

The player pack is the key element of the distributed instrumentation system. Each player is equipped with a player pack and becomes a completely autonomous element of the test. No command and control element or central data processing facility is required since each player carries all the computational capability necessary for his role in the scenario. The same unit is used to instrument many different types of players; fixed objects such as doors, buildings, emplaced weapons, etc. (key elements in the test) can be players as well as the more traditional humans, vehicles, and aircraft. In addition, the player pack is used to instrument umpires and observers so that their observations are easily incorporated into the total data base. Finally, the player pack can be augmented with additional capabilities for use as a repeater/transponder controller or even as a micromaster station. This commonality of usage allows considerable reductions in cost and logistics.

As shown in Figure 1, the player pack is ruggedized to withstand the abuse of free-play force-on-force activities. The size and weight have been minimized to avoid interference with normal player activity, and the modular design allows special-function printed circuit boards to be added to or deleted from the player pack as required, making the unit extremely flexible.

The player pack is basically a microcomputer which provides all of the needed real-time data processing capability for a single player. Real-time player activity data are acquired through pack interfaces with the weapons effects, position location, and RF communications subsystems. These data are processed in real time by the player pack, producing a record of a player's position, fire events, and real-time casualty assessment. This record is stored in the player pack and then unloaded to the master station at the end of the test sequence. The software for the player pack microcomputer is modular for enhanced flexibility and ease of use; because it contains single-player software, it is very simple.

The weapons effects simulator is provided by a weapon-mounted bore-sighted laser whose beam of light simulates the projectile. Pulse position modulation of the laser beam allows data to be transmitted between the firer and the target. These data are received by detectors on the target player and are both stored in and acted upon by the player pack in real time.


Figure 1. Free play force-on-force activities.

The position location subsystem transfers raw player position data to the player pack where it is processed to derive the player's location relative to the local field coordinate system. The position location subsystem can be either a LORAN-C or transponder system.

RF communications, an optional subsystem, provides two-way radio communications between the player packs and the master station. With this subsystem, the master station can be used for command and control. The command and control feature allows multiple trials to be run without redeploying the players. In addition, it makes a real-time display of player activity possible by simply polling each player periodically for his current status and position. It is possible to use the RF subsystem to rapidly unload the data stored in the player packs, either posttest or during a test. This feature is only usable where data security is not a problem.

Magnetic bubble memories will be used in the player packs as a nonvolatile storage medium for all real-time player-related data. This same bubble memory is also used to store the player pack software, further enhancing the flexibility of the player pack since the software is easily modified. When the transponder position location option is used, a player pack is used as a controller. In this application, data storage is not required. Therefore, to reduce cost an EPROM card replaces the bubble memory module.

## 1-2 THE MASTER STATION.

The primary functions of the master station are to initialize the players with player identification numbers prior to the test sequence, perform as a test controller, accumulate the data logged in all of the player packs at the end of the test, quickly check data for validity, and produce a merged event data tape of the trial for later detailed analysis. The master station, housed in a single 8- by 40-foot van for ease of mobility, will also act as a field maintenance station.

## 1-3 THE REPEATER/TRANSPONDER NETWORK.

Whenever real-time monitoring of player activity or master station command and control is desired, the RF communications subsystem must be used. To guarantee full radio coverage, a series of repeaters is used to propagate the radio signal into areas that would be shadowed if only a single transmitter were used. The repeater element consists of a player pack transceiver, an amplifier, and a player pack as a controller.

When the highly accurate TNFS3 transponder position location subsystem is used, it "piggy backs" on the RF communication subsystem.

For this application, the repeaters also act as transponders and, consequently, must be surveyed into place.

1-4 THE UMPIRE/MONITOR.

The use of umpires is optional, but they can provide on-site human intelligence to accommodate recording of unconventional events. An umpire is equipped with a standard player pack to record data for later entry into the test data base. Instead of a standard weapon simulator, the umpire carries a simple laser designator which is controlled by the same weapons effects simulator used by the players. This designator allows the umpire to make administrative kills or to re-activate a player who was assessed as a casulaty when he shouldn't have been.

1-5 INSTRUMENTATION DEVELOPMENT SUMMARY.

The DNA TNFS3 Instrumentation Development Program has been a highly successful development and acquisition program. It is generally agreed that the measures of merit in system acquisition programs are costs, schedule, and achievement of the specified system performance. The development schedule is shown in Figure 2. It has been well documented that in the past several decades very few system acquisitions have successfully achieved their predicted measures of merit. The reasons for the poor record have been attributed to a variety of factors but numerous studies have shown that developments at the forward edge of technology and those with a high degree of Government involvement are least likely to achieve predicted cost, schedule, and performance. In sharp contrast, the DNA Instrumentation Development Program is an advanced technology program with a degree of Government involvement (major system components are contracted for by the Government and provided as Government-furnished equipment (GFE) for integration into the system) and the program is:

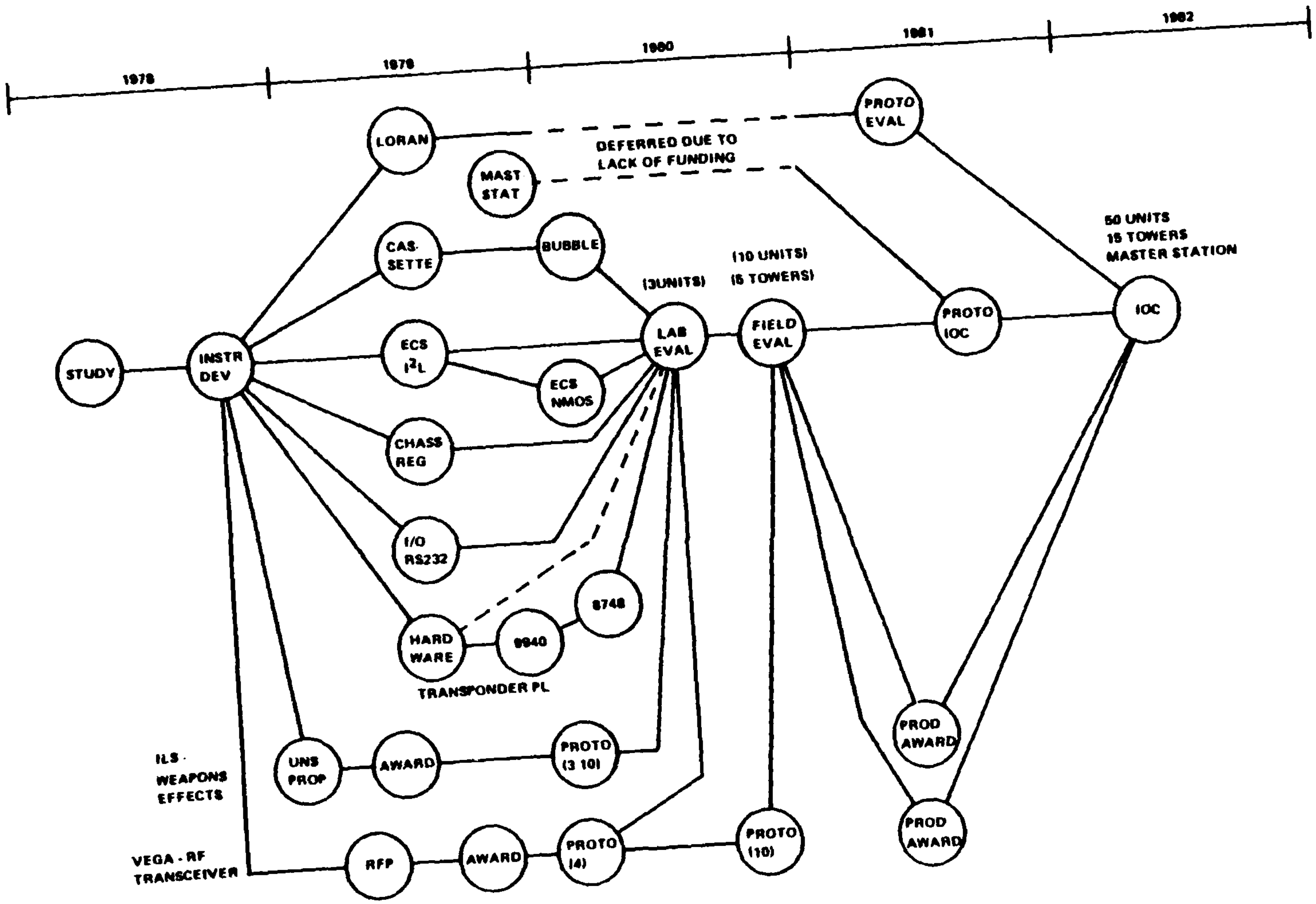


Figure 2. Instrumentation development plan.

| | | | |
|---|---|---|---|
| 1. | On Cost | - | Unit cost of the player unit has been reduced to $19,500 from $27,000 predicted in December 1978. |
| 2. | On Schedule | - | Development has progressed as scheduled with the only delays being programmed by DNA. |
| 3. | Within Specifications | - | There has been no compromising of the systems capabilities. Each subsystem meets or exceeds the initial design specifications. |

## 1-6 SUMMARY.

The use of distributed processing eliminates catastrophic instrumentation failures. Any failures occur on a player-by-player basis, allowing the system to degrade gracefully and controllably.

Single player software is orders of magnitude simpler than multi-player software. Instead of a single copy of the software handling the real-time processing for many players, we have many copies of the software each handling the processing for a single player. This software simplicity allows rapid response to changing test conditions.

The player autonomy inherent in the distributed instrumentation facilitates rapid addition and deletion of players as test conditions are altered. In fact, the number of players in a test is limited only by the number of available player packs.

## SECTION 2

## HISTORICAL OVERVIEW OF THE TNFS3 PROGRAM

### 2-1 INTRODUCTION.

The Theater Nuclear Force Survivability and Security (TNFS2) program was initiated in January, 1977, by the Secretary of Defense as he communicated to the Director of the Defense Nuclear Agency (DNA) his concern about the survivability and security of the Theater Nuclear Forces (TNF). He directed DNA to establish

> "...a broad technological program that will allow decisions to be made on issues surrounding the survivability and security without degradation of the resultant effectiveness of the theater nuclear weapons and their delivery systems..."

DNA was further directed to accomplish this objective by

> "...utilizing, to the maximum degree possible, systematic investigations based on realistic operational test data..."

In 1979, the TNFS2 program was expanded in scope to explicitly include Safety, thus becoming the Theater Nuclear Force Survivability, Security, and Safety Program (TNFS3).

### 2-2 PROGRAM SCOPING PHASE.

The scoping phase, which was performed in 1977, concluded that "...systematic investigations based on realistic operational test data..." required instituting a testing program in which "real-time" performance data were gathered for evaluating both the current survivability and security of the TNF and the effectiveness of any proposed improvements.

Furthermore, the scoping effort identified the need for "...free-play, force-on-force test scenarios using real-time casualty assessment..." as the primary procedure for gathering the data necessary to validate the models used in assessing the S2 posture of the TNF. In addition, these data will be used to evaluate both tactics and training effectiveness. To maintain realism, tests will be conducted at multiple sites in both CONUS and in Europe.

Examination of the issues supplied by USAFE allowed development of a spectrum of test scenarios with the following general characteristics:

1. The number of players is typically 30 to 50 with an occasional requirement of 100.

2. The typical playing area is several hundred meters (300 by 300) with a maximum area of 2 by 2 kilometers.

3. Weapon engagements will occur at very short ranges (3 to 10 meters) as well as at longer ranges.

4. The weapon systems are primarily man-portable.

Finally, the scoping phase concluded that "...some kind of instrumentation is required to gather the necessary real-time data...", and furthermore, it must have the following functional and operational characteristics:

1. Affordability -- The instrumentation development and initial procurement must not be significant in relation to the total overall cost of the TNFS2 program.

2. Cost of Operation -- The set-up time, facilities, and operations personnel costs must be minimized.

3. Maintenance and Logistics -- The instrumentation must be easily maintained and easily transported to remote test sites in CONUS and Europe.

4. Useful Lifetime -- The useful lifetime of the instrumentation must exceed the projected 5-year duration of the TNFS2 program.

5. Flexibility -- The instrumentation must accommodate many different player types (humans, vehicles, aircraft) and adapt to variable player roles.

6. Operability -- The instrumentation must function in adverse weather, hilly forested terrain, and in both day and night tests.

7. Realism -- The instrumentation must provide realistic weapon simulation including Real-Time Casualty Assessment (RTCA) and real-time player attrition, especially for close-in engagements.

## 2-3 INSTRUMENTATION STUDY PHASE.

The Instrumentation Study effort was performed in 1978 and developed the detailed specifications for instrumentation meeting the requirements identified in the scoping phase. Furthermore, this effort was to identify which of the available instrumentation systems would meet the TNFS2 requirements.

### 2-3.1 Detailed Specifications Development.

Development of the detailed specifications requires simultaneous analysis of how the instrumentation is to be used (operational); what data are to be gathered and how they will be used (functional); and the financial impact of the instrumentation, both initial and recurring, on the program (economic).

2-3.1.1 Operational Requirements. The system operational requirements are extracted from the generalized phraseology of the scoping phase document and all of these must be simultaneously assessed for their combined impact on the instrumentation requirements.

2-3.1.1.1 Mobility and Foreign Test Security. The requirement to test at multiple sites implies that the instrumentation must be highly mobile. Many of the identified potential test sites are quite remote. This means that a certain amount of routine maintenance capability must be included in the mobile installation. Testing in Europe introduces additional constraints on security. Any instrumentation signature must be uninformative. In particular, the system must NOT depend for its operation on the telemetry of raw data from which weapon lethality or performance information might be derived.

2.3.1.1.2 Flexibility to Incorporate Identified Scenarios. The instrumentation must be flexible enough to adapt quickly to widely varying scenarios; including rapid changes in the number of players, variations in player types, and a wide range of weapon types including those of foreign manufacture. The last is particularly true of European scenarios.

2-3.1.1.3 Life-Cycle and Long Term Growth Potential. Instrumentation life-cycle is highly dependent on initial loading and growth potential. The history of instrumentation indicates that the load placed on it will increase rapidly as it is used. Consequently, the system must be able to handle all of the identified requirements with ease and have significant reserve capacity to handle new requirements as they surface.

2-3.1.2 Functional Requirements. Functional requirements identify which data are to be gathered and how it must be done. The ultimate use of these data and the operational restrictions placed on the system must be simultaneously accommodated.

2-3.1.2.1 Data Identity and Accuracy Requirements. Data requirements and, therefore, the required data acquisition capabilities of the instrumentation are shown in Table 1. These were determined by examination of the models being validated and by the issues supplied by EUCOM and USAFE. Data accuracy requirements are driven by the specific use of the data.

## TABLE 1. TNFS2 DATA REQUIREMENTS

| Player Position | Data Type Requirement/Accuracy | Instrumentation System |
|---|---|---|
| Deployment Analysis | 15 to 25m | Position Location Candidates |
| Movement Analysis | 5 to 10m | DME - Direct Range Measurement |
| | | Multi-Instrumentation |
| Tactics Analysis | 2 to 5m | TDOA - Time Difference of Arrival |
| Decision Criterion Analysis | 2 to 5m | Radar - Range/Angle |
| Indirect Fire | 2 to 5m | Inertial - Onboard Guidance |
| Real-Time Casualty Assessment | 2 to 5m | Accurate Position Location |
| | | Player-to-Player Direct Ranging |
| | | Sensor Hit Pattern Recognition |
| | | Probability of Kill Calculation |
| | | Player Cueing |
| Line-of-Sight Weapon/Target | Pairings to 2km | Laser Transmitter |
| Pairing | with No Anomalies | Laser Sensors |
| | | Player Cueing |
| Indirect Fire Simulation | | Radio Link to Players |
| and | 3 to 5m | Flash/Bang Simulator |
| Hand Grenade/Explosives | | Accurate Player Position |
| | | Player Cueing |
| Detailed Engagement Information | 1 to 3m | Audio and Video Records |
| Quick-Look Data | 1 to 4 Hours After Exercise | Mobile Computer |
| Test Initiation/Control | Pretest/Test/Posttest | O&M Capability in the Field |
| Data Logging | Up to 10 Hours | Onboard Bulk Storage |
| | | RF Link to O&M Facility |

The wide range in accuracies is a function of the specific issue and scenario, the size of the area involved, the number and types of players, and the weapons employed.

2-3.1.2.2 Real-Time Casualty Assessment Requirements. The requirement for RTCA dictates both that weapon simulators be used and that the instrumentation include an element with the computational capability to perform casualty assessments for all players in real-time.

The small number of players in the TNFS3 scenarios makes accurate RTCA very critical. When many players are involved, large number statistics and random choice are suitable. When only a few players are involved, inappropriate attrition affects a sizeable percentage of the force. This results in highly biased attrition ratios and naccurate conclusions. Small forces also make consideration of wounds very important. In actual combat situations, wounded individuals are very often still functional, although their operational efficiency is reduced.

Again, the small number of players requires that casualties be removed from action in real time. The alternative results in "dead" players continuing to engage, thereby nullifying the usefulness of any attrition ratios in the final analysis.

Detailed analysis of the critical parameters involved in casualty assessment was performed in the Transportation Safeguards Effectiveness Model (TSEM) Program for the Department of Energy in 1978. TSEM concluded that the following parameters were qualitatively most important for accurate casualty assessment:

1. Range
2. Body area affected
3. Firer posture
4. Immediately adjacent vertical shielding

5. Body armor

6. Weapon type

7. Firing mode and round type

8. Firer marksmanship

Data from AMSAA on weapon lethality must be used to produce quantitatively accurate and validated results.

Simulation of direct-fire weapons has been under development by TRADOC for several years. However, the TRADOC system is designed for training and relies heavily on large number statistics for casualty assessment.

2-3.1.2.3 Position Location Requirements. The requirement for position location derives in part from its use in tactics evaluation and movement analysis and in part from the requirement that the tests be "free-play" such that player movements are in no way predetermined. Consequently, the players must be tracked, inobtrusively, by the instrumentation. The wide range in position accuracy requirements indicates that more than one method of position location should be used if an acceptable reduction in accuracy can result in a cost savings. The system must, however, be capable of meeting the most stringent accuracy requirements when necessary.

2-3.1.3 Economic Requirements. Economic requirements both impact and are impacted by all of the operational and functional requirements. This is particularly true of recurring costs which have a tremendous impact on the choice of technologies used.

2-3.1.3.1 Initial Acquisition and Development Costs. The initial acquisition cost must be kept as low as possible so that the bulk of the total program budget can be devoted to using, rather than purchasing, the instrumentation.

2-3.1.3.2 Recurring Operational Costs. Recurring operational costs must be naturally low as a feature of the system design. Recurring costs are predominantly determined by the size of the skilled staff required to operate and maintain the instrumentation system. To this end, the instrumentation must be simple to use and maintain. This implies built-in initialization and modular construction to minimize orchestration and logistics which, in turn, minimize the ratio of operators to players. Finally, the system must be inherently simple in order to further reduce the number of skilled operators required to keep it running or to prepare it for new scenarios.

2-3.2 Instrumentation Selection Process.

After a thorough examination of available hardware, the instrumentation study concluded that, of the several existing fielded instrumentation systems, none was able to meet the combination of critical requirements imposed by the TNFS3 mode of operation.

2-3.2.1 Failure to Meet Operational Requirements. The instrumentation systems in use today were not conceived with the intention of ever meeting the operational constraints of the TNFS3 program. In fact, the state of the art in technology at that time could not begin to address these requirements. It is, therefore, not surprising that these systems are unable to adequately meet the specified operational requirements.

2-3.2.1.1 Inadequate Mobility and Foreign Test Security. All existing systems depend on a large central computer or complex of computers to handle the real-time processing load of many players. For example, the central complex at the U.S. Army Combat Development Experimentation Command (CDEC) consists of 12 mid-sized computers linked to a thirteenth, larger computer for coordination. Such a facility is clearly not mobile in the sense required for TNFS3 applications. Furthermore, failure of even one of these computers is catastrophic to the conduct of a test.

These "centralized" systems all depend on telemetry of raw data from the players to the central computer for real-time processing.

Consequently, they all exhibit a highly informative signature which makes them totally unsuitable for use in Europe or anywhere else where eavesdropping may occur. Additionally, a failure of the telemetry network is catastrophic to the test in progress in the same was as central computer failure.

2-3.2.1.2 Inflexibility and Lack of Growth Potential. Modifications to the complex multi-player real-time software is a lengthy and expensive process entailing a great deal of risk. The additional staff required to make these modifications with the responsiveness required for the TNFS3 testing program would be prohibitive.

Finally, all of the instrumentation systems in current use utilize the technologies of the 1960's and were designed to operate optimally in only a very specific test environment. Consequently, none is flexible enough to adapt quickly and cost effectively to the widely varying requirements and scenarios identified for TNFS3.

2-3.2.2 Functional Capabilities Do Not Meet Requirements. The existing systems were designed to do the best they could in acquiring the real-time data needed for the specific application at hand. These systems are pressed to the limit of the technologies that were available at the time they were designed. Addition of the performance requirements of TNFS3 is beyond their ability.

2-3.2.2.1 Weapon Simulators Do Not Meet RTCA Requirements. Of the available weapon simulation systems, all but one were designed to operate with the help of a central computer and were designed for use with armor. Consequently, they are overly large for routine use by humans. The one system that does not depend on a central computer was developed by Xerox for TRADOC (MILES) and is a fully independent firearms traininq device. Because it was designed specifically for training, MILES makes absolutely no engagement data available for either real-time or posttrial analysis. Furthermore, the RTCA methodology employed by MILES is built into the hardware and cannot be modified to meet the stringent TNFS3 requirements.

All of these systems work well in the environment for which they were designed, but the TNFS3 environment is sufficiently different to make them unusable.

2-3.2.2.2 Position Location Techniques Are Not Suitable. The position location techniques employed by existing systems were designed to operate in conjunction with the central computer and to cover large areas as would be used in armor exercises. They require the accurate survey of many radio towers which are quite expensive. None of them can adequately handle the accuracy requirements in the small areas envisioned in the TNFS3 scenarios on a routine basis.

2-3.2.3 Existing Instrumentation is Costly. The acquisition cost of all existing systems is moderate to high with central facilities costs in the 1 to 2 million dollar range and player telemetry units costing approximately 20 to 30 thousand dollars each. Equipping these systems for mobile operations would add an additional 500 thousand dollars to the purchase price.

The recurring costs of operation are very high for all the instrumentation systems in use today. The central computer requires a resident staff of highly skilled operators to keep it operational. The additional burden of mobility would very likely increase the number of operators required, thus further exacerbating the already high cost of operation.

## 2-4 INSTRUMENTATION DEVELOPMENT PHASE.

The Instrumentation Development Phase was initiated to develop a new generation of instrumentation meeting both the known and anticipated requirements of the TNFS3 program and having wide applicability across the entire range of the OT&E and Joint Test programs of the DOD. This has not been a technology development program, but rather has focussed on implementing the latest proven technologies and design philosophies wherever applicable to best meet the overall program objectives.

To date the program has been singularly successful in meeting all of the objectives identified in the scoping phase: function, logistics, cost, and schedule.

2-4.1 The New Instrumentation Meets All Operational Requirements.

The technology developments of the 1970's have made it possible to meet the TNFS3 operational requirements, not only as they are presently identified but also anticipating future requirements.

2-4.1.1 Mobility and Foreign Test Security. In order to meet the security requirements of a European test, the system must not depend for its operation on telemetry of raw data. This requirement alone establishes the architecture -- distributed processing -- of the entire system. Use of this architecture has been desired for a long time in the test and evaluation community, but has never before been technically feasible.

Each player unit of the TNFS3 instrumentation system performs all of the real-time computations necessary for the individual it instruments. Thus the data processing load is "distributed" to all of the players in the test. All raw data is stored in the player unit for posttest analysis. This architecture eliminates the need for telemetry of raw data and makes the system usable in Europe. Furthermore, the real-time software is greatly simplified since it only processes the data related to a single player.

In order to meet the TNFS3 mobility requirements, the entire system is small, collapsable, and portable. This too is made possible by the distributed architecture; the large central computer complex is no longer needed. In its place is a "central" minicomputer completely housed in an air-liftable semitrailer. This minicomputer provides a "quick-look" posttest data validation capability that can further reduce the costs of testing. Player data can be validated before dispersing the players, thereby saving the cost of reassembling them should the data prove unusable.

The central site can serve in an optional command and control mode which exhibits no usable signature. Data transferred over the RF network can be void of RTCA and weapons effects information, but still provide a real-time display of player activity, should the test director desire it.

2-4.1.2 Flexibility Is Designed In. To meet the flexibility requirements, the entire system is highly modular. This allows easy addition of new modules to add new functions as well as redesign of old modules to incorporate new technologies in accomplishing the same function. This structure vastly reduces the operational logistics and the associated costs of using the instrumentation system and makes transitions from one scenario to the next quite straightforward.

2-4.1.3 Long Life Cycle Is Designed In. Long life cycle is a natural benefit of the modular design of the instrumentation. As requirements and/or weapon systems evolve, new modules, either hardware or software, can be easily incorporated into the system in a natural uncomplicated way. This feature makes the system lifetime virtually unlimited. Additionally, the player pack microcomputer has been designed to have nearly a 100 percent growth capability in terms of loading. This additional capability will allow it to handle the additional requirements anticipated in the future.

2-4.2 All Functional Requirements Are Met or Exceeded.

The distributed architecture of the instrumentation combined with the available technology makes it possible to not only meet all of the identified functional requirements, but in most cases to exceed them.

2-4.2.1 Weapon Simulation and Real-Time Casualty Assessment. In order to meet the stringent RTCA requirements of the TNFS3 scenarios, the weapon simulator has features never before feasible. All of the engagement data necessary for accurate RTCA is made available to the player pack by the weapon simulator. This maintains player autonomy and allows the test director, not the instrumentation designer, to determine the way casualties are assessed. The problem of close-in engagements has been solved by the development of a laser sensitive fiber-optic panel. Using these panels of laser detecting cloth, it is now possible to make any area of a human or vehicle sensitive to the weapon simulator. Helmets, vests, and other odd shapes are now easily instrumented. The system also selectively detects the areas of the body illuminated in an engagement making it possible for the first time to realistically consider wounds as a part of attrition analysis. The simulator is very flexible and can be easily adapted to incorporate new weapon types as required. It currently handles the M16 and the .357 Magnum handgun. It is scheduled to include the M60 machine gun next year. To handle future growth, it is also adaptable to certain kinds of indirect-fire simulators.

2-4.2.2 Position Location Requirements Are Met. To accommodate the wide range in position location accuracies required by the identified scenarios, the system is designed to use any one of several methods. The choice depends on both the accuracy requirements and availability.

LORAN-C can be used if the test is being conducted in an area where it is available and if the inherent accuracy of LORAN-C is adequate for the particular test.

Transponder multilateration is used when exceptionally high accuracies are required or when the test must be conducted in an area where LORAN-C is unavailable. This system employs portable collapsible towers and can be set up quickly anywhere.

The TNFS3 instrumentation is designed to be compatible with GPS/NAVSTAR for future applications whenever that system becomes operational.

2-4.3 Low Cost Is Designed In.

Low cost, both initial and recurring, is a natural feature of the chosen instrumentation architecture. This approach was unavailable to designers in the past and so the costs of owning and operating past systems were very high.

2-4.3.1 Acquisition Costs Reduced Through Commonality. Acquisition costs have been kept low by using a modular design and then using the same instrumentation modules in all of the subsystems. This allows the buyer to take advantage of quantity discounts in the initial procurement and reduces the number of separate items that must be oought and stored as spare parts.

2-4.3.2 Recurring Costs Reduced Through Simplicity. Low recurring costs of operation are a natural feature of the total system architecture. The simplicity of modular hardware and software reduces the size of the staff required and, therefore, reduces the recurring direct labor costs. The simplified logistics results in reduced maintenance costs.

2-5 SUMMARY.

The distributed processing architecture is the key to the success of the development program. It is this approach that allows the myriad of apparently conflicting requirements to be simultaneously satisfied by a single instrumentation system that is not only very flexible and very powerful, but at the same time is inexpensive to own and operate.

# SECTION 3
# SYSTEM FUNCTIONAL ELEMENTS

## 3-1 INTRODUCTION.

The complete instrumentation system consists of a set of modular subsystems working together in a coordinated manner to provide the required real-time data acquisition and weapon simulation function established by the program scoping phase.

This section describes the basic features of the TNFS3 subsystems and how these subsystems interact to fulfill the requirements specified in the scoping phase. The player pack is the primary element of an instrumentation system which also includes a master station, a repeater/transponder network, and a position location subsystem. All subsystems are modular; a variety of combinations may be implemented to meet specific needs. This section describes the potential combinations which are available; Appendix A describes in detail the functional and circuit operation of these various sybsystems.

The player pack subsystems are composed of the following elements whose operational capabilities are also described in this section:

1. Microcomputer
2. Weapons effects subsystem
3. RF communications subsystem
4. Data logging subsystem

## 3-2 PLAYER PACK ARCHITECTURE.

In order to meet the stated requirement for adaptability and flexibility, the player pack was designed to architecturally resemble a standard commercial minicomputer. A computational/control element (the microcomputer) drives a standard common peripheral bus. All of the additional modules appear to the player pack computer as peripheral devices, interfacing through the common bus and observing the standardized bus protocols. The player pack chassis, assembled and disassembled, is shown in Figure 3.

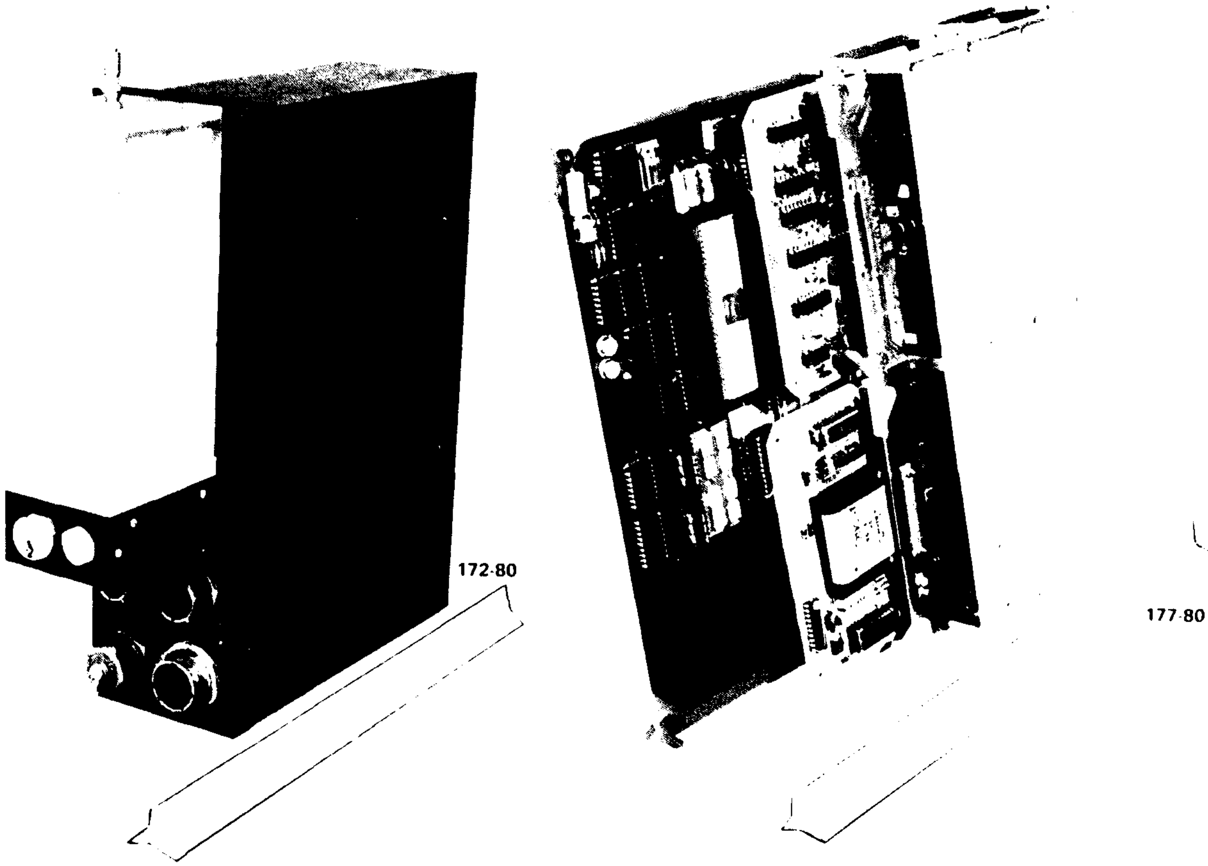


Figure 3. Player Pack Chassis.

The instrumentation subsystems all act as "peripheral" devices, using the common bus and observing the bus protocol. This architecture is shown schematically in Figure 4. The weapons effects, RF communications, position location, and data logging subsystems are general in nature and communicate with the computer via the standard bus. This "peripheral device" role of all the hardware elements assures easy reconfiguration of the player pack as player roles change.

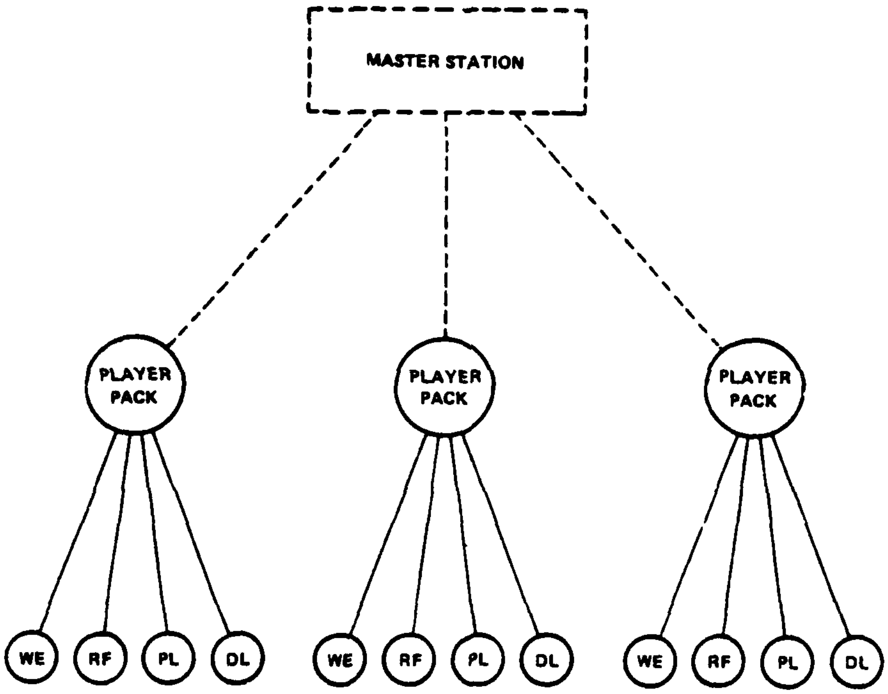


Figure 4. Instrumentation Subsystems

Each of the printed circuit board modules forms a unique functional element within the player pack. These elements are independent in their operation from any other element. Any module, from any source, for any purpose, which observes the bus protocol can be incorporated into the player pack as a peripheral device.

The player pack software also reflects the flexibility requirements of the program and is implemented in a manner which complements the modularity of the player pack hardware. This software consists of an operating system kernel which controls allocation of computer resources

(CPU time, memory, access to peripheral devices, etc.) in a consistent manner based on the operational real-time importance of the currently active processes. Peripheral device drivers are software modules that "plug in" to the operating system kernel in the same way that the peripheral hardware plugs into the player pack. To further increase flexibility and ease of use, the player-related computational processes are also plug in software modules called "tasks." The division into tasks vastly reduces the effort involved in producing unique player software.

## 3-3 PLAYER PACK FUNCTIONAL ELEMENTS.

### 3-3.1 Player Pack Microcomputer.

The player pack microcomputer is the key element of the instrumentation system (Figure 5). It provides the player with the computing power necessary for the distributed architecture of the system. Its

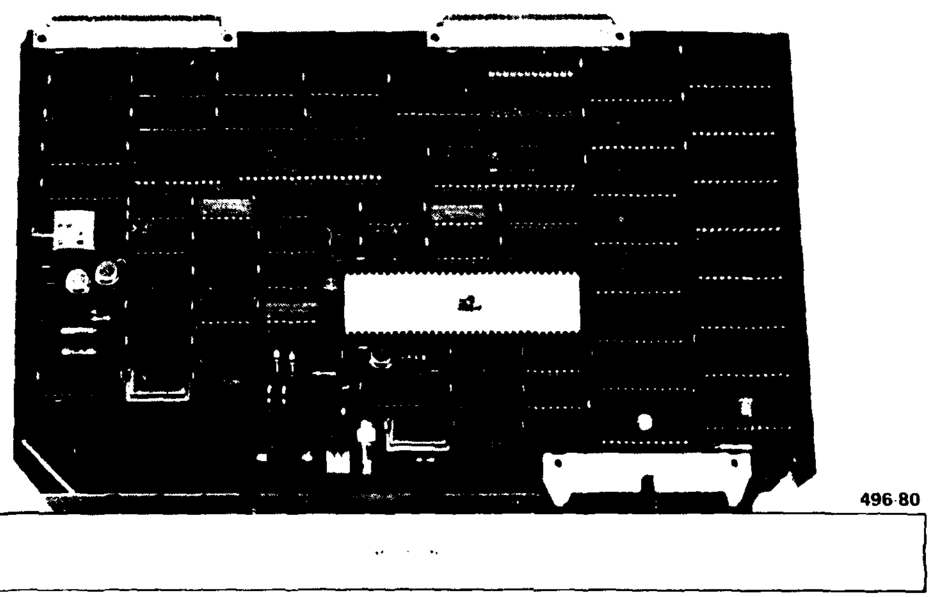


Figure 5. TNFS3 Microcomputer

function is to process, in real time, all of the player activity data supplied by the peripheral modules and subsystems. It is the replacement for the central computer of the older centralized instrumentation systems, performing RTCA and position location calculations for a single player. The microcomputer has been designed to assure that it can meet all of the current requirements of TNFS3, and, wherever an option exists, features have been implemented in the way that reduces the initial loading on the system and provides the greatest growth potential.

To assure meeting the requirements of flexibility and future growth stated in Section 2-3.1, the microcomputer has been designed as a general purpose, high speed, very powerful computing element. As with any computer, the software provides the final operational function, whereas the microcomputer itself provides the capabilities necessary to implement the programmed functions.

3-3.1.1 The Central Processing Unit. A 16-bit microprocessor manufactured by Texas Instruments was selected for the central processing unit (CPU) in order to meet both the computing capability requirement and the instrumentation development cost requirement. The following were key decision factors in that choice:

1. The microprocessor is fully supported by a development system which includes emulators and peripheral devices.
2. The instruction set and interrupt structure is optimized to support real-time processing.
3. An efficient software development system allows software to be flexible and adaptable.
4. The microprocessor power requirements are reasonably low; it operates at 4 MHz.

3-3.1.2 Memory. The microcomputer memory is designed to be flexible and expandable for future growth. Initial loading on the system is reduced by selecting random access memory (RAM) components which operate at high speed, with low power consumption. These memory devices execute software which is loaded from the EPROM board or provide temporary data storage during field tests.

3-3.1.3 Interrupts. High speed prioritized response to player activity is obtained by the use of "interrupts" for data acquisition. Each peripheral device in the player pack issues a signal to the CPU when it has data ready for it. These signals are prioritized so that the data of most importance to the test has the highest priority signal. When any of these signals is activated, the CPU stops whatever it is doing and attends to the peripheral device (the CPU gets interrupted). The CPU always services the interrupt of highest priority first.

3-3.1.4 System Clock. In order to maintain timing synchronization between the independent players, each is equipped with a real-time clock. The clock, initialized when the player receives his ID code, maintains an accuracy of better than 1 second per day. The resolution of the clock is 10 milliseconds, and all player activity data is time tagged to the nearest 10-millisecond interval as it is acquired.

3-3.1.5 Direct Memory Access. Direct memory access (DMA) is provided to implement high speed data transfers. This technique allows data to be transferred at rates up to 1,000,000 bytes per second with no CPU intervention. Removing the high speed transfer load from the CPU allows it more available time for computational tasks, thereby increasing its growth potential. The devices presently slated to use DMA are the weapons effects subsystem, the RF communication subsystem, and the data logger.

3-3.1.6 Floating-Point Hardware. To guarantee adequate computational capability and responsiveness to computationally driven processes such as

RTCA, the microcomputer is equipped with floating-point hardware. Mathematical operations such as trigonometric functions, exponential functions, logarithms, and others are provided by this on-board peripheral device. Since it operates as a peripheral, it performs these functions in parallel with the CPU. This increases the total throughput of the system by allowing both the normal CPU processes and mathematically intensive processes to proceeed simultaneously.

3-3.1.7 Terminal Interface. To provide a convenient means of unloading data at the end of each test, an industry standard RS-232-C interface is included on the microcomputer board as an on-board peripheral device. Because this is a general purpose standard interface, it can be used for a variety of purposes as the need arises. It provides the interface to the key entry display unit (KENDU) when the player pack is used to instrument an umpire and can be used for communication with a wide selection of other standard terminal devices such as teletypes, line printers, etc. as required.

3-3.1.8 Summary. The microcomputer board has been designed to have the equivalent computational capability of a small minicomputer. It is a flexible, expandable, adaptable, low power, general purpose computer with a great deal of growth potential. The architecture is optimized for the stringent TNFS3 processing environment. The technology developments of the late 1970's have made this development possible at very low cost. The entire microcomputer costs only $1,600, a small fraction of the cost of an equivalent minicomputer. Design details on the microcomputer can be found in Appendix A, Section A-1.

3-3.2 Weapons Effects Subsystem.

The need for a weapons effects subsystem for TNFS3 stems from the real-time casualty assessment (RTCA) requirement established in the scoping phase of the program (Section 2-4.2.1). This subsystem provides all the necessary hardware for simulating many different types of direct fire weapons. The weapons effects subsystem performance requirements imposed on the TNFS3 instrumentation are more stringent than any previous requirements, and several key developments have been necessary to meet these requirements. Most notable of these is the development of the laser-sensitive fiber-optic panel which solved the close-in engagement problem.

The weapons effects subsystem basically does three things: (1) it activates the weapon simulator when the player pulls the trigger; (2) it provides for detection of the simulator signal at the target player; (3) it makes the engagement data available to the player pack microcomputer for casualty assessment processing. All of these are done in a manner that provides a sense of realism to the players and minimizes negative training effects.

Because each player pack operates autonomously, all the information relevant to RTCA must be made available to the target's player pack. Since there is no central computer to supply this data, everthing must be done by the weapons effects subsystem. The necessary information is also described in Appendix A and includes:

1. Attacker ID
2. Weapon type
3. Attacker posture (upright/prone)
4. Firing mode (auto/single shot)
5. Attacker position coordinates (for slant range)
6. Attacker marksmanship

3-3.2.1 Weapon Firing Simulation. To simulate firing events, an eye-safe laser is mounted on each weapon. The laser beam is used to simulate the projectile. Using lasers is particularly effective since the divergence of the beam can be adjusted to closely emulate the ballistic spread pattern of different types of weapons. To provide the necessary realism, the laser is activated by the muzzle flash produced by firing a blank round (M-16 configuration is shown in Figure 6). This technique requires that the player not only carry blank ammunition but also reload the weapon as would normally be required in combat.

The laser beam itself is used to transmit the attacker-related data needed for real time casualty assessment (RTCA) in the target's player pack. Pulse-position modulation is used to impress 72 bits of data on the beam. Therefore, when a pairing is detected, the data needed are automatically present.

3-3.2.2 Weapon Simulator Detection. To detect the laser beam from the weapon simulator, the target player must be instrumented with detection devices which are sensitive to the laser beam. These detectors, located on cloth panels incorporated into a harness worn by the player, cover four critical parts of the body: 1) head, 2) front upper torso, 3) front lower torso, and 4) rear torso. When the laser beam from a weapon simulator illuminates a target player, these sensors detect the presence of the beam, and the weapons effects electronics (see Appendix A, Section

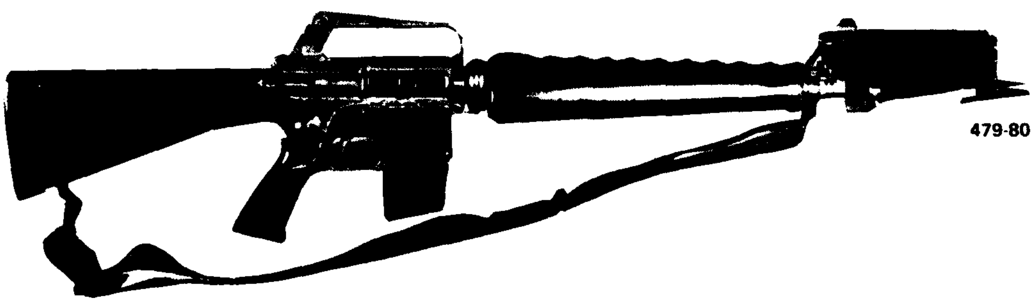


Figure 6. M-16 Configuration.

A-5) decodes the information content of the modulated beam. Since RTCA for TNFS3 must be highly accurate and must include wounds, the electronics also records exactly which of the detectors on the body were illuminated and the target player's posture.

3-3.2.3 Transfer of Engagement Data to the Player Pack. When an incoming laser message has been properly decoded, the information is transferred to the target's player pack for casualty assessment processing. This is accomplished through a high priority data channel in the player pack. Segmenting the acquisition of the engagement data and the RTCA process in this way makes the weapons effects subsystem quite versatile and adaptable to many weapon types. No changes to the subsystem are required, simply a change in the RTCA algorithm in the microcomputer.

3-3.2.4 Combat Realism. Simulations must occur with the highest degree of realism possible. To enhance the realism of the TNFS3 weapons effects subsystem, several key developments have been accomplished.

1. Trigger-pull is detected by the muzzle flash from the weapon. This requires the player to carry all the ammunition he intends to use and to reload in a normal fashion. It also means that players who run out of ammunition can no longer impact the scenario, as would be the case in a real force-on-force engagement.
2. There is no direct connection (wire) between the player and the weapon. This allows the player to use any weapon available during a scenario.
3. If the player is determined to be a casualty, the player pack microcomputer disables its simulator. This assures that the player can no longer inflict casualties and removes him from action.

3-3.2.5 No Negative Training. The psychological effect of cumbersome instrumentation and the time required for the player to adjust to idiosyncrasies of the equipment is referred to as negative training. The weapons effects subsystem has been designed to minimize this effect. The weapons used are real, not toys or replicas. Therefore, they retain the feel and balance of the actual weapon. Furthermore, the player is never required to perform any activity solely related to operation of the simulator. He only does those things he would do in an actual combat situation.

3-3.2.6 Sensor Development. Although every portion of the weapons effects subsystem has been designed to enhance realism, minimize negative training, and provide "human" engineering aspects to the system, the single most important development has been the area sensor. Previously used sensors presented simulation deficiencies which are now overcome by the use of the area sensor. In the past, the laser detectors used were discrete photosensitive elements placed in strategic locations on the body. As long as the separation between the attacker and the target was great enough, the natural laser beam expansion would guarantee that at least one of these discrete detectors would be illuminated. However, if the engagement were "close-in," it was highly likely that the small laser beam would entirely miss all the sensors, illuminating a small spot in between the sensors. Thus, it was likely that a player shot at point-blank range would "survive." The cost in both dollars and weight of using a dense pattern of sensors to eliminate the "blind spots" is prohibitive. To solve this problem the area sensor was developed.

The area sensor is fabricated on cloth panels using fiber optics for light coupling; these are lightweight, rugged, inexpensive, and flexible enough to conform to odd shapes. The panels can be used to form a "jump suit" for humans, making the entire suit a detector. The helmet is wrapped with an area sensor to instrument the head. These panels are ideal for coverage of large areas such as vulnerable parts of vehicles.

The area sensor does not have quite the sensitivity of the discrete sensors. It is effective to a range of about 300 meters; therefore, for completeness a few discretes are retained. Figure 7 shows the location of these sensors on the player's vest. Using both types of

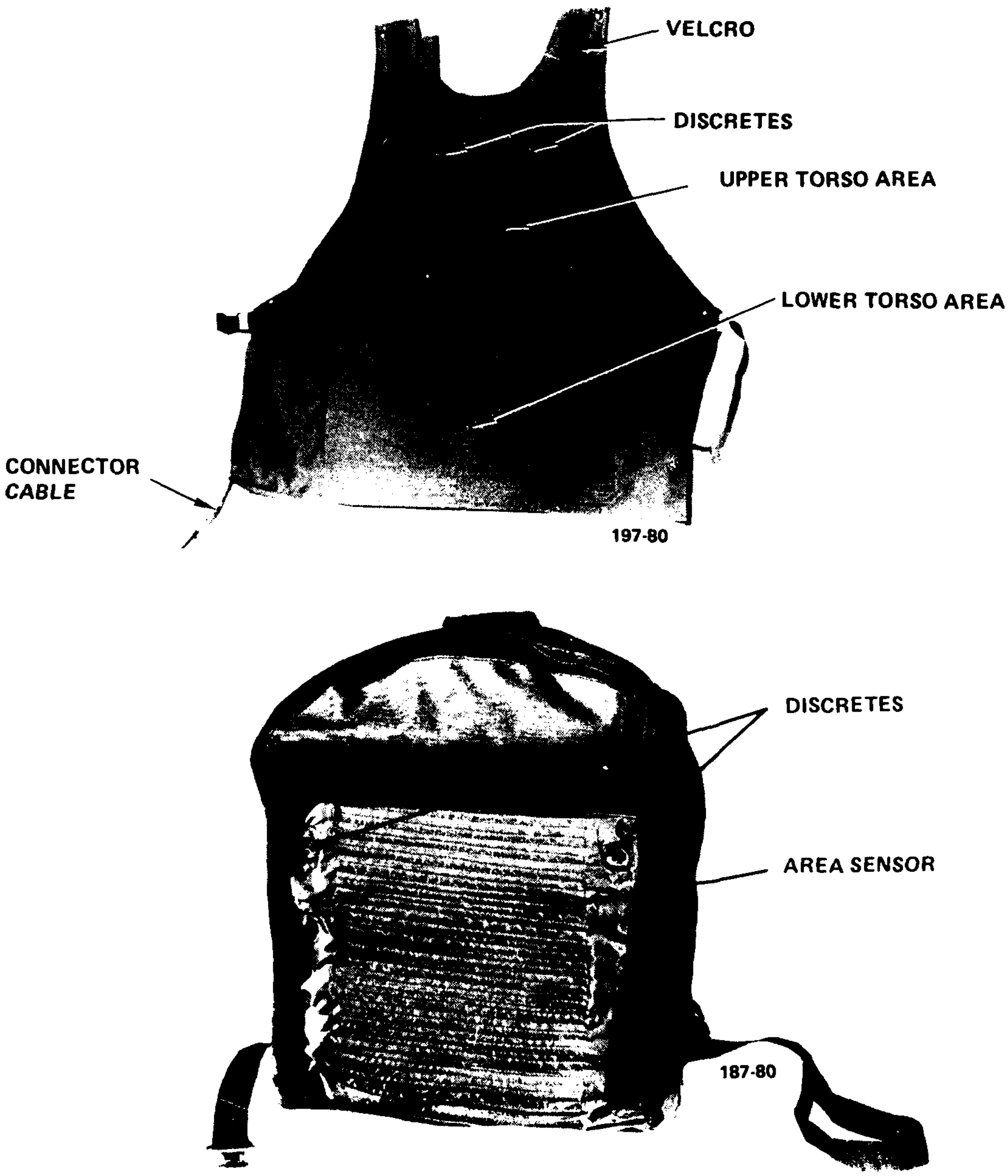


Figure 7. Weapons effects sensors.

sensors, the weapon effects subsystem promises to be the most accurate, realistic, and flexible weapon simulation scheme developed to date.

3-3.2.7 Weapon Simulator Development. To date, two weapon simulators have been developed for the weapons effects subsystem. These are for the M-16 and .357 Magnum handgun. (see Figure 8). The laser beam spread is designed to simulate the ballistic spread of each type of weapon instrumented and therefore is flexible enough to adapt in the future to simulation of additional weapons such as the M-60 machine gun and the .45 caliber handgun.

3-3.3 Position Location Subsystem.

The TNFS3 program requires instrumentation that can accurately track the position of moving players during the test scenarios. The scoping phase detailed the importance of accurate RTCA which in turn depends on accurate slant-range determination. Other studies (see Section 2-3.1.2) have detailed the direct relationship between slant range and weapon lethality. The most straightforward means of determining the slant range is to compute it from accurate player position information.

Engagement model verification in troop deployment or perimeter defense can be obtained only by having a continuous record of player location during the test. Because the accuracies required for model validation vary a great deal, depending on both the model and the particular scenario, the TNFS3 instrumentation has been designed to implement at least three techniques for this function. This approach does not tie the instrumentation to a single mode of operation but instead allows it to adapt to external constraints as required.

One of the possible techniques that can be used in the future is GPS/NAVSTAR, a satellite-based navigation system which is still under development and slated to be operational in 1984. The other two systems are fully operational and available now. These are LORAN-C, a ship navigation aid, and a transponder-based system developed especially to meet the TNFS3 high accuracy requirements.

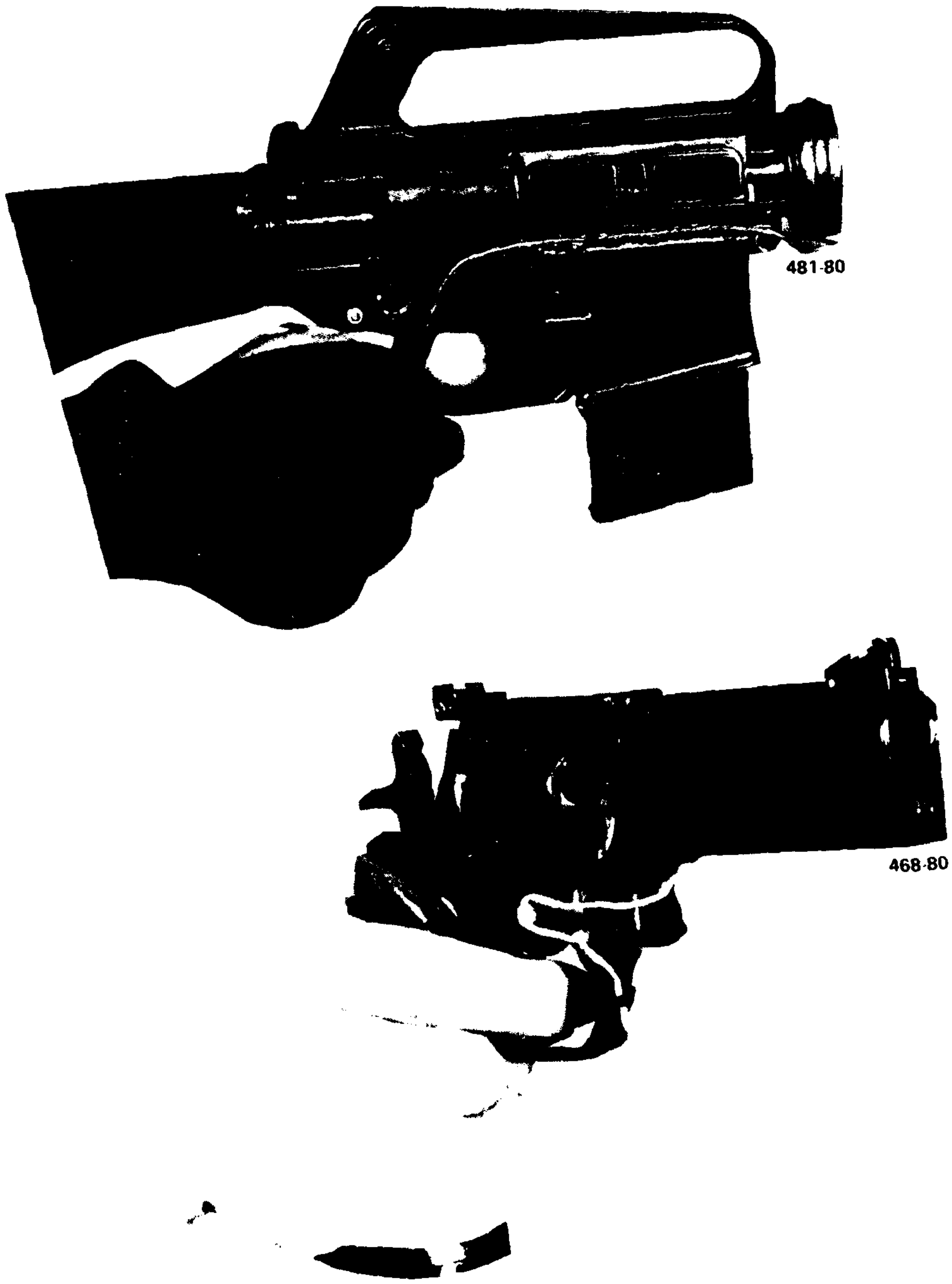


Figure 8. TNFS3 weapons.

3-3.3.1 LORAN-C Characteristics. The constraints that are placed on position location accuracy limit the potential methods of calculating position location. One low-cost method presently available in most parts of the world, shown in Figure 9, is the LORAN-C navigation system. In the United States LORAN is maintained and operated by the Coast Guard at the frequencies specified in Figure 9. The system is a pulsed, low-frequency (LF), hyperbolic radio-navigation system that derives its accuracy from time difference measurements of the pulsed RF signals and the inherent stability of LF propagation. Wide coverage areas are made possible by the low propagation losses of LF groundwaves and the resultant long baseline lengths (transmitter station-to-station separation). Hyperbolic navigation systems operate on the principle that the difference in time of arrival of signals from two or more transmitter stations, observed at a point in the coverage area, is a measure of the distance from the point of observation to each of the transmitter stations.

Ranges of 800 to 1200 nautical miles (NM) are typical, depending on transmitter power, receiver sensitivity, and losses over the signal path. Variations in propagation, transmission power losses, and velocity introduce errors resulting in position errors. These errors, and those introduced by the receiver, will normally yield a position location accuracy of ±200 feet (60 meters) at 500 NM and decrease to ±500 feet (150 meters) at distances of 1000 NM from the transmitters.

Results from the LORAN-C RECEIVER TESTING AND EVALUATION FOR POSITION LOCATION (report No. BDM/M-005-80) revealed that position location errors were reduced significantly when the receivers were used in the "repeatable" mode. Repeatable mode simply means that the receiver was calibrated with known time differences of arrival and that variations due to temperature, humidity, etc. cancelled out. This method, using raw LORAN-C data, resulted in position location variations of less than ±50 meters. Subjecting the raw LORAN-C data to filtering and smoothing programs reduced position location variations to ±20 meters. Other, more elaborate methods, such as strategically placing several (four or five)

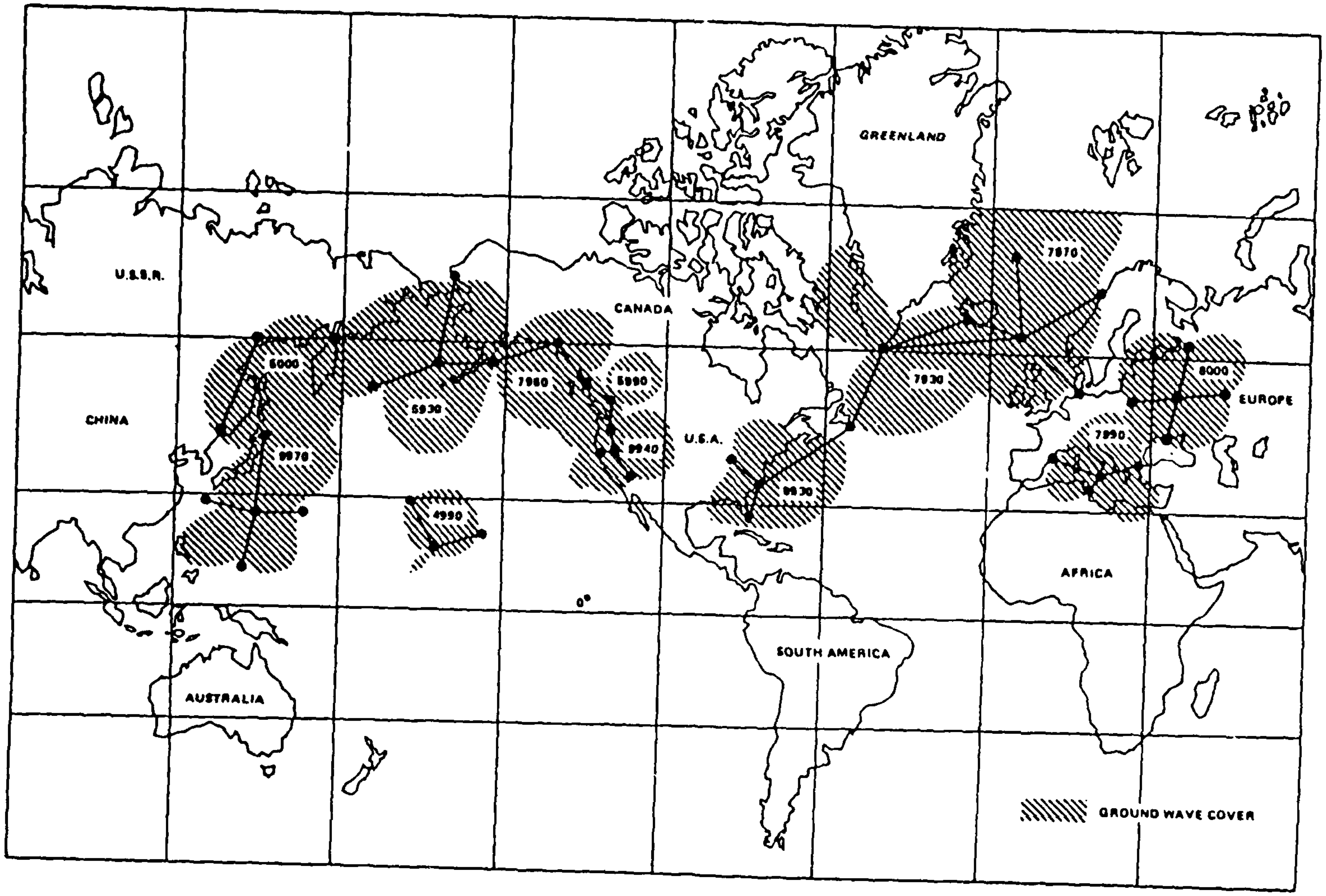


Figure 9. Worldwide LORAN-C coverage.

surveying-type LORAN receivers in the testing area and feeding back dynamic grid variations to player receivers, could potentially further reduce position location errors.

A LORAN-C system may be easily incorporated into the TNFS3 instrumentation. A lightweight low-cost LORAN receiver is "piggy-backed" on the player pack and an interface module properly routes the receiver data to the microcomputer. Software in the player pack can easily perform the necessary grid conversions and smoothing of the raw LORAN data.

The limitations of the LORAN-C system must be considered in light of the scoping requirements mentioned earlier. LORAN-C can only be used where the LORAN chain is established and operational. This includes the costal areas of the United States and limited areas elsewhere in the world as shown in Figure 9. LORAN is only moderately accurate (+20 meters). This is suitable for many types of convoy or large-scale dispersal tests but is not acceptable in the small close-in engagement scenarios identified in the scoping phase of the TNFS3 program.

3-3.3.2 Transponder-Based Position Location. To solve several of the problems which are inherent in LORAN-C systems, a transponder position location (TPL) subsystem was developed by BDM. The TPL system is easily transportable to anywhere in the world, requires only a short setup time, and provides the high accuracy position location capability required by many of the TNFS3 issues.

The TPL system operates much like TACAN aircraft navigation system. Using a low power radio transceiver, each player pack can measure the round-trip signal flight time to each element of a grid of preset transponder towers. The signal flight time is proportional to the distance between the player pack and the tower. Combining these separate range measurements in a multilateration calculation yields the player position relative to the transponder network.

The TPL system uses the same radio units as the RF communication system. A single module is added to the player pack to provide the additional range measuring capability. Since measuring the flight time of a radio signal is equivalent to electronically measuring the velocity of light, very high speed circuitry is used.

Test results to data indicated that the position location error will be less than ± 3 meters with this system.

3-3.3.2.1 Direct Ranging. An additional feature of the TPL system not available with any of the other options is direct ranging. This feature is available with no additional hardware and allows the direct measurement of the slant-range between two players. This capability is very important for engagements occurring inside metal enclosures, such as aircraft hangars, which block the external radio signals. Preliminary test results indicate an accuracy of ±3 meters can be expected.

3-3.4 The RF Communications Subsystem.

The RF communications subsystem is an optional feature of the TNFS3 instrumentation system. In areas where absolute secutrity is not a requirement, it can be used to enhance the operational features of the system. Its basic function is to provide a bidirectional data link between the players and the master station. This subsystem is a very flexible, software-controlled use of the repeater/transponder network hardware. In its basic configuration, shown in Figure 10, it provides a

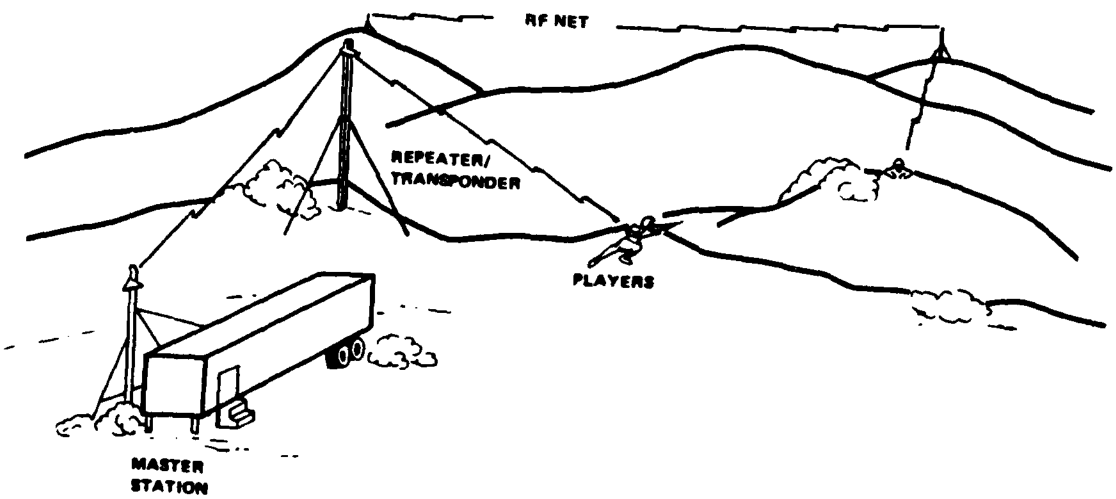


Figure 10. RF communications network.

medium by which the test director can control and monitor the progress of the test scenario. The more exotic possiblilities include real-time player software changes and raw data streaming. It can be used during player initialization to reduce the level of orchestration required to begin a test.

Even where security is an issue, the RF communications subsystem can be used to acquire player status and position for display purposes since no lethality or activity data is actually transmitted.

3-3.4.1 Communication Protocol. All communications are initiated by the master station. The master station sends a message which commands a specific player or a group of players to perform some specified activity. Each player in the test is assigned a unique player ID number. Whenever the master station needs to communicate with a single player, it does so by addressing the message to the player ID. In addition, there is a universal ID to which all player packs respond. The universal ID is used for global messages such as: start test, stop test, initialize time of day, etc. If the master station needs data from a particular player pack, it sends a command to that player requesting the data. The sequence of events is:

1. Master station requests status from player X.
2. Player X identifies that this message is addressed to him.
3. Player X transmits his status.
4. Master station receives player X's message.
5. Master station transmits to player X either a "data received" or a "data no good--retransmit" message.

This "handshaking" protocol accomplishes two major procedural objectives: First, the master station is in complete control of all radio traffic. The player packs simply respond to commands, they do not initiate any communications. This assures that the communication channel does not get garbled by asynchronous transmissions. Secondly, the handshake assures that data are properly received at the master station. This eliminates the problem of unknown radio failures or storage of meaningless data in the test data base. The problem is solved at its source rather than after the test is over, when it is too late to do anything about it.

3-3.4.2 Control Messages. Universal control messages are used to simultaneously coordinate the activities of all the players in the test. These messages are addressed to the universal "all players" ID and require no radio response from the player pack. Examples of control messages are:

1. Start test
2. Stop test
3. Change time (synchronize all player packs)
4. Indirect fire (future expansion option)

3-3.4.3 Command Messages. Command messages can be addressed to all players, a selected group of players, or an individual player. Commands generally result in a response by the affected player. There are many possible commands but three are of particular importance:

If the transponder position location option is used, there is a group command to begin a transponder cycle. This message causes the repeater/transponder network to switch to the transponder mode of operation, as described in Section 3-3.3, and the addressed group of player packs begins acquiring position data.

The second command is addressed to a single player and requests a status update. The player pack responds by transmitting his current position, number of rounds fired, whether he is still alive, and other generic information useful for real-time display purposes. Included in the status message is information about the operational state of the player pack hardware. This facilitates early identification of possible instrumentation failures and aids in the maintenance operation.

The third important command is similar to the status message request but is used only during very long tests where security is not a problem. This command requests the player to transmit his raw engagement data to the master station. This can be used to unload players during regrouping to save time or, during long tests, to free space on the player pack's internal data logger.

3-3.5 Data Logging Subsystem.

Security requirements when testing in Europe mandate that no telemetry of raw test data should take place. To satisfy this requiremnt a data logging subsystem is included in the player pack to retain the test data. Shown in Figure 11, it is implemented using the latest state-of-the-art memory device -- a magnetic bubble memory. The bubble memory device is nonvolatile so its contents are retained even if power is removed. During a test the microcomputer transfers all of the player activity data to the data logger where there are kept until the test is over. After the test the data are transferred to the master station for validation and quick-look analysis.

In addition to test data, the status of the player pack is continously stored in the data logger so that if a power failure occurs, the state of the player pack can be analyzed. Also, if the player pack is power cycled during deployment, to conserve battery life, it remembers its previous state when it is repowered.

The data logging subsystem also stores the player pack operating software. Using the bubble memory device for mass storage facilitates changes and updates to the player pack software. Whenever software changes are needed, a new version of the software is downloaded to the player pack from the developement system through any of the available interfaces or by simply replacing the data logger module in exactly the same way as replacing a disk cartridge on a minicomputer.

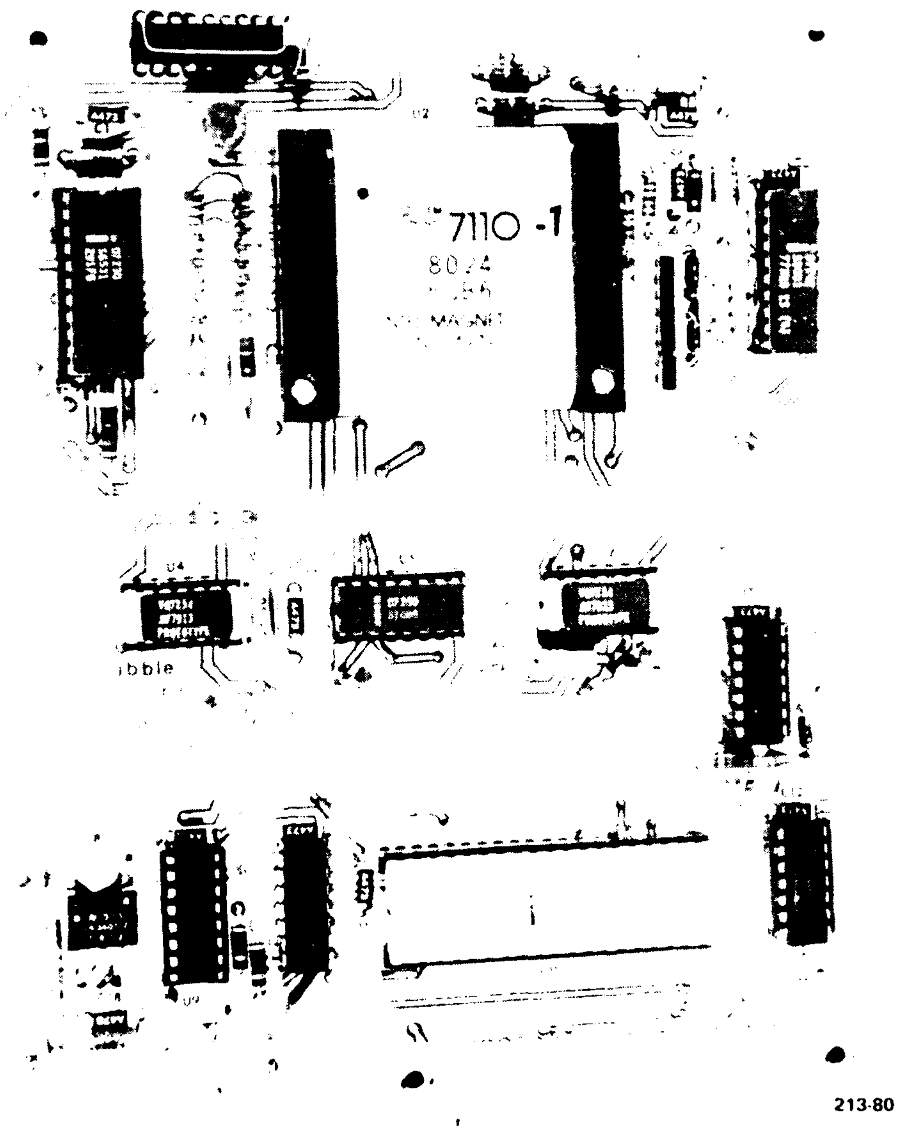


Figure 11. Bubble memory board.

The magnetic bubble memory has storage capacity of 1,000,000 bits of data, enough for a normal 10-hour test.

3-3.6 Software Storage Subsystem.

The repeater/transponder controllers are implemented using a player pack microcomputer. In this application there is no data storage requirement but there is a software storage requirement. To reduce costs, a "plug in" compatible software storage module was developed using relatively inexpensive EPROMs to replace the magnetic bubble memory. This module, shown in Figure 12, is power cycled when not in use to conserve batteries.

3-4 MASTER STATION.

A primary objective of the TNFS3 Instrumentation Program is to provide complete, autonomus operation anywhere in the world. This requirement suggests the need for a mobile, self-contained support facility capable of monitoring or controlling any test scenario.

The master station has three secondary/optional uses: it facilitates on-site O&M operations, it may be used for command and control of RF communications, and it may be used to produce a real-time display of player activity.

The master station will be housed in an air transportable semi-trailer outfitted with ride suspension and self-contained heating, cooling, and humidifying systems. Its interior will be split into two sections, isolating the maintenance area from the computer. Power will be supplied from either a commercial power grid or a portable generator.

The computer area is being designed around a Texas Instruments minicomputer capable of handling communications protocol, able to store data unloaded from the player packs, and capable of performing the necessary data validation and quick-look functions. As shown in Figure 13, the master station controller consists of two processors, one acting as a

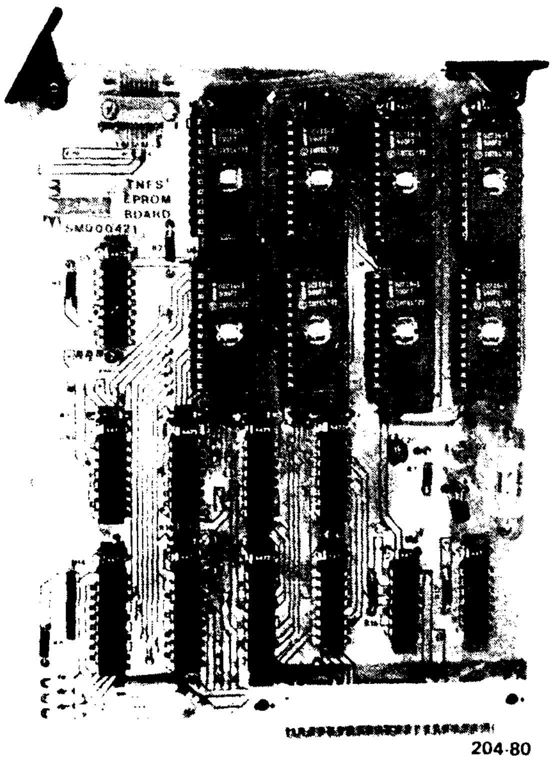


Figure 12. EPROM board.

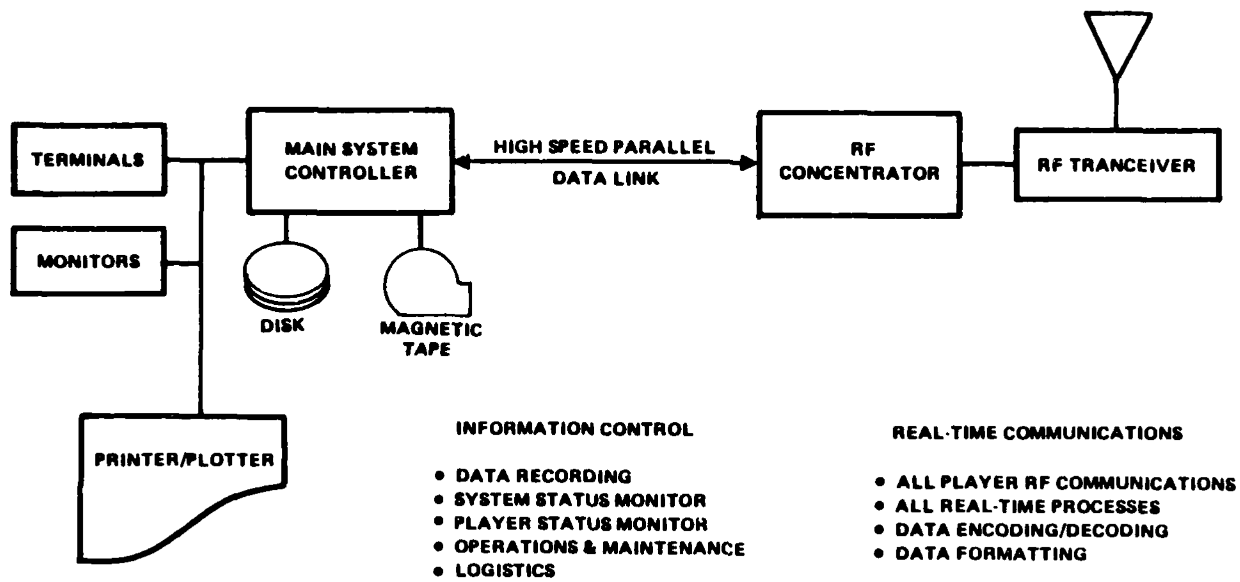


Figure 13. Master station controller.

concentrator for the RF communication system. It will handle all RF system related processing and provide data in the burst mode to the main controller for recording and display. The hardware for the controller and concentrator will be identical, thus significantly reducing the spare parts logistics.

The software for the main master station controller will run under TI's commercial operating system (DX10). This will significantly simplify the software generation task and reduce the time and risk. All software for the concentrator remains to be developed, and is scheduled for FY81.

The data validation feature will be activated immediately after the test, allowing the test director to quickly make decisions regarding the outcome -- was the trail valid or should it be re-run. The ability to validate the test data prior to player recall can save the expense of redeploying all the players. It can also increase the number of trails per day since the director can immediately move to the next issue if valid data have been collected. This will decrease the total testing time and the associated cost.

The maintenance area of the master station will have work benches, test equipment, spare parts, and a computer terminal to assist the small staff in repairing damaged player packs. The planned layout of the master station is shown in Figure 14.

To complete the mobile test facility, one or two additional trailers will be required. They will be used to store and ship player equipment and will be organized so that a minimum of setup time is required to prepare the players.

To accomodate very small tests (5 to 10 players maximum) and to facilitate instrumentation tests prior to a master station being available, a lightweight substitute for the master station has been developed. Called a Player Initializer, it is a player pack with extended capabilities. Equipped with a hand held key entry display device or data terminal, it can be used to perform a subset of the master station functions.

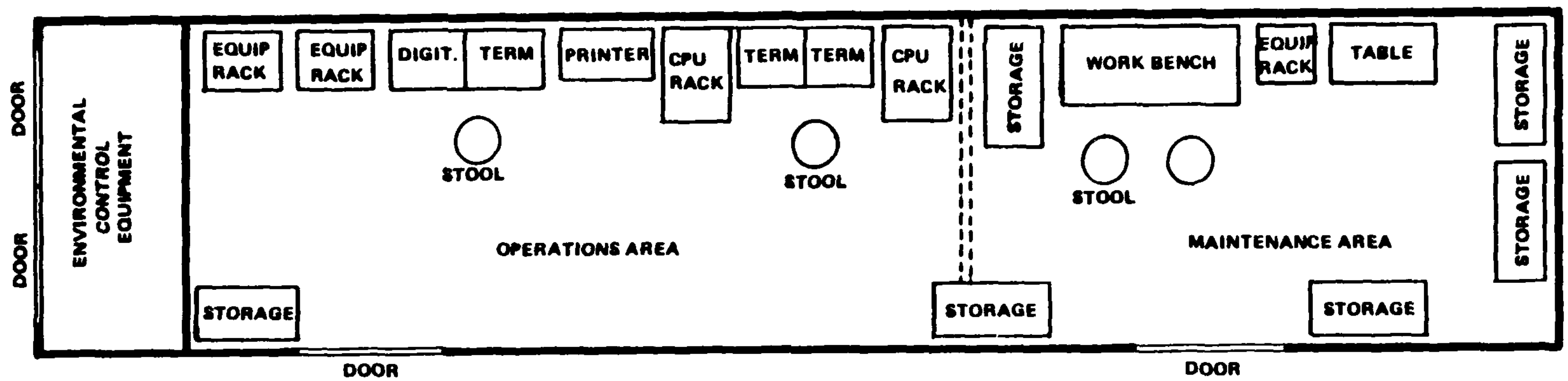


Figure 14. Operations and maintenance trailer.

It can initialize players, control transponder activity, monitor player activity, and unload the player packs posttest. It cannot perform quick-look validation, generate displays, or handle the more detailed uses of the RF communication features. Its use as a test controller is tied to the nearby availability of a master station for support.

## 3-5 REPEATER/TRANSPONDER NETWORK.

The repeater/transponder network provides the hardware necessary to implement both the RF communication subsystem and the transponder position location subsystem. These systems are optional, so the network is required only if either of these features is desired.

Several elements from the scoping phase of the program are simultaneously addressed in the design of the network: In order to perform accurate transponder ranging for position location, it is necessary that the radio frequency be kept quite high so that the signals propagate in straight lines. This sets the frequency at or above 1 GHz. However, the TNFS3 tests will be conducted in "hilly rolling terrain." Therefore, a series of "repeaters" is required to propagate the "line-of-sight" high frequency signal across this terrain and around metal buildings which the signal cannot penetrate. To meet the mobility requirements, these repeaters are lightweight, portable, quickly erected, and easily maintained. The radio unit on the player pack is small, lightweight, and low power to conserve batteries. The system must operate in heavy foliage, so the low power radio units must be compensated by the design of the repeaters in order to have adequate signal strength to punch through the foliage.

### 3-5.1 Repeater/Transponder Station Hardware.

The repeater/transponder stations consist of three elements: a collapsable tower, a 1.35-GHz radio tranceiver, and a controller implemented with an enhanced player pack. Figure 15 shows a complete

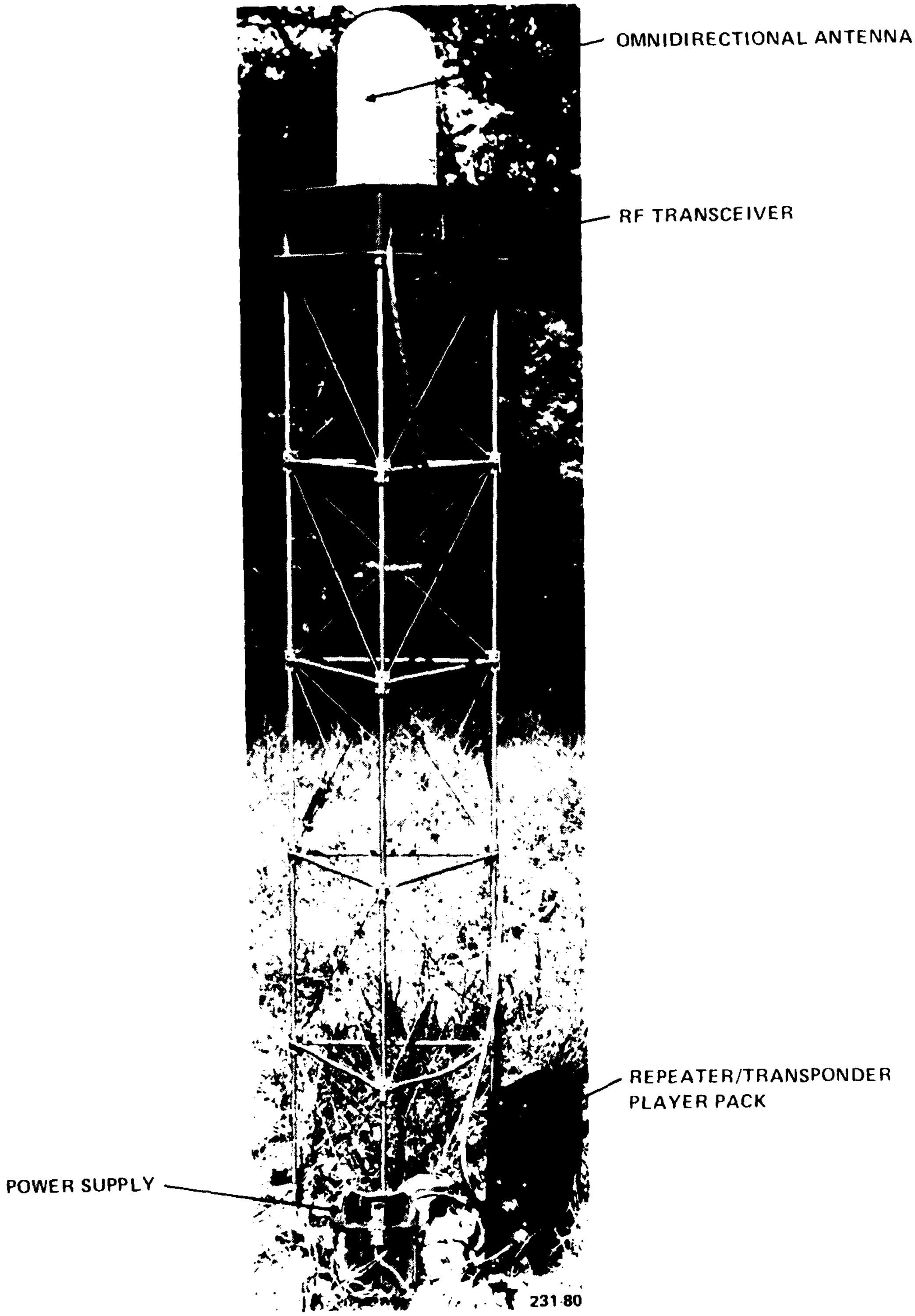


Figure 15. Repeater/transceiver station.

repeater/transponder station. Initial setup procedures require two persons to transport and secure the antenna-tower. Surveying is only required if the transponder position location option is to be used. The lightweight aluminum towers expand from their collapsed configuration into a lattice structure whose maximum height is 30 feet (9 meters) and which will withstand winds of up to 80 mi/hr (128 km/hr). A weatherproof antenna is mounted atop the tower; the controller and battery are placed on the ground. The battery is a high capacity rechargable unit sufficient for a full week of operation. A special module is added to the player pack controller to monitor temperature and voltage.

3-5.2 Radio Transceiver Operation.

The same radio transceiver is used on the players and on the repeater/transponder towers. This provides additional system module commonality and helps reduce both initial and recurring costs. The radio unit, shown in Figure 16, weighs approximately 2 pounds (1 kg) and has a peak power output of 20 watts. To provide the additional signal strength for reliable communication through dense foliage, the repeater/transponder stations can be equipped with optional output amplifiers and high sensitivity receiver preamplifiers. This combination allows the repeater to both detect the weaker player pack transmission and to transmit a strong enough signal for the player pack to detect.

The radio is pulse modulated with a low duty cycle so that there is no safety problem. The combination of high frequency, low power, and pulse modulation yields a system that nether interferes with nor is easily interferred with by others.

3-5.3 Repeater Mode of Operation.

The repeater mode of operation provides the signal propagation necessary for communication beyond line of sight. To guarantee proper operation, tower placement must be chosen so that no matter where on the field a player may go, he is always within line of sight of at least one repeater/transponder tower. This placement allows the repeater to relay, or echo, messages to and from the player and the master station.

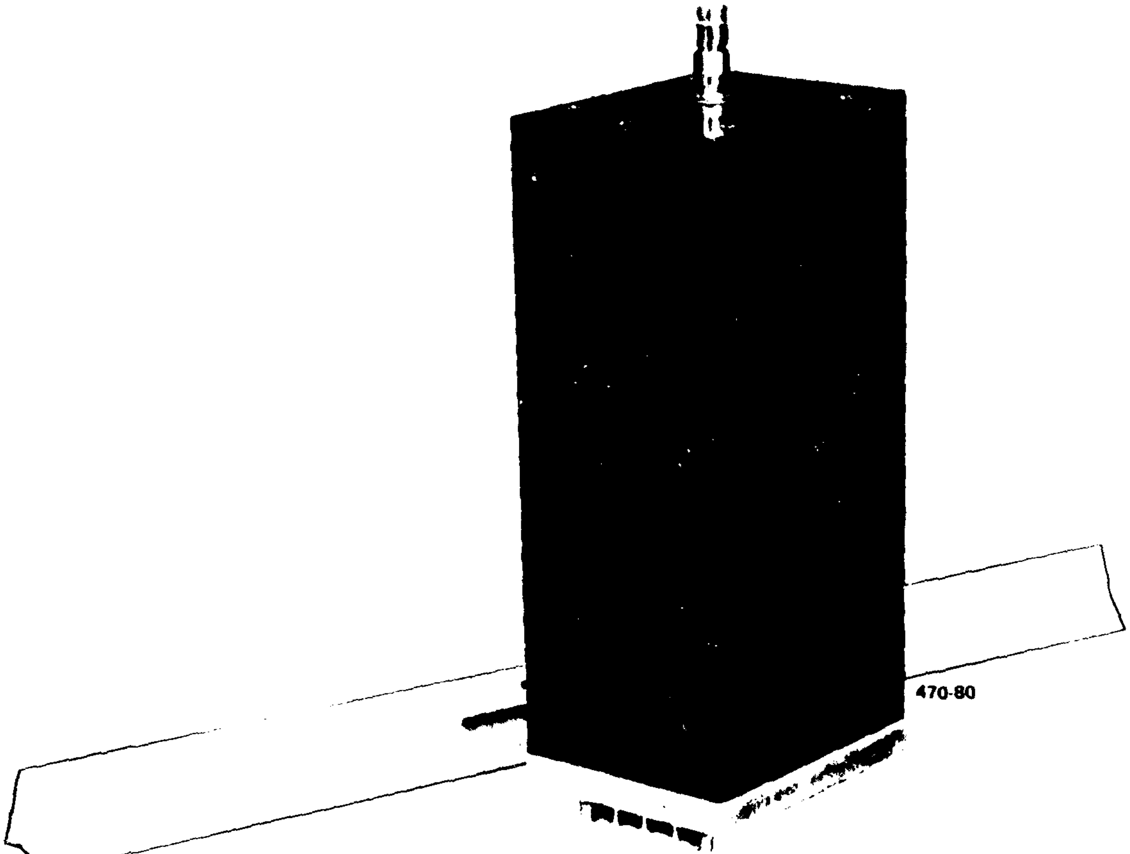


Figure 16. RF transceiver.

3-5.4 Transponder Mode of Operation.

Whenever the TPL subsystem option is used, three additional requirements are placed on the repeater/transponder network:

First, the repeater controllers and player packs are equipped with a TPL controller module (see Appendix A, Section A-8). No other hardware changes are required. This module recognizes the special "do position location" command issued by the master station; this command causes the controller to switch to the transponder mode of operation. The TPL module also controls the timing of the transponder ranging sequence.

Secondly, the towers must be surveyed into position. In most cases this means only that, once erected, the tower coordinates must be determined by surveying. Only rarely must the towers actually be erected in precisely predetermined locations. The surveying requirement arises from the mathematics of the position multilateration algorithm. In order to locate the player on the field, the distances between the player and at least four towers of known position must be available. As described in Section 3-3.3, the TPL subsystem provides only the ranges; the positions of the towers must be known beforehand. The positioning accuracy of the towers is reflected in the final accuracy of the multilateration results, and surveying provides the best accuracy. However, Section 3-3.4.1 describes a means of attaining moderate accuracy without actually surveying all of the towers.

Finally, the network coverage must be more dense than for the repeater-only mode of operation. The multilateration algorithm requires range data from at least four transponders in order to locate the player in three dimensions. This means that instead of the player always being within line of sight of one tower, he must always be within line of sight of at least four. The accuracy of the algorithm is improved if more than four ranges are provided. In practice, this configuration is not difficult to achieve and usually requires only addition of a few towers.

Additional details of the transponder mode of operation can be found in Appendix A, Section A-8.

3-5.4.1 Tower Self-Survey Feature. The unique feature of "self-survey" is a method of installing radio towers without extensive surveying. Four of the towers must be surveyed into position to serve as a coordinate system reference grid. The remaining towers are emplaced wherever it is convenient and where they will provide the necessary coverage. After emplacement, the individual towers are treated as if they were players and are told to "do PL". The towers measure the ranges between themselves and the surveyed towers and then compute their own positions. Although this method of determining the tower coordinates is not as accurate as surveying, it is totally acceptable for many of the scenarios and it greatly reduces the pretest setup time.

3-6 UMPIRES.

The addition of umpires to the TNFS3 instrumentation system contributes to the flexibility requirements, mentioned in Section 2-4.1, whereby a wide range of scenarios may be accomodated, quickly and at low cost. Umpires are valuable observers during a test, communicating with the master station or acting independently. Each umpire will carry a hand held key entry device and a player pack, so that specific actions of players may be recorded. The umpire may trigger indirect fire simulation casualties resulting from it. Other possibilities include initializing player packs at remote locations, testing player equipment which may become inoperative, or aiding the master station in controlling the test.

All of the above-mentioned activities are simplified through the use of a hand held key entry display device. The touch-sensitive keyboard will be coded with any combination of numbers, letters, or pictures which can improve the efficiency of the umpire. This provides a choice between single key messages or complete messages as might be recorded in a notebook. Since the umpire is also a mediator, this person may reinitialize players which have been declared dead or out of ammunition. The umpire also carries a laser weapon which may wound or kill selected players as might be necessary in indirect fire situations.

## SECTION 4

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APPENDIX A

DETAILED FUNCTIONAL DESCRIPTION

## A-1 MICROCOMPUTER-CENTRAL PROCESSING UNIT.

### A-1.1 Functional Elements of the Microcomputer.

The CPU selected is the TMS9900-40, an NMOS device manufactured by Texas Instruments. It operates in conjunction with three other devices, a CMOS oscillator, a programmable systems interface (PSI), and a four-phase clock generator which operates at a rate of 4 MHz. Memory access, to a maximum of 64K bytes, is achieved through a 16-bit data bus and a 15-bit address bus. The PSI prioritizes and encodes 15 interrupt inputs into the CPU. As an interval timer it is programmed to generate an interrupt, acting as a real-time clock. The CPU is shown in Figure A-1.

System memory provides storage for programs and data. CMOS components (EPROM and RAM) were selected for their low power consumption. The EPROMs operate during board power-up to boot the system program stored on the EPROM board. The contents of the EPROM board are transferred into RAM by the CPU. When this process is complete, the CPU turns the EPROM board off to reduce power consumption. The RAM devices on the microcomputer board represent 28K bytes of memory, with an additional 32K bytes potential for off-board expansion.

The module select logic provides an efficient method of selecting dedicated circuit board slots or devices. Its decoding scheme minimizes circuit components when selecting DMA, APU, PSI or any off-board device. The module select circuitry decodes the 10 most significant address lines to produce 16 unique MODSEL signals. The remaining five address lines provide 32 addresses within each MODSEL field.

The direct memory access (DMA) controller is the AMD9517. Data acquisition transfers are greatly improved when this component acts in place of the CPU, achieving a maximum transfer rate of 1,000,000 bytes per second. This is possible on any one of the four DMA channels available. Anticipated users of DMA included the weapons effects, RF communications, and bubble memory subsystems.

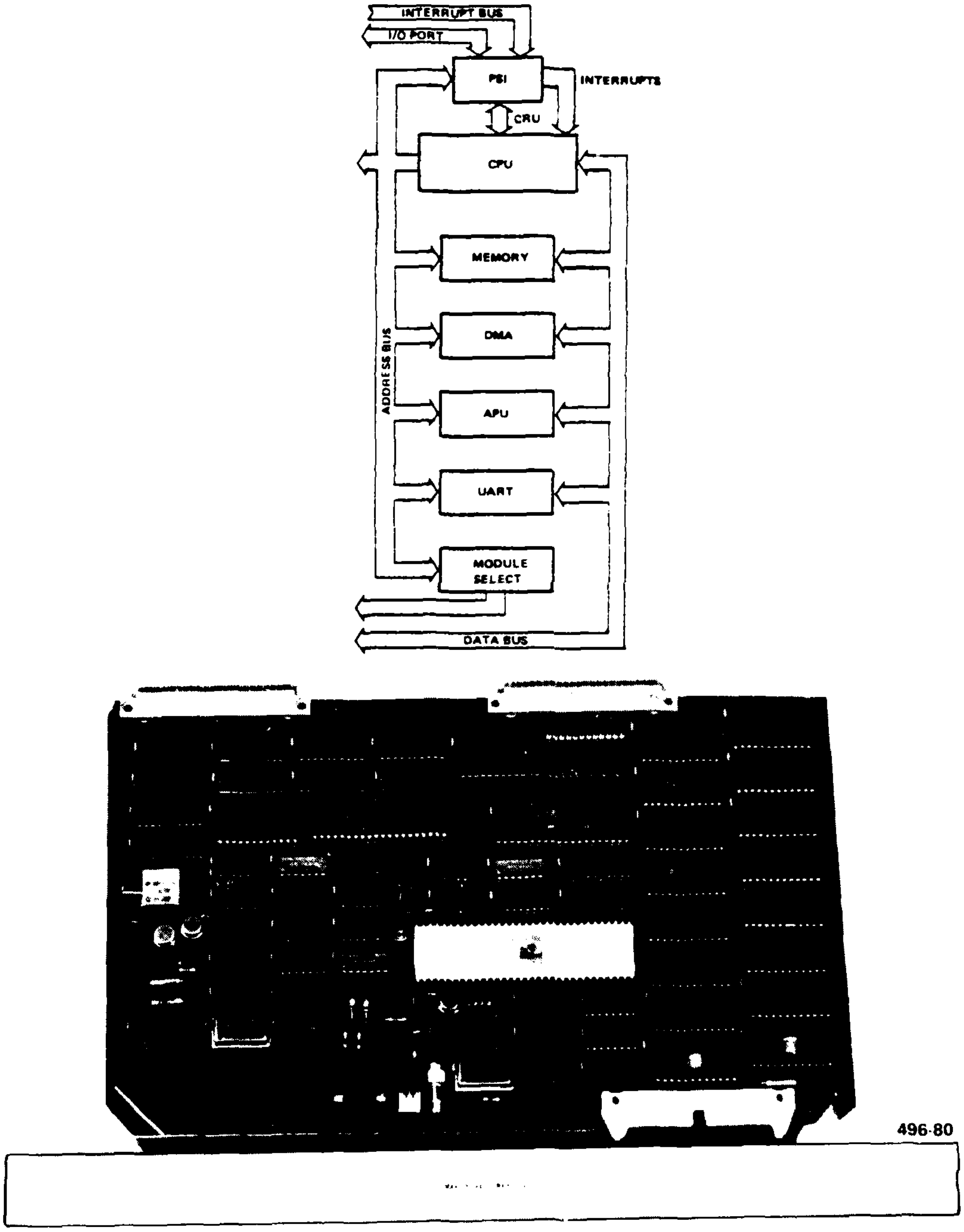


Figure A-1. Player pack microcomputer.

The APU, an AMD9511, is a dedicated processor which operates in parallel with the CPU. Arithmetic calculations in fixed or floating point notation are performed on trigonometric, logarithmetic and exponential functions. This NMOS device is power cycled by the CPU when not in use. During operation it consumes 1.2 watts.

The UART is a CMOS device, the RCA 1854, dedicated as a terminal interface between the CPU and peripherals over an RS-232-C type line. Such devices as video display terminals, line printers, and the key entry device communicate with the player pack through this interface. The UART is programmed by the CPU, selecting between five and eight bits per byte and a parity check if desired. Seven jumper selectable baud rates, 300 to 19,200 baud, are available.

A-1.2 Power Requirements.

In order to permit battery operation, power usage for the microcomputer was minimized through the careful selection of low power components and the design of power cycling circuits. CMOS devices are utilized wherever possible; low power Schottky devices are a desirable substitute when necessary. This procedure was valuable in producing a microcomputer whose average power consumption is 3.5 watts.

A-1.3 Board Layout.

The microcomputer board size was selected to be that of two peripheral boards, assuring maximum efficiency and meeting packaging goals. It is fabricated on a Multiwire™ board measuring 6.60 by 10.87 inches (16.76 by 27.61 cm). The Multiwire method of fabrication provides maximum circuit density without sacrificing quality or durability. The board interfaces to a motherboard through three 40-pin connectors. A picture of this board and a functional block diagram is shown in Figure A-1.

A-1.4 Summary.

The general purpose of the microcomputer is to function as a nigh speed computer with features needed for the TNFS3 program. It is one component of a modular, flexible, expandable system which is both durable and affordable. The software it contains makes it "be" a player, for whoever and whatever is desirable.

## A-2 DATA LOGGING SUBSYSTEM.

Security requirements when testing in Europe mandate that no telemetry of raw test data should take place. To satisfy this requirement a data logging subsystem was implemented using a magnetic bubble memory. The data logging subsystem stores all player test data in the player pack and thereby eliminates the need for telemetry.

For the repeater/transponder stations, where test data are not stored, a different memory subsystem is used for software storage alone. The EPROM module is much less costly and replaces the data logging subsystem in the repeater/transponder stations.

### A-2.1 Functional Description (Bubble Memory).

To provide the necessary data storage capability, data density, high reliability, and immunity to shock and vibration, a bubble memory devi.. has been selected for the TNFS3 player pack data logger.

The bubble memory system, shown in Figure A-2, consists of a one-megabit storage device together with its associated control electronics. It interfaces to the player pack microcomputer's standard peripheral bus in the same way as all other peripheral devices. If additional storage capability is needed, several data logging modules can be plugged into the player pack.

The data logging subsystem utilizes one of the high-speed DMA channels for data transfers, thereby relieving the CPU of the burden of transferring all the data.

Operation of this device requires a great deal of power. Therefore, power is turned off completely when the micrcomputer is not accessing the device. Additionally, data to be written to the bubble memory are stored in RAM until enough have accumulated to allow burst transfer of a large data buffer. This also helps reduce the total powe- consumption.

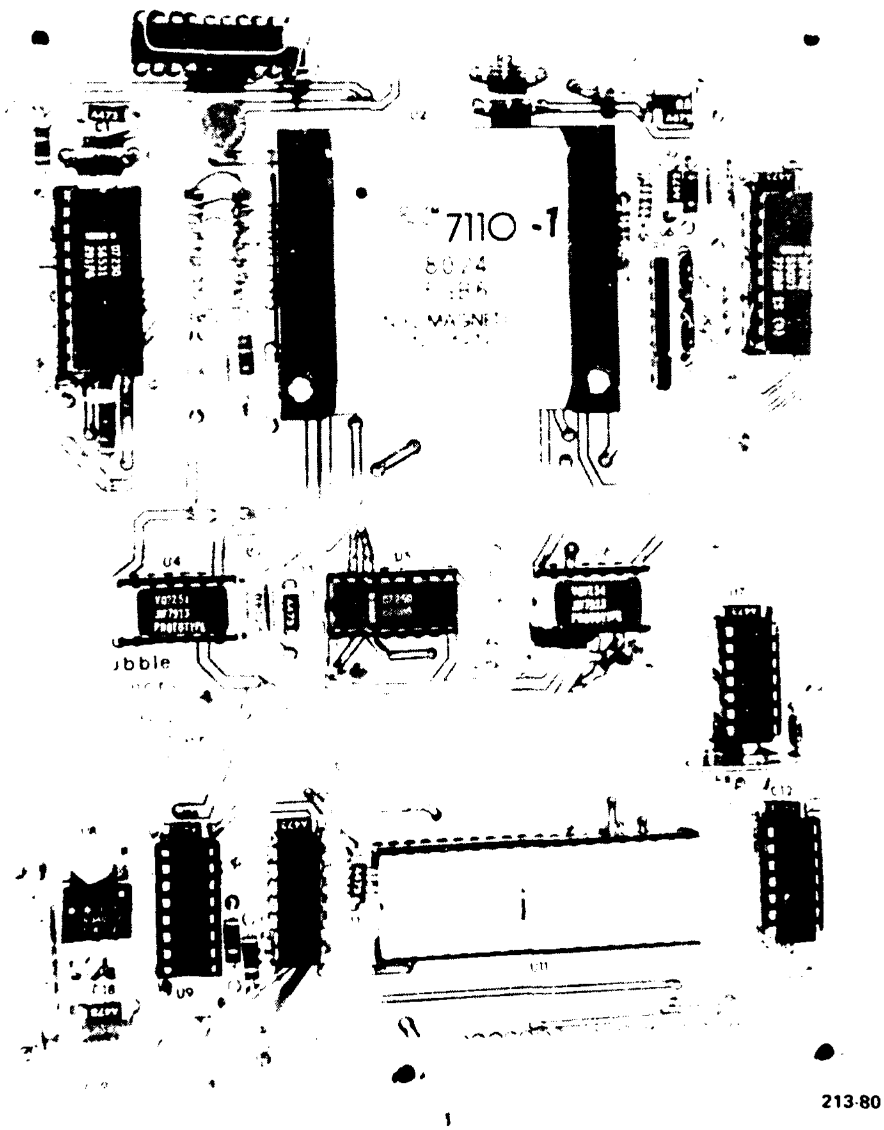

Figure A-2. Bubble memory board.

The bubble memory controller has built-in capability for data error detection and correction in addition to implementing parity for error detection.

A-2.1.1 Principle of Operation. The principle of operation is quite simple: the CPU programs the DMAC to transfer the data stored in RAM to the bubble memory, it then turns on power to the device and programs the controller to accept the data. When it is ready, the bubble memory controller signals the DMAC to begin. The DMAC takes control of the peripheral bus and does a high speed transfer of the data. When the transfer is complete, the bubble memory controller signals the CPU and the CPU turns off power. The direction of the transfer is reversed to remove data from the bubble.

A-2.2 Software Storage Module (EPROM).

The EPROM board, shown in Figure A-3, was developed to replace the bubble memory module when data logging is not needed. In the repeater/transponder application, data logging is not needed and the EPROM module serves as low cost storage for the operating software. Similar to the bubble memory, the module is power cycled to reduce power consumption.

The EPROM module has a storage capacity of 32K bytes of software. In the repeater/transponder application the module also supplies the microcomputer with a unique ID that identifies each repeater/transponder so that it can be independently addressed during transponder position location cycles as described in Section 3-3.5.

A-2.2.1 Principle of Operation (EPROM). The EPROM module is software controlled by the microcomputer board. Address and data transfers are initiated by the CPU, allowing the contents of the EPROMS to be loaded into RAM. Whenever desired, the EPROMs may be reprogrammed by exposing the EPROM chips to ultra-violet light.

Power cycling buffers isolate the EPROM data bus from the system data bus when the board is in the stand-by mode. This mode of operation consumes about 100 mW compared to 1.5 watts when fully powered up.

The counters sequence through the local addresses of the module so that each time the CPU reads a byte from the module the next byte is present at the interface. The counters can be accessed by the microcomputer and programmed to start sequencing at any address and, if necessary, read partial contents of the module. Likewise, the unique ID code used in the

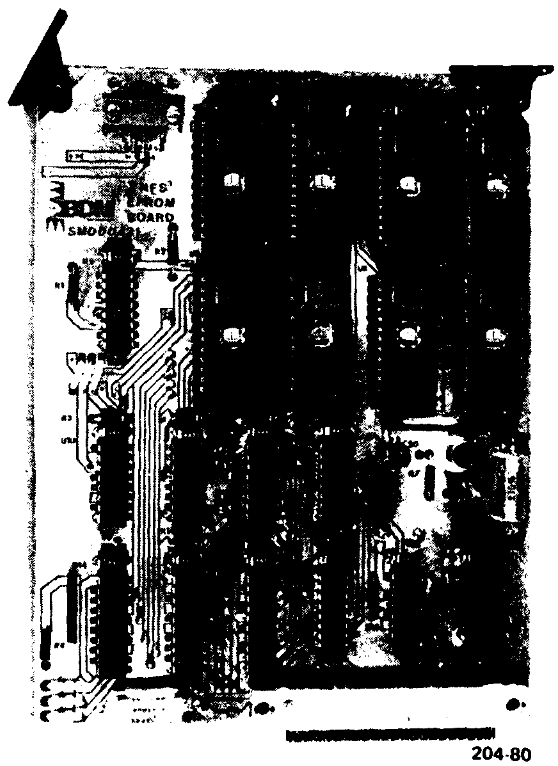


Figure A-3. EPROM board.

repeater/ transponder application can be accessed and read. Each EPROM module also contains another ID code which is used to distinguish between EPROM modules and bubble memory modules. This ID code can also be used to identify different versions of software stored in the module.

## A-3. PLAYER PACK POWER SOURCE.

Since the player pack is to be man portable, it must operate from a battery source. This power source must be conditioned by the appropriate regulator circuit to supply adequate current and voltage for expected player pack operation. It was designed for automatic shutdown should the battery drop below a predetermined minimum where regulation becomes impossible. A warning system is included to alert the player of such a failure, with a beeper, so that a defective battery can be immediately replaced. Also, any player data still in RAM locations of memory must be transferred to the nonvolatile bubble memory device before the regulator card turns off the entire player pack. This procedure eliminates catastrophic failures and allows graceful failure of the player pack, should it fail unexpectedly.

### A-3.1 Functional Description of the Regulator Card.

The regulator card is a plug-in module, shown in Figure A-4, that is carried in every player pack. Its prime function is to supply 5 volts to all electronic circuits in the pack. The voltage conversion is acceptable as long as the supply battery is between 15 and 24 volts. Conversion is made with a high efficiency (75 percent) switching circuit to maximize battery life and time between charge cycles. Additionally, the regulator card monitors the battery voltage to provide data-retention security if a battery pack fails. This shutdown also occurs in the case of a microcomputer failure.

To extend scenario test time, a power saving circuit on the regulator card allows portions of the player pack electronics to be shut down when not in use. This feature is applicable during deployment phases of testing when the data logger and RF communications subsystems are not operating.

## A-4. INTERFACE MODULE.

The purpose of interface modules is to improve the flexibility of the player pack in communicating with the outside world. As mentioned in Section 2-2.1, peripheral devices are to be easily reconfigured and still

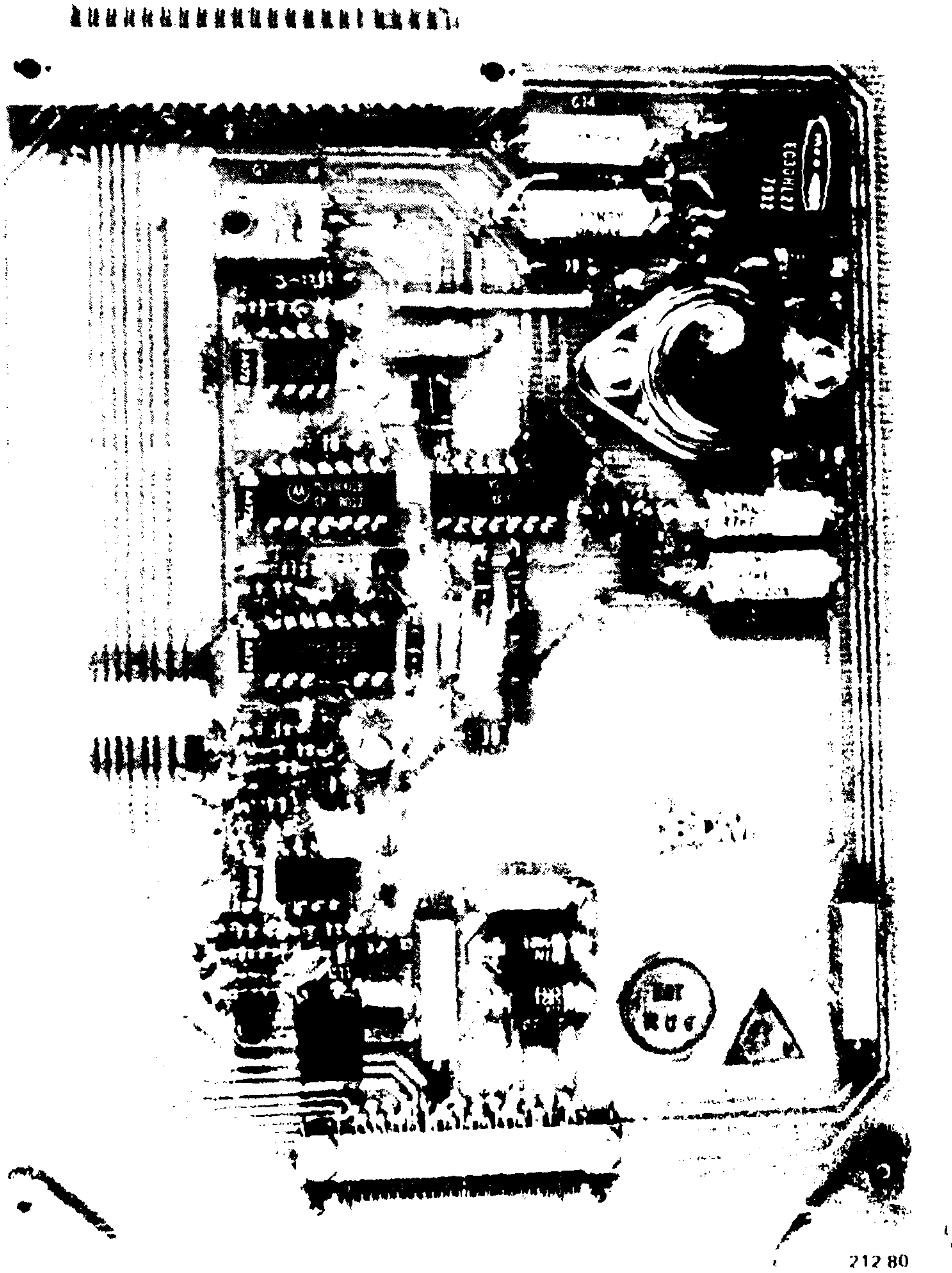

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Figure A-4. Regulator board.

provide two-way communications with the player pack. Their response to data transfers adheres to specifications in Section 1-1.4, whereby the "quick look" feature for posttest data validation is successful.

A-4.1 Functional Description of the Interface.

A *general purpose interface module* has been developed to allow the microcomputer to communicate with external devices. The Universal Input/Output (I/O) module, shown in Figure A-5, is a software activated device that facilitates the transfer of data. Presently the module is an add-on feature for test equipment or cueing devices. It interfaces with almost anything (e.g., RS-232, IEEE-488, other logic devices, and data busses). As a controller, the Universal I/O could be used to activate or monitor flash/bang/smoke devices, TV cameras, intrusion detectors, or weather stations.

A-4.2 Operation of the Universal I/O.

The Universal I/O module provides 16 input lines and 16 output lines. The microcomputer may address each input or output line as an independent digital signal or in groups of up to 16 lines. Communication is provided through the communication register unit bus.

Each output will interface to any system requiring a 0 to 24-volt swing with almost any load requiring several hundred milliamps of current. The outputs are capable of driving inductive loads such as relays. Input voltages from a standard 24-volt logic level system are acceptable, with protection from input transients of up to 2 kilovolts for 1 second.

A-5. WEAPONS EFFECTS SUBSYSTEM.

The *weapons effects subsystem* consists of three major components: (1) weapon-mounted electronics, (2) laser sensors, and (3) communications interface unit. Information is bidirectionally transmitted from the weapons effects interface to the microcomputer.

A-5.1 Weapon-Mounted Electronics.

This portion of the weapons effects subsystem includes the laser with associated circuits and the interface between the weapon and player.

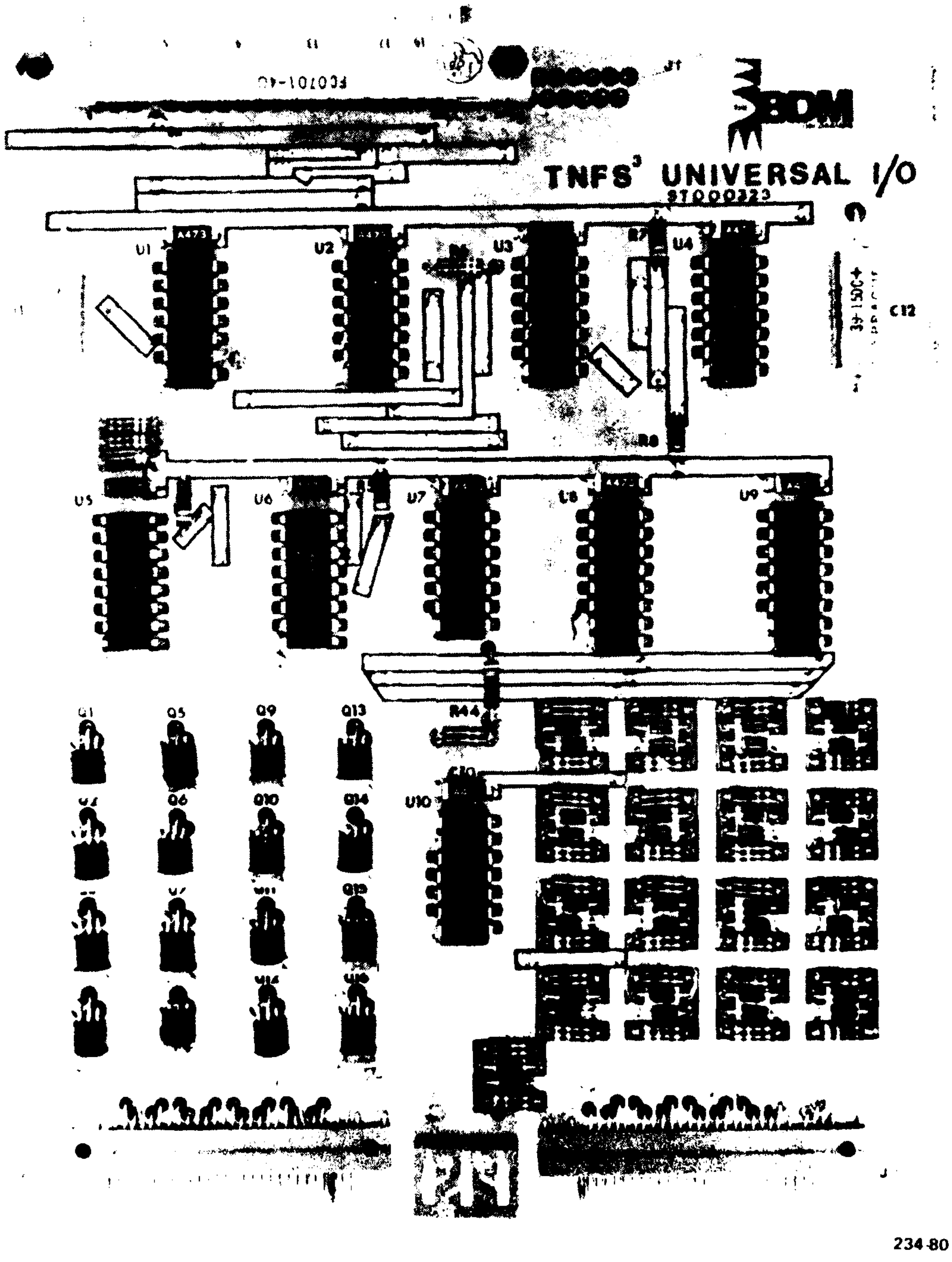


Figure A-5. Universal input/output board.

For the M-16, the laser and circuitry is housed in an aluminum casing which mounts on top of the rifle barrel. A 9-volt alkaline battery to power these circuits is also in this casing. This is a compact, lightweight (about 8 ounces) design which is boresighted to the weapon. Figure A-6 provides a view of this attachment.

The laser beam divergence is 1.2 milliradians and exits the folded optics window with a diameter of approximately 3/4 inch (19 mm). Peak power laser output is approximately 2.5 watts for the M-16. With current sensor designs, the rifle is effectively simulated at distances exceeding 1 kilometer. A signal cable connects the laser to the modified handgrip. This handgrip contains a coil of wire which serves as one side of an air-core transformer. The transformer forms a wireless coupling for signals between the weapon and a glove (worn by the player) which contains the other transformer winding. This technique eliminates any direct hard connection between the player and the weapon, allowing the player to interchange weapons at will. The glove is a fingerless design (see Figure A-7) which can be worn either under or on top of regular gloves. This interface glove is designed

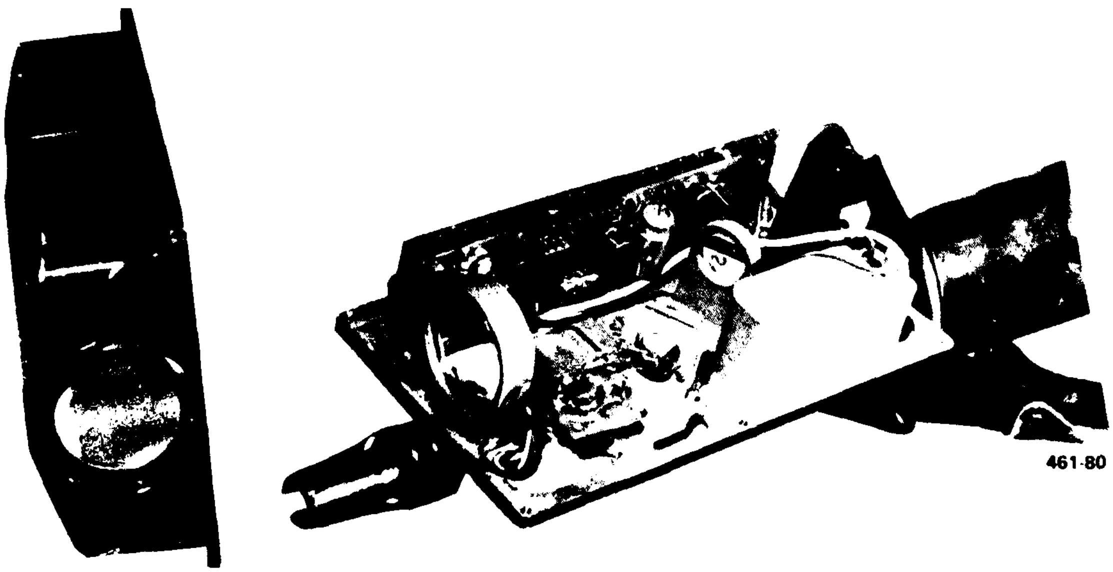


Figure A-6. Laser attachment for an M-16.

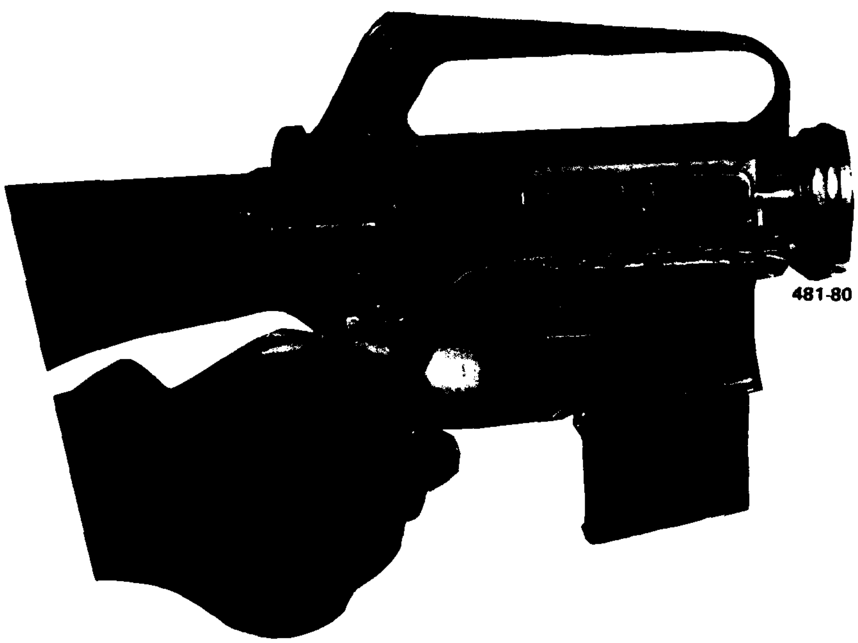


Figure A-7. Palm interface.

to be worn with the coil located on the back side of the hand in order to preserve the feel of the weapon.

A .357 Magnum handgun (see Figure A-8) has been configured with electronics but is presently in the development phase. For this handgun, the barrel casing is replaced with a laser transmitter casing. The beam spread of this laser is approximately 4 milliradians. This simplifies the optics and keeps the size of the unit as unobtrusive as possible. The wider beam spread for the handgun and a lower power laser (approximately 2.0 watt peak) makes this weapon simulator usable to about 100 meters with current sensor designs. As with the M-16 implementation, data transfer is via inductive coil in the weapon handgrip. On the .357 Magnum, however, both the circuit for the laser transmitter and the battery (a 6-volt mercury cell) are housed in the handgrip. The original handgrip is detached from the weapon by removing one screw and replacing it with the electronics/ interface kit grip.

A-5.2 Laser Sensors.

There are two types of sensors used to detect the laser beam: (1) discrete sensors and (2) area sensors. Each has different characteristics and the combination of the two enhances the weapons effects subsystem performance.


Figure A-8. .357 Magnum handgun.

A-5.2.1 Discrete Sensor Characteristics. The discrete sensor shown in Figure A-9 is a high sensitivity unit capable of detecting pairings at distances of over 1 kilometer (where the laser beam intensity is very low because of spreading). A silicon photodiode is used as the detection device. It is housed with a signal conditioner circuit in a small aluminum box. The conditioner circuit amplifies the signal from the photodiode, making it compatible with electronics inside the player pack. The design of the signal conditioner also nulls out ambient light effects on the photodiode. The photodiode is mounted against a window in the box with an EMI shield between it and the glass window. The main deficiency of the discrete type sensor is that it is susceptible to reflections because of its high sensitivity. It is not a cost effective solution to instrumenting large areas of the target because of its relatively small window area.

A-5.2.2 Area Sensor Characteristics. In contrast to the discrete sensor, the area type sensor, shown in Figure A-9, has relatively low sensitivity. Nonetheless, it is usable at distances of over 300 meters with a 2.5-watt peak power laser weapon (M-16). It is not susceptible to reflections of the beam to any significant degree. This sensor employs the same silicon photodiode and signal conditioner as the discrete sensor type; however, the light coupling is not via a window on the aluminum box. The light is coupled to the photodiode via fiber optic strands which are sewn to the cloth of the players' suit. For ruggedness, the fibers are jacketed in teflon tubing prior to attachment to the cloth. A reflective material is used behind the fibers to enhance light scattering effects and maximize coupling of light energy into the fibers. An outer cloth covering the fibers serves as a protective layer and allows a camouflauge outer appearance to be maintained for the player. The ends of 10 loops are terminated in a connector on one end of the signal conditioner/photodiode box, and the photodiode is aligned with the fiber ends for maximum light transmission. The main advantages of the area type sensor are: (1) detection of close engagements, (2) low susceptibility to reflections, and (3) easy coverage of large, irregularly shaped objects.

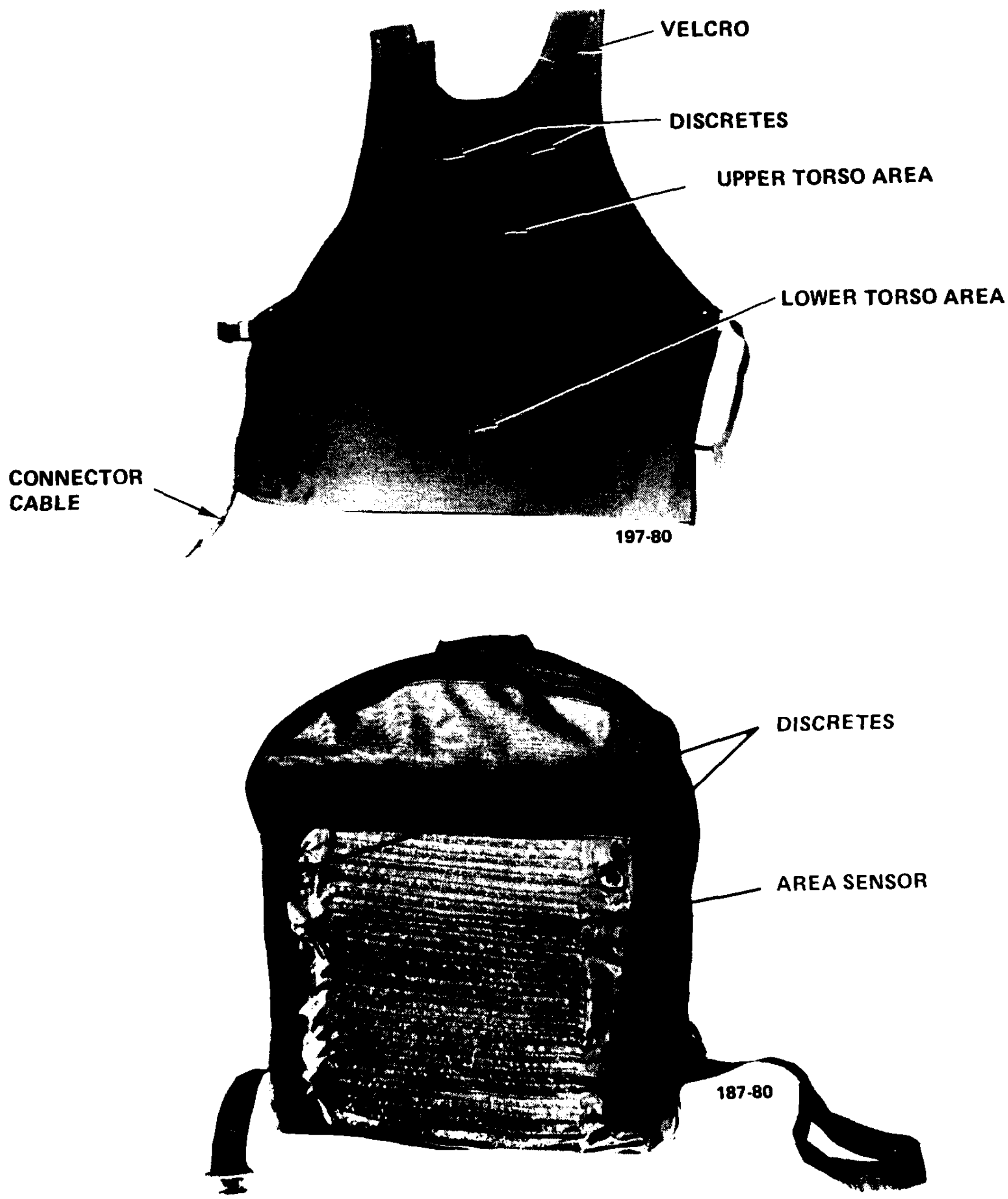


Figure A-9. Weapons effects sensors.

A-5.2.3 Combined Sensor Arrays for the Player. Using combinations of the two types of laser sensors, the player "suit" enables detection of hits on the head, upper and lower front torso, and rear torso of the player. The head coverage is via an area sensor attached to a helmet, shown in Figure A-10. The front torso coverage combines one area and two discrete sensors for the upper half and one area sensor for the lower half. This vest or apron is fabricated as a detachable panel and is worn over normal clothing. The back torso is covered by one area and two discrete sensors. This is also a detachable panel which is attached to the back of the player pack. All cables to the sensor panels are routed through a single connector on the interface plate (outer cover) of the player-pack box. Also mounted on the shoulder area of the vest is a sonalert which is used to cue the player when he has been hit/wounded/killed. The electrical connections to the beeper are routed through the weapons effects connector.

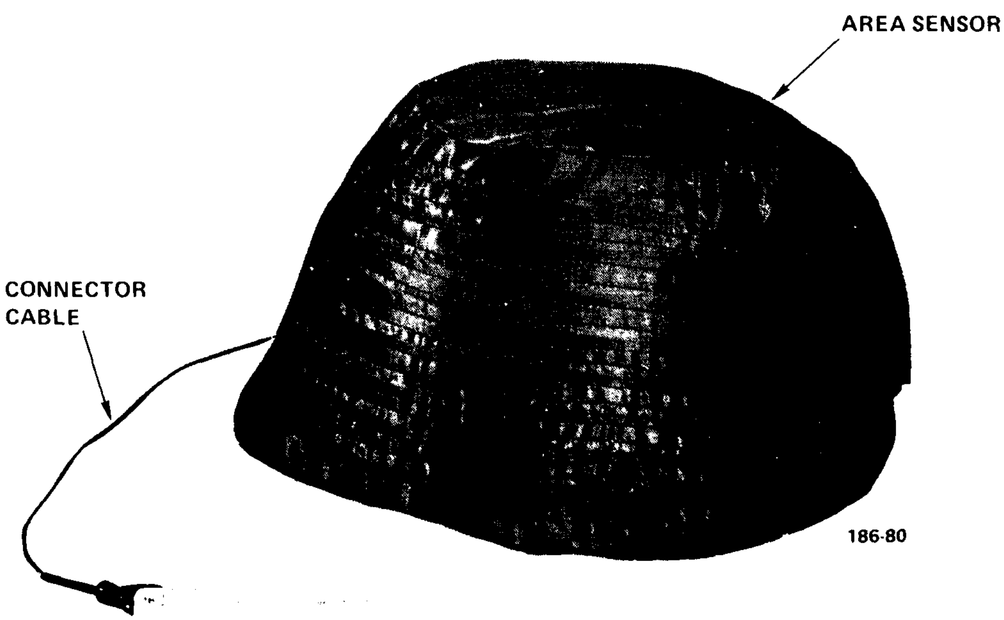


Figure A-10. Player helmet with area sensor.

A-5.3 Communication Interface Unit.

In order to determine the status of the player after illumination, the engagement data must be transferred from the weapons effects subsystem to the player-pack microcomputer. This is accomplished by the communications interface unit (CIU). The CIU is the module which controls all communications between microcomputer and the weapon/sensor/glove subsystem. As shown in Figure A-11, the CIU contains two major electronics circuits. The first one is the encoder. Upon detection of a trigger pull, the encoder formats player status information into a pulse-coded message which modulates the laser beam. Conversely, the decoder circuit of the CIU receives incoming data (modulated laser light) from the discrete and area sensors and transforms this pulse train into parallel data for the player pack microcomputer. The CIU also contains a memory area to buffer incoming and outgoing information. This allows asynchronous operation of the encoder and decoder. In other words, a firing player can be hit at the same time with no loss of data. The CIU also contains circuitry to operate the glove side of the coil interface to the weapon. Power consumption of the CIU is approximately 0.25 watts.

A-5.4 System Dynamic Operation.

To detail the operational aspects of the weapons effects subsystem, it is convenient to divide the sequence of events into two sections; (1) a firing event and (2) a hit event.

A-5.4.1 Fire Event. A fire event begins when the player pulls the trigger of his weapon. The fire event is detected by the weapon-mounted electronics and, in the case of the M-16, the muzzle flash is detected (blank round fired). For the .357 Magnum, the impact of the hammer is sensed. Once the trigger pull is detected, a set of pulses which correspond to the type of weapon fired are sent to the coil in the weapon handgrip. The coupling from the handgrip to the glove enables this set of pulses to be received by the CIU. If the player has changed weapon types since last firing, the microcomputer is notified of this and a player status buffer is updated to reflect the new weapon ID number. If it is not a new weapon type, the contents of the player status buffer need not be updated and the message is ready to send. This buffer contains the following information:

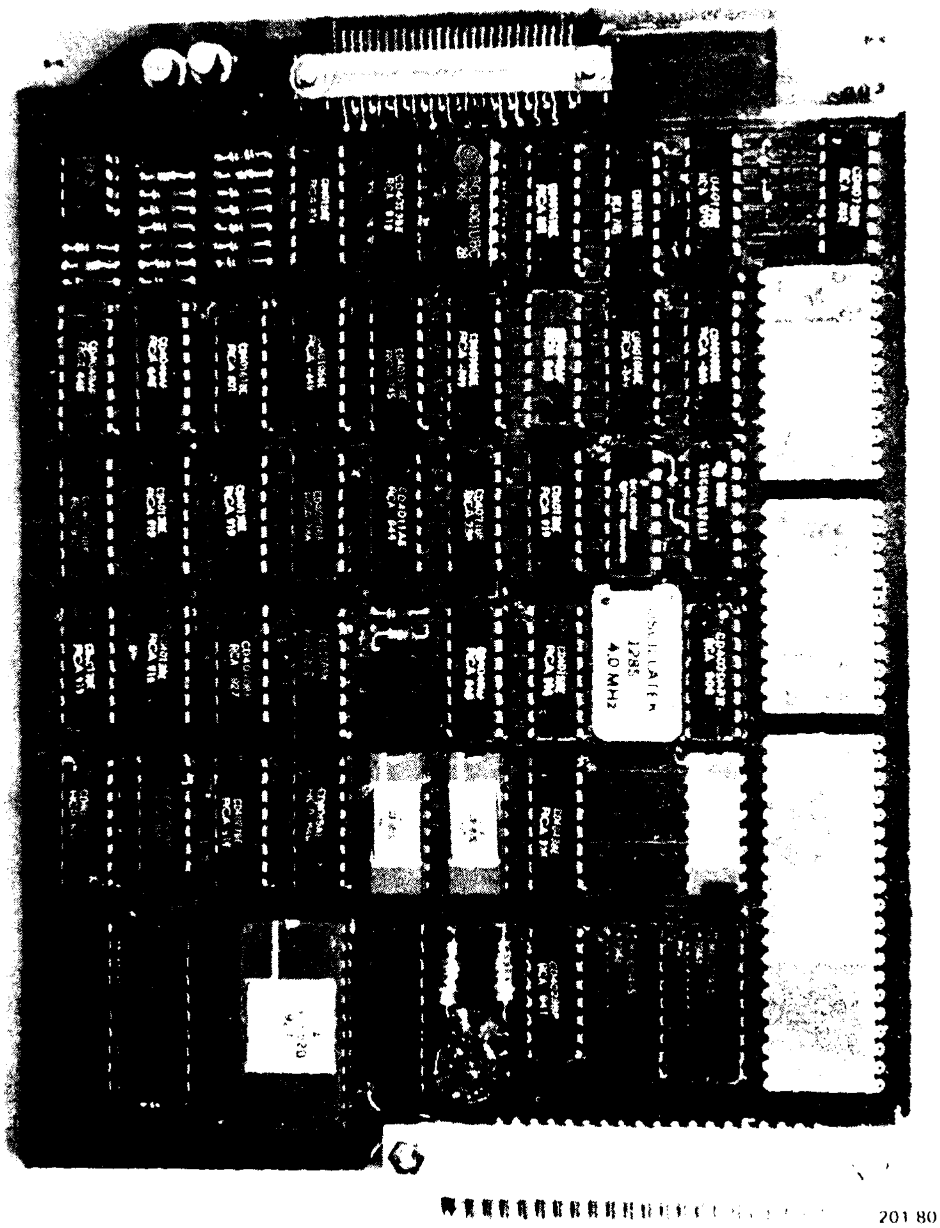


Figure A-11. Weapon effects communications interface board.

1. Attacker ID
2. Weapon Type
3. Attacker posture (upright/prone)
4. Firing mode (auto/single shot)
5. Attacker location (x,y,z)
6. Attacker marksmanship

To send the message, the encoder circuit reads this buffer and formats it into a pulse-coded serial output. The output of the encoder is used to transfer data back to the weapon via the coil driver circuit on the CIU. As before, this series of pulses is coupled between the player glove and the weapon handgrip inductively. The laser beam of the weapon is in turn modulated on/off to output the same pulse-coded message, this time on a beam of infrared light. This complete sequence, from trigger pull detection to laser message output takes from 2-5 milliseconds, depending on the buffer contents at the time of a trigger pull (how much of the buffer data is current). When the laser is transmitting the message, its power output is monitored by circuitry in the weapon-mounted electronics. If the output power is critically low, another set of pulses is sent from the weapon to the CIU to indicate a weapon failure. This indication of a weapon failure is then passed on to the microcomputer CIU so that the player can be cued of this fact and a bad weapon status stored in the player-pack data logger. The time of transmission of the pulse-coded message is approximately 1.5 milliseconds.

A-5.4.2 Hit Event. When a player is "hit" or illuminated by a laser, the incoming message is first validated to insure that it is properly encoded. This validation is accomplished by identifying a predata header consisting of a pulse pair spaced in time by 63 microseconds. This header is affixed to the message data during the time of transmission from the firing player. All infrared light reaching the sensors which does not begin with this header is considered garbled (reflection) and is ignored by the CIU.

Once a message is validated, the pulse string is decoded and stored in a buffer for use by the player pack microcomputer. In addition to the firer's data received in the laser message, the hit location on the target is read by the CIU and this is stored in the receive buffer. The CIU can store up to three messages at a time, thus circumventing the loss of data during high levels of weapon engagement activity. Corresponding to the location of the area and discrete sensors, the following is a list of bit locations (these can be also used to discriminate against reflections of the laser beam due to the characteristics of the two sensor types previously described):

| DISCRETE | AREA | LOCATION |
|---|---|---|
| X | X | Back |
|  | X | Head |
| X | X | Upper Front |
|  | X | Lower Front |

The outputs of the sensor signal conditioners are hard-wired to a connector which plugs into the playerpack. As noted before, the micro-computer uses the weapons effects subsystem message data to perform real time casualty assessment on the target player.

## A-6. PLAYER PACK PACKAGING.

The packaging task consisted of providing a suitable enclosure, appropriate harnessing or mounting, and adequate power supplies for the TNFS3 instrumentation. An extensive packaging effort began in 1979 to test and evaluate designs for both the player pack and the battery pack. Several iterations have been completed with significant improvements in weight, cost and durability.

### A-6.1 Early Testing of the Player Pack Unit.

The player pack is equipped with a harness engineered for comfort over long periods of use. The electronics package is lightweight, weather-tight and durable. This enclosure allows easy access to the electronics for maintenance while providing protection against water, mud, dirt, etc.

A market survey revealed that a commercial backpack harness and frame suitable for the player pack was available. The harness was evaluated and decisions were made to also evaluate a soft pack, as another option. Environmental simulations and tests on the packs were completed with significant differences noted in the internal temperature of an aluminum enclosure carried in each of the packs. The goal of this evaluation was to develop a backpack which was insulated from solar absorption so as not to overheat the electronic components. Temperature testing with high intensity heat lamps was conducted at 120°F for an 8-hour period. Results indicated that an enclosure with active components consuming 10 watts of power will reach a maximum temperature which is 20-25°F greater than the external environment. The softpack is configured to allow both top and bottom venting, as shown in Figure A-12, using a rough weave fabric separated from the enclosure by a sheet of lexan to meet all TNFS3 environmental requirements. The cost of the chassis and softpack is less than earlier versions and more easily maintained.

A-6.2 Meeting Durability Requirements.

One of the challenging aspects of packaging was to design a player pack unit which was both lightweight and durable. An aluminum enclosure, 11.5 inches by 3.5 inches by 8.5 inches (29.2 cm by 8.9 cm by 21.6 cm) was designed with a wall thickness of 1/16 inch (1.6 mm) and seamless welds on all corners. It is painted with a special reflective olive-drab paint to minimize solar heat transfer. System modules are mounted on 5-inch by 6.5-inch (12.3 cm by 16.5 cm) shock and vibration resistant boards which are half the size of the microcomputer board. Several card cage designs were tested prior to selecting a framed structure which is durable and lighter than previous versions. As shown in Figure A-13, the enclosure is completed with an interface panel which has a weather-tight gasket and four connectors to interface the player pack with external devices. This packaging method allows easy access to the modules for maintenance or system testing. A completely assembled player pack weighs approximately nine pounds (4 kg). Field tests were conducted this year to assess the weight and durability factors. This included normal field exercises such as rolling, jumping, and climbing. The results to date indicate that the packaging effort is

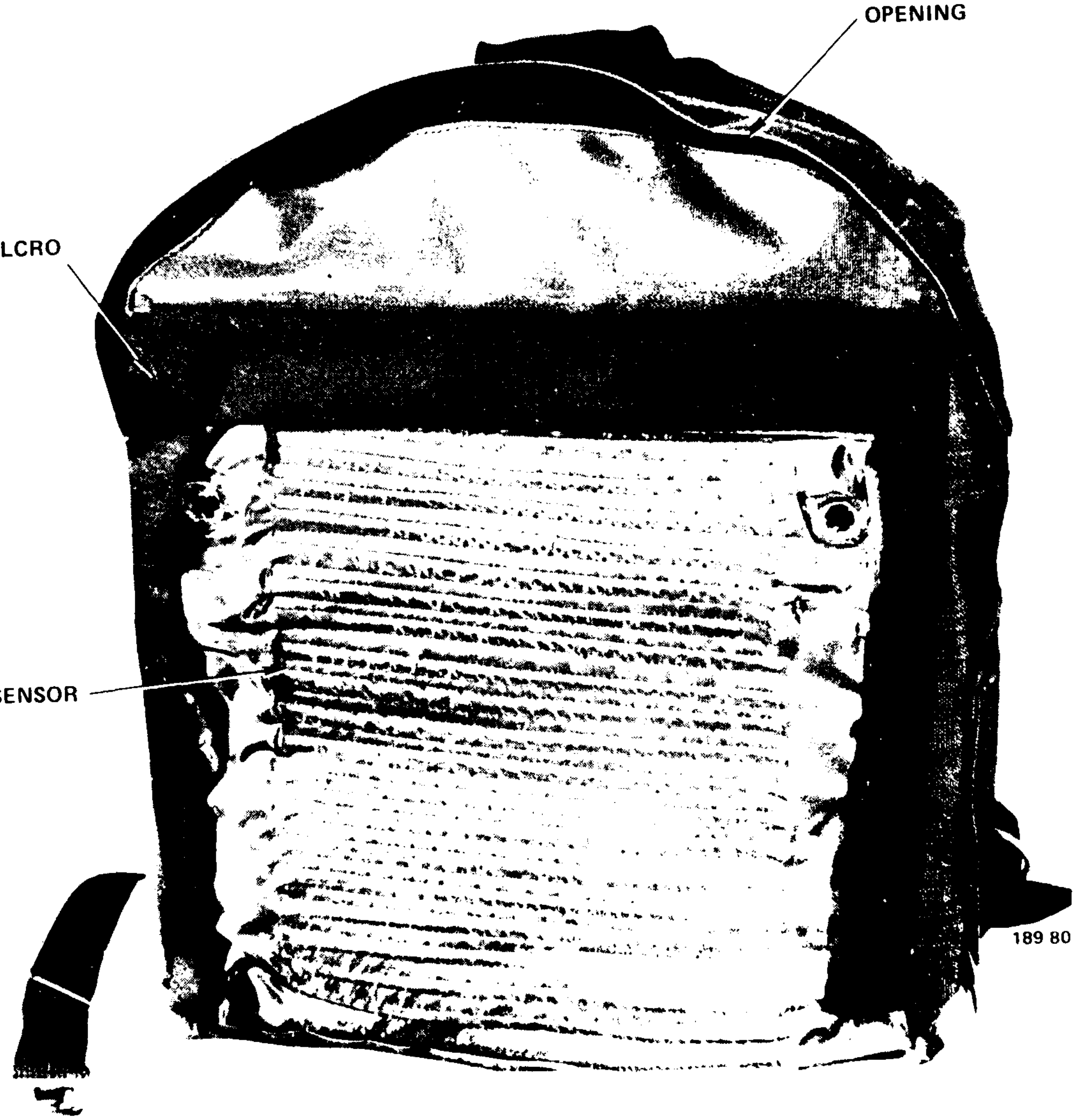


Figure A-12. Player softpack.

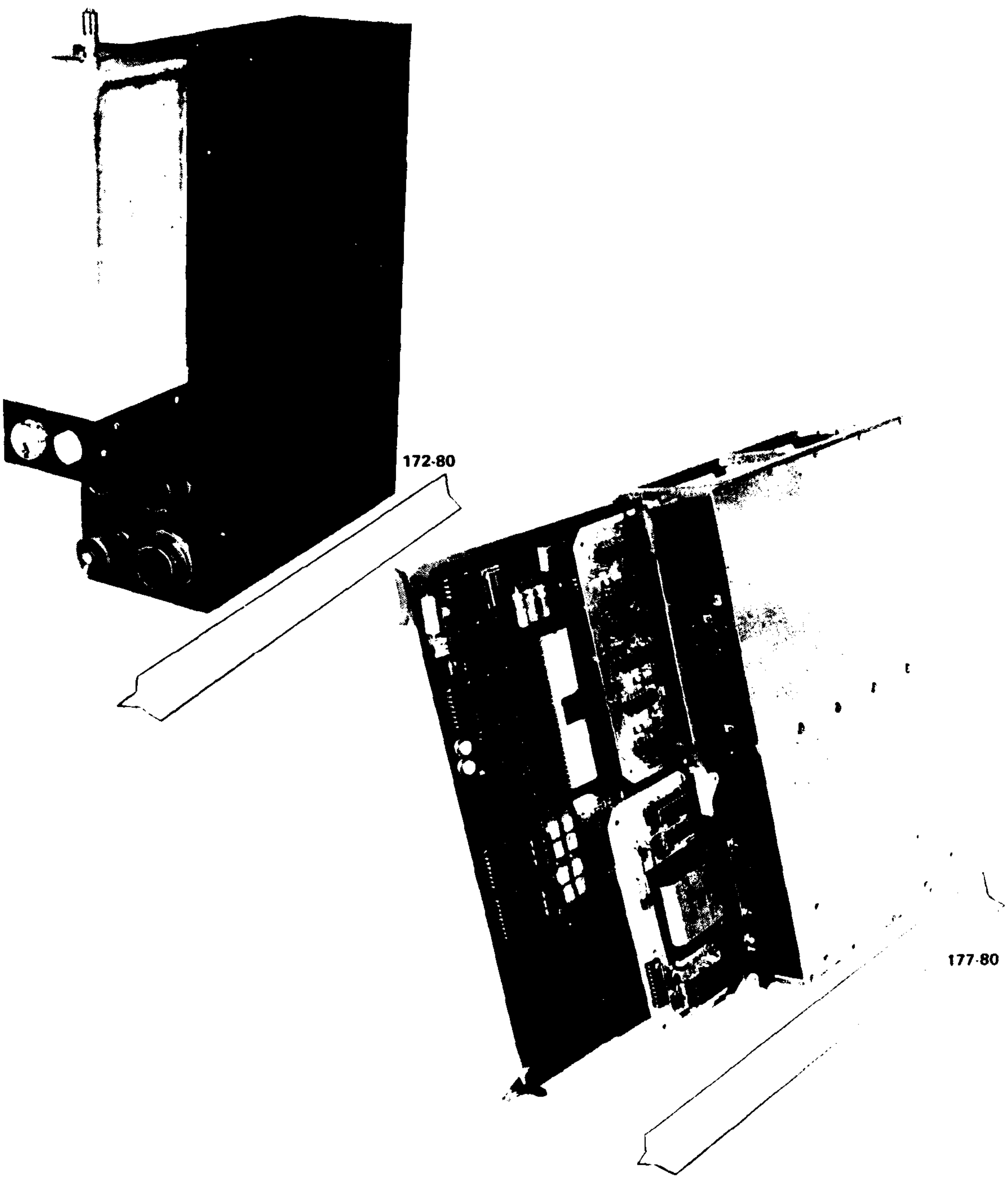


Figure A-13. Player pack enclosure and instrumentation.

successful, with the enclosure capable of withstanding the force of a 250-pound (117 kg) player falling on it.

A-6.3 Selecting a DC Power Source.

Since the player pack is to be man portable, it must operate from a battery. The battery must be lightweight and capable of powering a player pack for 8 to 10 hours of continuous use. In order to minimize operational costs, a cost/benefit analysis was performed to select a suitable power source, one which is easy to operate and maintain.

A-6.4 Battery Packaging and Operation.

A silver-zinc configuration was chosen because of its minimal weight and size, high capacity, and long life cycle during recharging. The cells are connected in series, forming a battery pack that can be worn by the player on a belt-clip ammunition pouch. (See Figure A-14).

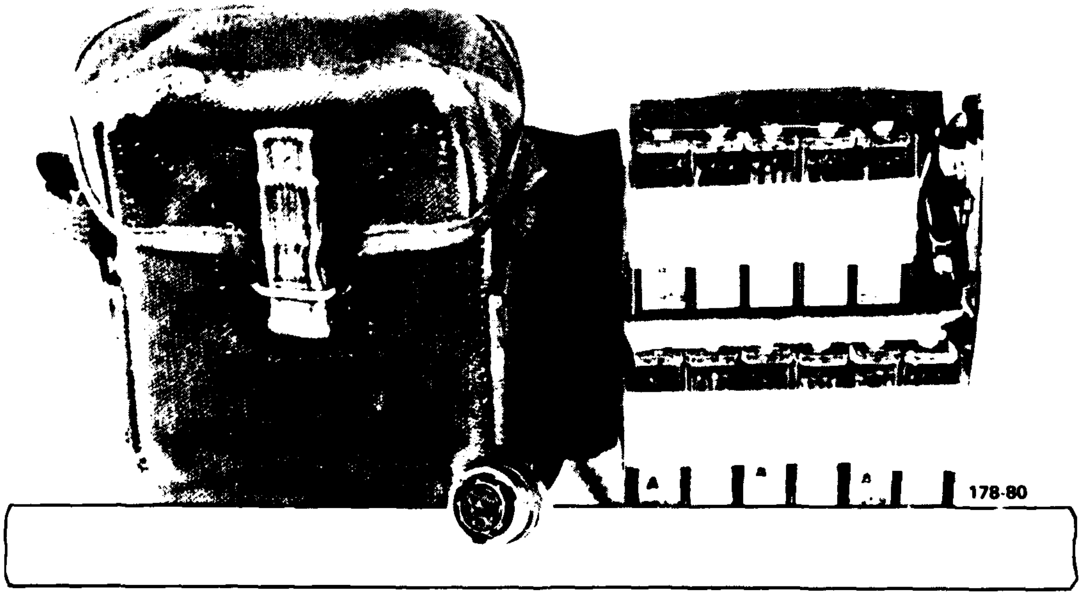


Figure A-14. Battery pack.

A ruggedized aluminum container was developed to carry 11 of the batteries, allowing it to be easily inserted or removed for maintenance. The package has adequate room for a fuse, a posture sensor, and 1/4 inch (6.3 mm) of foam which cushions the batteries from external damage. A connector interfaces the batteries to the player pack, with a complete package weighing less than 4 pounds (1.8 kg.). The final battery selection is still open, as low cost primary batteries are rapidly being developed and a final decision will not be necessary until FY 1982.

## A-7. RF SUBSYSTEM.

The RF subsystem is comprised of transceivers operating at 1350 to 1400 MHz and a communications interface unit. The basic function of the system is to provide a communications link between master station and players in the TNFS3 scenario. Operating in a second mode known as transponder, the RF subsystem employs the use of a transponder position location card and is used to obtain range measurements between players and fixed-location repeater towers. For a more detailed explanation of the transponder mode of operation, please refer to Appendix A, Section A-8 of this report.

As shown in Figure A-15, the RF subsystem has three main components: (1) master station RF unit, (2) repeater tower, and (3) player transceiver. All three units operate at the same frequency.

The RF transceiver, shown in Figure A-16, is used at the master station, repeater towers, and player packs. It provides an output pulse at 1350 to 1400 MHz (tuning range) approximately 2.0 microseconds long each time a command to transmit is given.

The transmit and other control lines to the transceiver operate at standard logic levels, thus enabling the transceivers to be easily interfaced to the digital electronics. The CIU used for RF communications, (Figure A-17) takes cares of formatting messages which are transmitted and decodes incoming pulses from the transceiver. Peak power output of the RF units is 20 watts nominal.

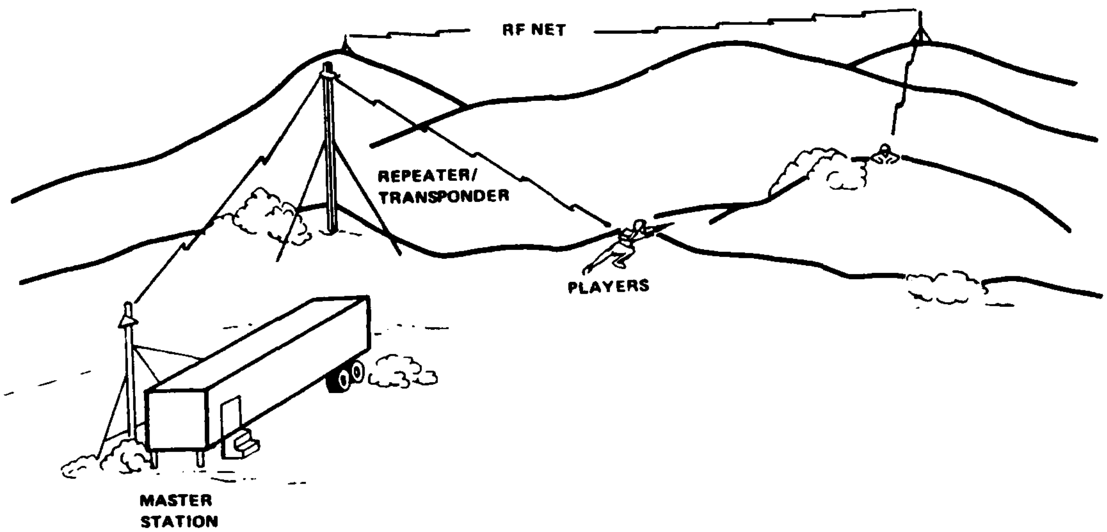


Figure A-15. RF subsystem network.

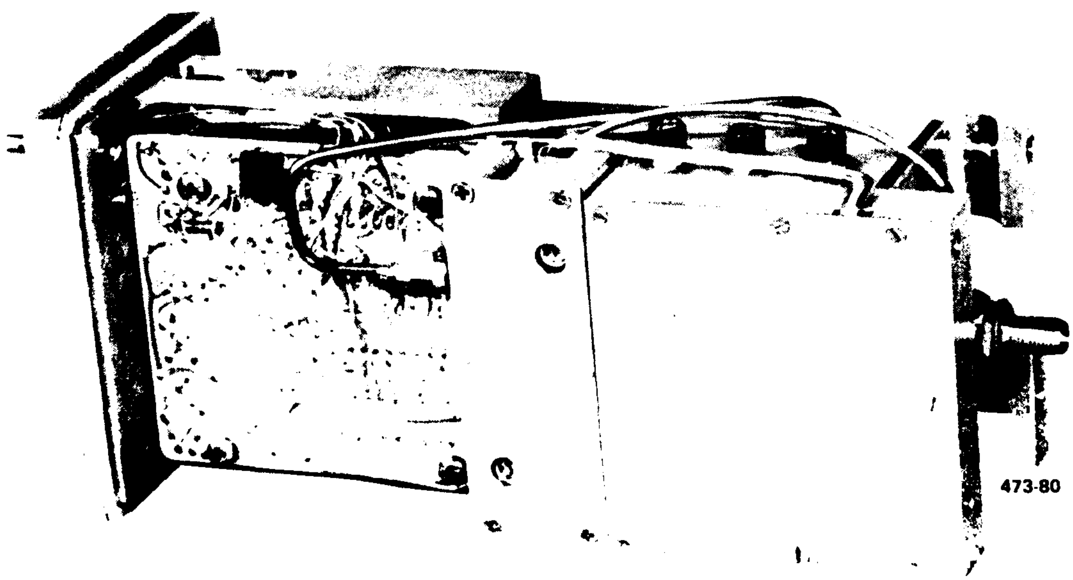


Figure A-16. RF transceiver.

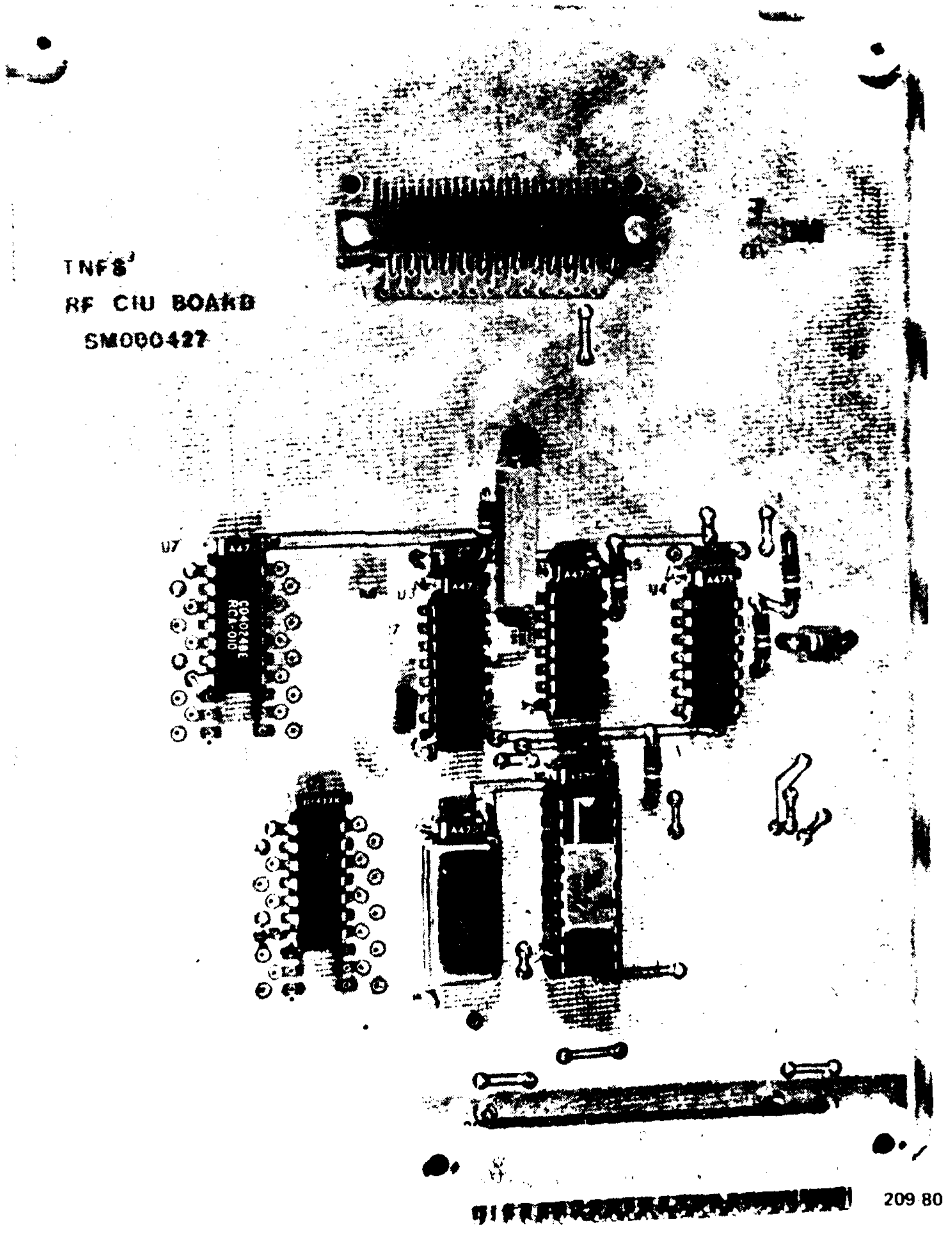


Figure A-17. RF communications interface board.

## A-8. TRANSPONDER POSITION LOCATION CIRCUIT (TPL).

### A-8.1 Operational Description.

The TPL uses a time-of-flight/triangulation method of determining position location. The TPL process begins by having the player pack send unique RF signals to each of the transponder towers, which respond by sending a signal back. The TPL card originating the signals then determines the time of flight to each of the towers. This time-of-flight data is then passed to the player pack microcomputer. The computer knows the location of all the transponder towers so it can later determine its own location based on the tower distances.

The TPL card can operate in four modes: repeater, transponder, interrogator, and direct range. The master station sends a message that each player pack decodes and then tells the TPL card which mode to be in. The towers are in either the repeater or the transponder mode; the player packs can be in either the transponder, the interrogator, or the direct range mode.

In the repeater mode, the TPL card retransmits every message it hears. In the transponder mode, the TPL card watches for a specific message (its own ID message) and waits for a fixed delay, and then retransmits that message. In the interrogator mode, the TPL card sends out the tower ID and starts a timer. When the tower responds with that ID, the TPL card turns off the timer and stores the elapsed time (minus the fixed delay time). The direct range mode is the same as the interrogator mode except the ID that is transmitted is one of another player rather than one of a tower. This mode is useful in finding the range between two players who are not within range of at least four towers (such as within a building). The direct range mode is also useful as a check to determine if two players are in line of sight with each other.

The position location (PL) cycle begins with a start message from the master station, simultaneously starting both the player packs and the towers. The players are told which transponder (either towers or other players) they should interrogate and how long the PL cycle will last. The next message from the master station commands the specified players and towers to begin the PL cycle. The towers then switch (under control of the tower's microcomputer) from the normal repeater mode to the transponder mode and stay in that mode until the PL cycle is over (the TPL time-out indicates the end of the cycle). The players involved in the PL cycle enable their TPL to begin its interrogation mode while the other time tells the TPL circuit when the PL cycle is over. The player pack is in the transponder mode until it is time to be an interrogator, it then interrogates the assigned towers (or players). After it has completed its interrogations the player pack goes back to being a transponder. When the PL cycle is over, the player pack stays in the transponder mode and waits for the next master station message.

A-8.2 Functional Description.

The heart of the TPL circuit is the microprocessor, shown in Figure A-18, an 8748 single-chip controller. The 8748 has built-in ROM and RAM providing a very efficient, low cost design. The 8748 can be controlled to handle several of the board's functions including: power cycling, input and output to the player-pack computer, storing the IDs of the transponders to be interrogated, storing the range data, and controlling the analog-to-digital converter.

The range counter block is made up of a 75-MHz clock and several high speed counters and gates (ECL and TTL). The range clock counts the time-of-flight to and from the transponder with 6.6-nanosecond resolution. The data collected by the range counter is stored in the microprocessor. The interface control block is made up of gates and multiplexers. The block handles the data traffic between the TPL card and the player pack microcomputer.

The ID verify block handles the recognition of any ID the TPL board might be looking for. The TPL card must be able to recognize its own ID and it also must be able to recognize the ID of any transponders it is interrogating. In order to be recognized, the ID is loaded into the ID verify block by the 8748 microprocessor, the TPL card then watches the received pulse input for the required ID. When this ID is seen, the ID verify block sends a stop-count signal to the range counter indicating that

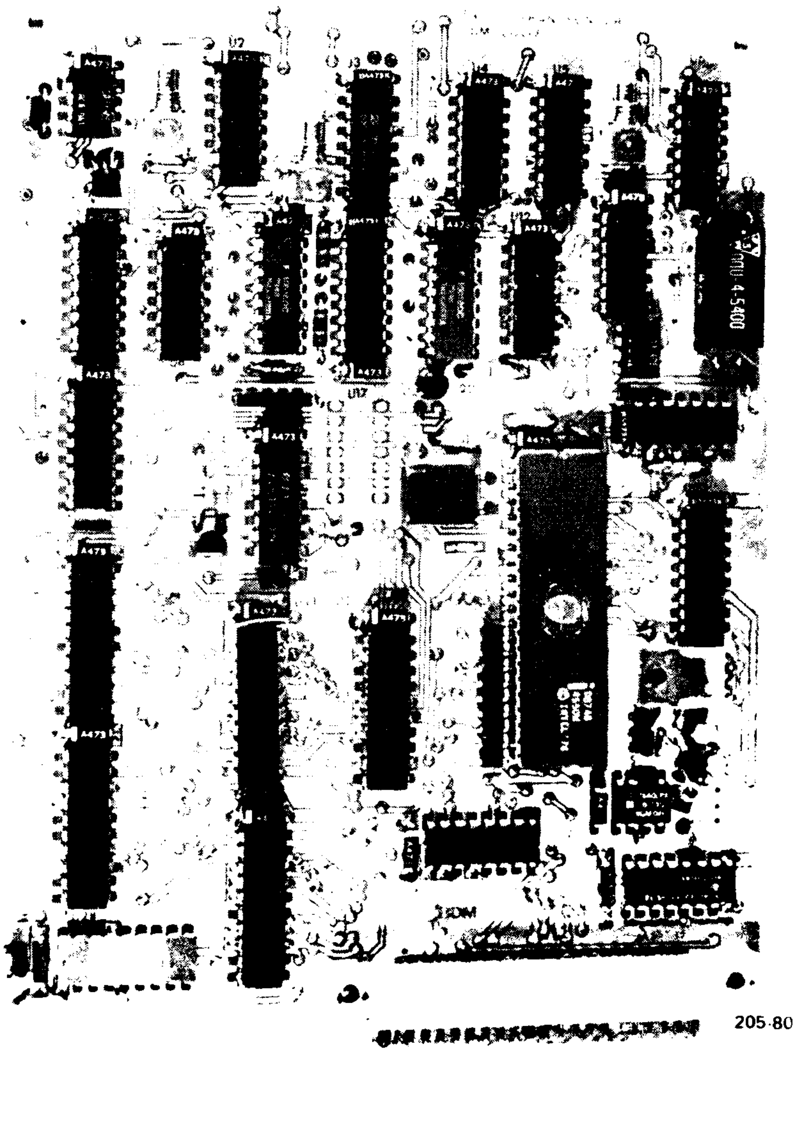

Figure A-18. Transponder poisition location board.

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THEATER NUCLEAR FORCE SURVIVABILITY, SECURITY AND SAFETY INSTRU--ETC(U)
DEC 80 T J ANDREWS, D R MORROW, H J TAUSCH DNA001-80-C-0083
UNCLASSIFIED BDM/TAC-80-619-TR DNA-5347F-1 NL

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the measurement of time-of-flight should cease. The analog-to-digital (A/D) block is used to digitize the signal strength of the return pulses. The A/D is controlled by the 8748 microprocessor, which tells the A/D to sample the return pulses and then store the data. The data are later used by the player pack computer to correct for range errors that are caused by fluctuations in signal strength.

### A-8.3 Circuit Description.

The TPL circuit was designed around several constraints. The player pack is man portable so it must be as compact as possible. This constraint leads to the requirement that the TPL circuit must fit on a single small card (approximately 6 by 7 inches). The man portable constraint also requires that the power consumption of all the circuits be low. The high accuracy constraint of the TNFS3 requirements dictates the use of high speed circuitry on the TPL card. These various constraints produced many novel design approaches in order to get a complex but small, low power but fast, TPL design. The end result is a circuit that combines the density of large scale integration (LSI) components with the the speed of emitter-coupled logic (ECL), and transistor-transistor logic (TTL) components with the low power consumption of CMOS and low-power Schottkey components.

## A-9. KEY ENTRY AND DISPLAY UNIT.

The purpose of the key entry and display unit (KENDU) is to provide means for a human operator to easily communicate with the player initializer (PI) or a player pack. The KENDU is designed to interface over a non-standard serial link. This serial link is similar to RS-232-C but the EIA levels (±12 volts) are not used. In-line translating modules are used so that the KENDU can communicate over standard RS-232 type interfaces with devices such as terminals and printers.

The KENDU is designed to operate in the hostile and demanding environment expected to be part of the TNFS3 scenario. The unitized and environmentally sealed keyboard surface, impervious to liquids, dust, or mud, is combined with the ruggedized packaging concept, making this device ideal as an all purpose human interface to the TNFS3 test instrumentation. Another desirable feature is high immunity to RF noise, implemented by using CMOS components in this design.

The KENDU keyboard is equipped with 40 keys and a function key which allows the operator to select and transmit up to 78 distinct characters or control characters. The KENDU character generator allows for 64 different characters to be displayed, as shown in Figure A-19.

The liquid crystal display (LCD) module is an alphanumeric 5x7 dot matrix capable of displaying 32 characters on two lines. The LCD display provides excellent viewability of the 1/4-inch characters under any lighting conditions. In poor lighting conditions, the operator can, by means of a switch, backlight the display.

The KENDU is designed to operate from a single 6 to 30-volt external power source. Power consumption is minimized since all circuitry is implemented using CMOS technology.

## A-10 PLAYER PACK SOFTWARE DEVELOPMENT.

Software is as important to modern instrumentation as hardware. It is through the software that the hardware is able to perform in a meaningful way. In other words, the instrumentation is "software driven." This applies equally to modern distributed instrumentation as well as to the older centralized architectures.

Software typically accounts for 75 percent or more of the costs incurred in an instrumentation system, and nearly all of the recurring costs are attributable to software generation. Several things have been done in defining the TNFS3 instrumentation that minimize both the initial and the recurring costs of software development. First, whenever possible, software supplied by the computer vendor is used. Second, all software is produced using modular, top-down structured programming techniques. This makes the software traceable, flexible, and maintainable. It can be easily and quickly modified as the situation demands. Finally, the computers used to form the master station and the player packs were chosen because they share a common instruction set. This commonality is true at both the coding and

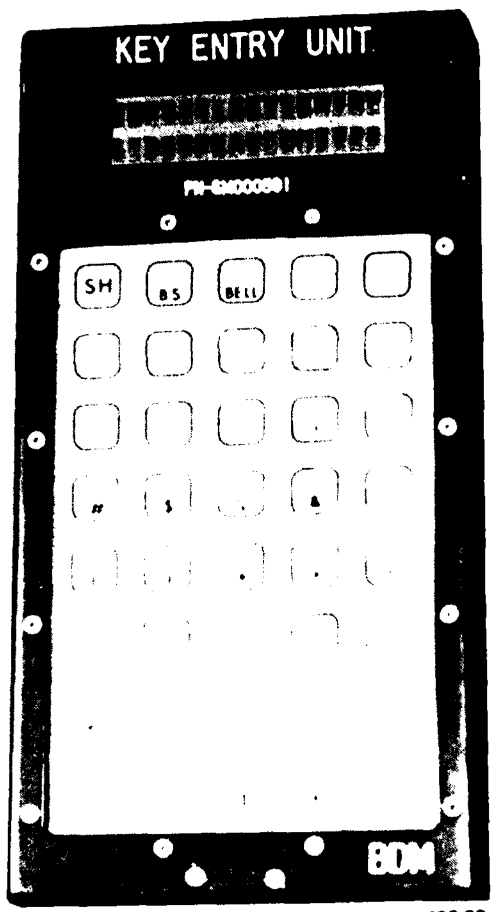


Figure A-19. Key entry display unit.

the object level. This commonality is unique and vastly reduces the total programming burden as well as providing module transportability between the master station and the player packs. This level of transportability would be only partially achieveable by use of high order languages if not for this compatibility.

A-10.1 Statement of the Requirement.

All of the requirements placed on the TNFS3 instrumentation as a whole, and implemented in the present hardware design, apply equally to the software. Fortunately, the distributed architecture of the TNFS3 instrumentation vastly simplifies the software and, consequently, reduces the associated risks.

The player pack software must handle the real-time data processing requirements of a single player and must be able to adapt quickly to changes in the player's role in the test. A change in role might be simply to change his vulnerability (i.e., body armor, etc.) or his marksmanship in order to evaluate any resultant improvements. On the other hand, such a change could involve new or different hardware modules along with the software modules for handling them. In short, the software must be highly flexible. At the same time, however, it must also be highly reliable.

Real-time processing in a test environment means a great deal more than simply speed. The processes in the computer must adapt to handle incoming player data on a priority basis. For example, position location calculation is a real-time process, but incoming weapon engagement data must cause the Real-Time Casualty Assessment (RTCA) process to be invoked immediately. If the player is assessed as a casualty, his position is of no further interest. On the other hand, if RTCA is already in progress when additional engagement data arrives, a new RTCA process must be started. In this situation, the RTCA processes should run concurrently since either could result in a "kill." Furthermore, the position location process that was interrupted must not be allowed to totally languish since the player may well be left "alive." Consequently, there are now three processes that should be executing concurrently. There are other real-time processes that must be allowed to execute in addition to RTCA and position location. Data logging, time-keeping, built-in test, RF communications, and weapon firing are examples of some of these. Thus a large number of real-time processes compete simultaneously for the resources of the player pack computer.

Finally, the software must be highly modular in order to take maximum advantage of the modular architecture of the player pack hardware. This combination of modularity in both hardware and software results in maximum flexibility.

This morass of apparently irreconcilable requirements is easily handled by a well known structure from minicomputer software known generically as a "multi-tasking operating system." This single concept, when fully implemented, provides the procedural, functional, and operational capabilities identified as requirements for the instrumentation in the scoping phase of the program.

The operating system structure automatically provides the process prioritization discussed above. It isolates the player-related computational tasks from I/O processes thereby further simplifying the production of the tasks and enhancing the overall reliability of the total software package. Device drivers appear as "plug in" modules rather than as imbedded portions of the system. These features combine to provide a very responsive system that is quickly and easily modified and still maintains a high level of reliability.

A-10.2 Functional Description.

The player software consists of three major modular elements: the operating system kernel, the requisite device drivers, and the player related processes called tasks. To change a player's role in a test, it is necessary to change only the set of player tasks. To change player type, the tasks are changed and probably the player pack hardware is changed. In this case, new device drivers are also supplied. In any case, each of the major software divisions is highly modular, making such changes quite simple. The primary goal of the software modularity is to maintain simplicity. For example: tasks need not be concerned with any I/O processing. When a task must input or output data, it simply requests the specified process of the operating system and relinquishes control of the CPU. The operating system and the device drivers handle the data transfer. Likewise, a device driver need have no concern for the ongoing computational processes. It merely transfers data as requested and then releases control of the CPU. All data transfers are interrupt driven in order to maximize total system throughput.

A-10.2.1 The Operating System Kernel. This kernel consists of six modular subsections: the memory allocation supervisor, the task control supervisor, the task scheduler, the I/O supervisor, the file manager, and a miscellaneous services module (see Figure A-20).

The memory allocation supervisor keeps track of the size and location of blocks of memory that are currently not in use and hence available to any process that needs additional memory. This dynamic allocation feature allows the player pack to work with much less physical memory than would be required without it. This in turn reduces the size, weight, and power requirements of the player pack.

The task control supervisor provides the task coordination services needed in a multi-task environment. Through this supervisor a task can: halt its execution, halt its execution for a specified time, halt its execution until a specified I/O process completes, activate another task which is halted, initiate execution of another task, schedule execution of a task at some specified future time, terminate permanently its own execution, and other functions necessary for smooth interactive process coordination. This module maintains the prioritized lists of tasks which are eligible for execution for the task scheduler.

The task scheduler is responsible for selecting the currently most important pending task and executing it. A round-robin algorithm is used to insure that low priority tasks don't get entirely "locked out." The scheduler is invoked every 50 milliseconds to prevent a task from "hogging" the computer and to provide concurrent processing. It is also invoked any time the executing task causes itself to be suspended, (i.e., "halt task" supervisor call, I/O, etc.).

The I/O supervisor is responsible for establishing and maintaining logical pathways for data transfers between tasks and peripheral devices.

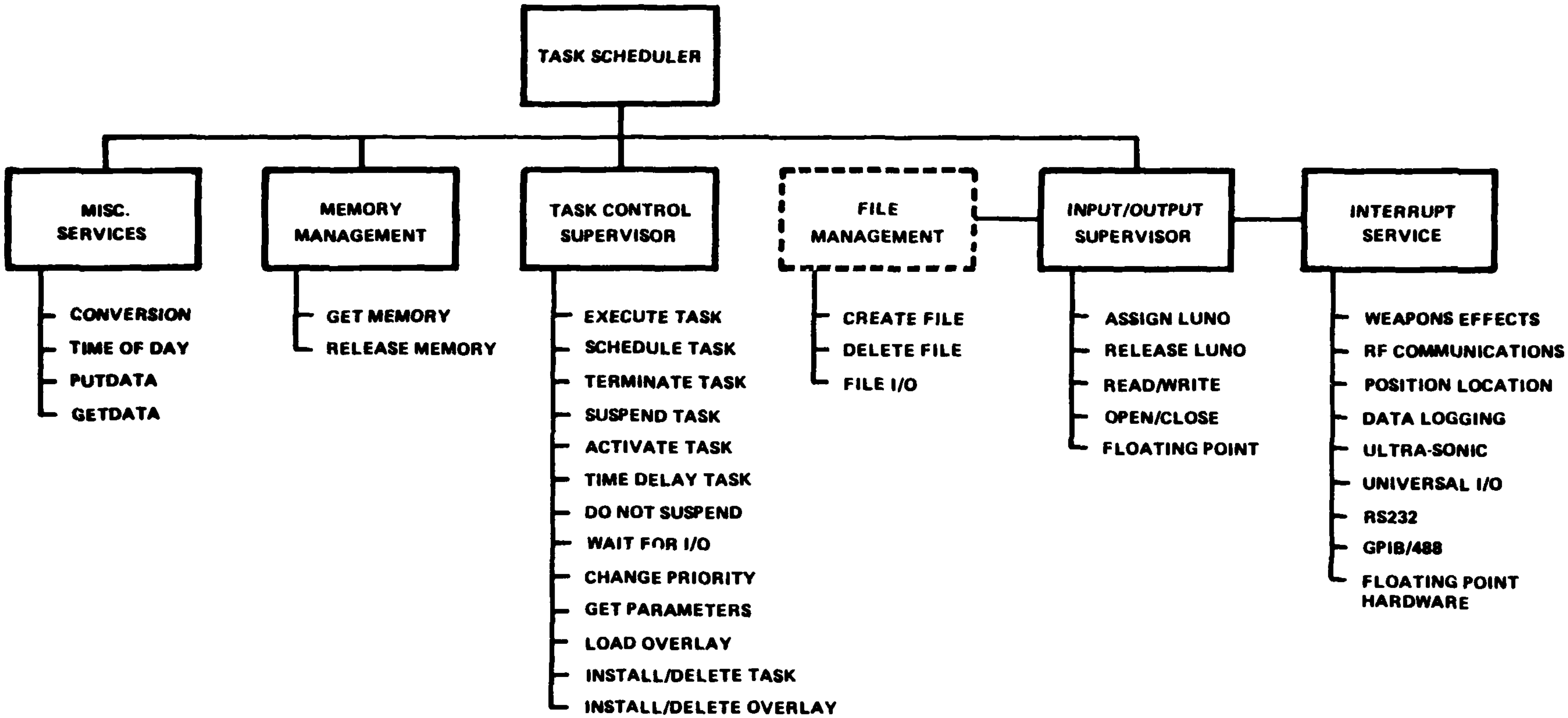


Figure A-20. Operating system kernal.

Tasks communicate with "logical" devices through the I/O supervisor rather than directly with the hardware. This assures that the data transfers always occur properly and relieves the task of the burden of manipulating the hardware. Furthermore, the means of communication is identical for all devices. This further simplifies the software production effort.

The file manager is a subsection of the I/O supervisor. Its role is to provide tasks with access to data stored in the magnetic bubble memory mass storage unit in a standardized manner. In fact, access to stored data is processed by the task in precisely the same way as access to external data via hardware is handled.

The miscellaneous services module is a catch-all collection of commonly required subroutines. It provides binary to ASCII and ASCII to binary conversions, access to the real-time clock, and intertask communication, among others.

A-10.2.2 Device Drivers. Device drivers are software modules dedicated to transferring data to and from hardware. They control the operation of the device in a manner consistent with its intended function. Each device in the player pack has an associated device driver and only those drivers needed are included in the total software package for the player.

Device drivers interface to the I/O supervisor through a rigidly defined software protocol to insure proper interaction between the operating system and the hardware. They service the interrupts provided by the hardware in a specified manner designed to maintain maximum process integrity.

The protocols defined for the device drivers are simple and short and allow such modules to be produced very quickly and easily.

A-10.2.3 Tasks. The collection of tasks installed in the player pack, shown in Figure A-21, define how the real-time player interaction data will be processed. Tasks call upon the operating system in a simple, consistent manner to request commonly needed services, drastically simplifying their production.

The tasks establish the "personality" of the player pack. There are no restrictions placed on the function of the tasks by the operating system.

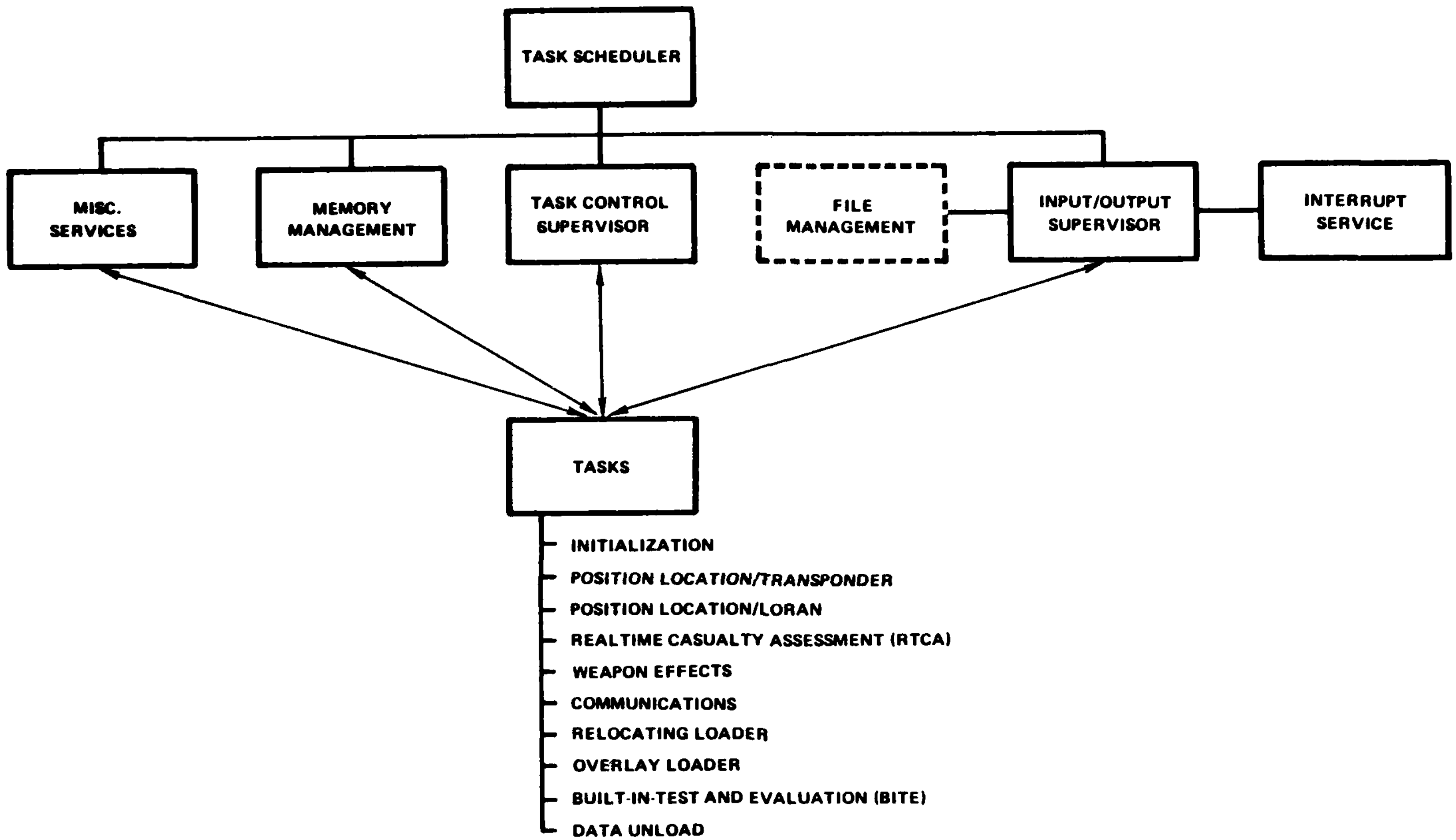


Figure A-21. Task communication paths.

# APPENDIX B
# GLOSSARY

| | | |
|---|---|---|
| A/D | - | Analog to Digital. An electronic means of converting a voltage continuous with respect to time into a number represented by a discrete set of voltage states. A continuous voltage is converted into a discrete digital word or number. |
| AMSAA | - | Army Materials Systems Analysis Activity |
| APU | - | Arithmetic Processing Unit. Provides floating point arithmetic, trigonometric functions, etc., on a single integrated circuit. Very high speed. |
| Bit | - | Unit of information equal to one binary decision, represented by a one or a zero. |
| Buffer | - | A sequence of locations in the computer's memory which are used for temporary storage of data. Used heavily when transferring data from the computer to an external device. |
| Byte | - | 8-bit packet of digital computer data. |
| CDEC | - | Combat Development Experimentation Command. |
| CIU | - | Communications Interface Unit. A module in the TNFS3 player pack which handles data conversion for both the laser weapon simulator and RF communications. |
| CMOS | - | Complementary Metal Oxide Semiconductor. Extremely low-power technology. Only a limited number of functional part types are available. Very slow operation compared to other technologies. |
| CONUS | - | Continental United States. |
| CPU | - | Central Processing Unit. In a microcomputer this refers to the microprocessor component. |
| CRU | - | Communications Register Unit. A serial data link used by the 9900 family of computers to communicate with devices external to the CPU. |

Appendix B. Glossary (Continued)

| | | |
|---|---|---|
| DMA | - | Direct Memory Access. The process of transferring information from one area of a computer to another without intervention by the CPU. It is orders of magnitude faster than CPU-controlled transfers. |
| DMAC | - | Direct Memory Access Controller. A single integrated circuit which, once initialized by the CPU, controls the DMA process. |
| DNA | - | Defense Nuclear Agency. |
| DSR | - | Device Service Routine. A software routine used to interface a device to the ECS software. An example of a DSR would be the software needed to transfer data from the computer to an external device such as the data logger. |
| DX10 | - | Operating system for the TI990 Minicomputer. |
| ECS | - | Executive Control System. The player pack microcomputer, including hardware and software, exclusive of the functional hardware modules. |
| EPROM | - | Eraseable Programmable Read Only Memory. |
| EUCOM | - | European Command. |
| GFE | - | Government Furnished Equipment. |
| GPS/ NAVSTAR | - | Global Positioning System. A position location system based on the use of synchronous satellites. |
| ID | - | Identification Code. Used to identify players, weapons, and weapon types. |
| IDF | - | Indirect Fire. Generic term referring to all military weapons except those used in a point-to-point mode, such as rifles. Examples: mortars, artillery, grenades, missiles, etc. Usually with explosive rounds. |
| ILS | - | International Laser Systems, Orlando, Florida. Awarded contract by DNA for the Weapons Effects system. |

I/O - Input/Output. Refers to the generic data transfer process. Usually implies communications between a computer and its peripherals.

Interrupt - A signal from a device outside the microprocessor which tells the microprocessor that the device is requesting some sort of service.

LOS - Line of Sight. Refers to weapons which are usually sighted on the target (rifles, etc.).

LORAN - Instrumentation developed for the purpose of determining time-correlated fixed and dynamic position locations of players.

Micro-Processor - A one-chip processing unit which contains an arithmetic/logic unit, temporary storage registers, and timing and control circuitry. Usually has a word length of 16 bits or less and an addressing capability of 65K bytes or less. Average instruction execution time is on the order of 1 to 10 microseconds.

MILES - Multiple Integrated Laser Engagement System, manufactured by XEROX for TRADOC. A weapons training device.

NMOS - N-channel Metal Oxide Semiconductor. NMOS is a logic family which is used primarily in memory applications. This logic family has a fairly high density while using relatively low amounts of power.

Operating System - The collection of software modules which control the allocation of the resources of the CPU and the external devices.

O&M - Operations and Maintenance.

PL - Position Location.

PROM - Programmable Read Only Memory. Memory which has the ability to be user programmed. Otherwise, same as ROM.

PSI - Programmable Systems Interface provides interrupts, I/O ports and interval timer for the 9900 System.

RAM - Random Access Memory. A memory which can be read from or written to in approximately the same amount of time. Used to store data which must be changed.

Real-Time Clock - Hardware external to the microprocessor which interrupts the processor on a periodic basis. The real-time clock can be used by the computer's operating system to implement such functions as time slicing and time of day.

RFCIU - Radio Frequency Communications Interface Unit.

ROM - Read Only Memory. A memory that is used for storage of fixed programs or data. Retains its information when power is turned off. Contents cannot be altered. Contents set during manufacturing.

RTCA - Real-Time Casualty Assessment. A computer algorithm which determines the probability that an engaged player has been killed.

Subroutine - A section of code which is used frequently can be placed into a form such that any program which needs the service can "call" the subroutine. The use of subroutines can result in a considerable savings in memory requirements.

Task - A computer program which performs some computational function. An example of a task in the TNFS2 player pack application would be the real-time casualty assessment calculation.

Appendix B. Glossary (Concluded)

| | | |
|---|---|---|
| Task Scheduler | - | The software module which determines which tasks in the system should become active and at which priority they should execute. |
| TI | - | Texas Instruments. |
| TNFS3 | - | Theater Nuclear Force Survivability, Security, and Safety. |
| TRADOC | - | U.S. Training and Doctrine Command. |
| TSEM | - | Transportation Safeguards Effectiveness Model. |
| TTL | - | Transistor-Transistor Logic. A logic family characterized by its input/output features. Very commonly used. |
| USAFE | - | United States Air Force in Europe. |
| VEGA | - | VEGA Precision, Vienna, Virginia |

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