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155-mm ARTILLERY REARM MODULE II, UNICHARGE, PHASE II

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A summary of the design, fabrication and tests for an improved 155mm Artillery Rearm Module, Unicharge (ARM II/Uni) is presented. This module is an improvement over a 155mm ARM fabricated and tested under previous contract (DAAA21-88-C-0161). The design and fabrication effort involving building a unit that automatically handled and transported projectiles and bare (unpackaged) XM230 unicharges for artillery rearm. Included was the automatic indentification of projectiles and fuzes. The testing of the unit included a safety/human factors evaluation at Aberdeen Proving Ground and a technology demonstration feasibility test with soldiers from the Field Artillery at Ft. Sill, OK.

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CONTENTS **Page**

TABLES

FIGURES

FIGURES (cont) Page

INTRODUCTION

This document is the phase II report for the 155-mm artillery rearm module II/Unicharge (ARM-II/Uni). U.S. Army Armament Research, Development and Engineering Center (ARDEC) awarded this two phase program to General Electric - Armament Systems Department, Burlington, Vt. on June 28, 1991. During the performance of the contract the Burlington facility became Martin Marietta Armament Systems. Phase I of the project was completed in November 1991 and was documented in Contract Report ARFSD-CR-92002, 155-mm ARTILLERY REARM MODULE II, PHASE I. Phase II is now completed and covered a period from December 1991 to February 1994. This report summarizes the phase II effort performed to design, fabricate and test an artillery rearm module. This project was sponsored by PM-AMMOLOG, Picatinny Arsenal, NJ.

A milestone chart of the major tasks performed on the ARM-II/Uni project is shown in figure 1. The phase I of the ARM-II/Uni program was limited to the development of the concept, a trade-study effort to select a candidate configuration and the preliminary design of the selected candidate. The trade-off study effort involved XM230 unicharge handling and storage, projectile storage orientation and access, transfer conveyor location and deployement method, and automatic munition identification concept.

The selected configuration included: a chain-ladder unicharge magazine with a separate manual upload station; two independently driven projectile magazines containing horizontally oriented projectiles restrained in carriers. The magazines allowed one-in-one access to the projectiles and operated in a high speed search mode. The configuration also had a manual swing-out and extendible transfer conveyor, which was independently powered, and came out the left (port) side of the vehicle. A 2-D matrix label reader for automatic munition identification was included. A chart of the trade study with the selected configuration indicated by solid lines is shown in figure 2. The preliminary design for this configuration was developed and presented at a Preliminary Design Review held at Burlington, VT in November 1991.

Phase II of the project involved the detail design, fabrication and testing the ARM-II/Uni. The detail design was developed and presented at a Critical Design Review in October 1992. The fabrication was completed and contractor testing began in August 1993. The contractor testing was completed in October 1993 and ARM-II/Uni shipped to Aberdeen Proving Ground (APG), MD, for a Safety/Human Factors evaluation. The APG test was completed and ARM-II/Uni was shipped to TEXCOM, Ft. Sill, OK, in early January 1994 for a technology demonstrator feasibility test with soldiers from a Field Artillery unit.

ARM-II/UNI DESCRIPTION

The ARM-II/Uni assembly was installed on a M987 Bradley Fighting Vehicle System (BFVS) and is shown with the transfer conveyor deployed in figure 3. The ARM-II/Uni assembly consists of four major components: the Transfer Conveyor Unit, the Projectile Storage Unit, the Unicharge Storage Unit and the Electrical Control System (fig. 4). The ARM-II/Uni layout has the projectile storage unit mounted on the left side of the BFVS host. The projectiles are stored with their center lines horizontal and perpendicular to the chassis center line with the fuze end pointing towards the right. The unicharge storage unit is to the right of the projectile storage unit. The XM230 unicharges are stored with their center lines horizontal and perpendicular to the vehicle center line. The conveyor unit is stowed to the left of the projectile magazine and swings out from the middle of the projectile storage unit.

In an upload operation, projectiles are manually placed on the transfer conveyor, which takes them into the ARM-II/Uni where they are automatically identified and handed off to the projectile storage units. Bare unicharges (removed from their canisters and packing) are uploaded using a separate upload station located at the rear of the unicharge magazine. In a download operation, projectiles and unicharges are automatically handed off to the transfer conveyor which brings them out for manual removal. This is done under the control of the electrical control system (ECS) which keeps track of the on-board inventory.

ARM-II/Uni Assembly and Components

The assemblies and subassemblies tree (fig. 5) provides further breakdown of the major components. For example, it shows that the projectile storage is broken down into two projectile magazines and serpentine assemblies, two drive assemblies, and a handoff assembly (fig. 6). The dual serpentine assemblies interface with the single bidirectional handoff assembly. Each serpentine assembly is separately driven by its own electric motor and gearbox, permitting one serpentine to search for a desired projectile while the other is transferring a projectile to the conveyor. Each projectile serpentine consists of an endless chain of carriers that have two sets of flexible retainers that cradle the center of gravity of either M107, M483, or M549 families of projectiles.

The tree also identifies the conveyor subassemblies as the handoff conveyor, stub conveyor, transfer conveyor and the support (fig. 7). The conveyor provides the means by which munitions are transported between the respective storage magazines and the Howitzer (or other resupply/rearm vehicles). Munitions can also be uploaded/downloaded to/from a pallet or other ground location. The conveyor system handles projectiles in both upload and download, but only transports unicharges in the download mode. The handoff conveyor extends from the download mechanism of the unicharge magazine, on the right side of ARM-II/Uni, passing through/between the common handoff area of the two projectile magazines to the inboard end of the stub conveyor. Its function for download is to accept munitions from any of the magazines and transport them to the remainder of the conveyor system. During projectile upload, this conveyor presents the projectile to the handoff mechanism to enable a controlled capture by the magazine's handoff selector mechanism. The other conveyor sections provide the means to accommodate the varied physical and operational interfaces, such as elevation, azimuth and length, presented by the mating vehicles. The weight of the conveyor is equilibrated to provide a tongue weight at the handles suitable for a one-man deployment/stowage operation.

The assemblies and subassemblies tree indicates that the unicharge storage consists of one chain ladder assembly, one box structure with upload station, a drive assembly and a download transfer mechanism (figures 8 - 11). In the magazine, two parallel runs of roller chain are connected with crossbars that drive the unicharge increments around the serpentine path. Positive control is maintained by guide surfaces that run parallel to the roller chain strands on either side of the unicharge. The magazine is five unicharge increments wide, consistent with the number of increments that are stored in the existing canisters.

The ECS consists of the electrical control unit (ECU) which is the "computer" in ARM-II/Uni, two motor control units (each able to control two motors), a power distribution box, and the munition identification decoder (fig. 12). Also included are the handsets, motors, sensors, actuators, cables, and software required to provide an interface with the operator and to control the operation of the ARM-II/Uni.

ARM-II/Uni Block Diagrams and Basic Functions

The functional relationship of the various components can be seen in the block diagram of ARM-II/Uni (fig. 13). The sensors have been left off the diagram for clarity. Note that the two projectile magazines are driven, independently, by their respective motors. The motors are powered by the ECS and provide speed (from the motor tachometer) and magazine location (from the gearbox resolver) to the ECS. The projectile handoff unit is mechanically coupled to either projectile magazine by the magazine selector on command from the ECS. Similarly, the unicharge magazine is driven by its own motor which is powered by the ECS from speed and position feedback signals. While the upload door is operated manually (with the appropriate electrical interlocks), the download mechanism is driven by the unicharge magazine on command from the ECS. Finally, the diagram also shows that the conveyor has its own motor, powered by the ECS based on speed and position feedback signal.

Projectile Download Function

This function (fig. 14) involves the operator keying in a download order via the remote handset. Depending on the location(s) of the projectiles needed to fill the order one or both magazines will be indexed to bring the projectile(s) in position to be transferred to the handoff unit. When a magazine has brought its projectile to the right position, the ECS will command the magazine selector to couple the handoff unit to that magazine. Both magazine and handoff unit moving together will cause the projectile to be stripped out of the individual carrier and place it onto the conveyor.

In the meantime the ECS has ensured that the conveyor is empty, via the position check sensors and has stopped the conveyor momentarily to accept the projectile. Once the handoff is complete the conveyor will start and the electronic inventory updated. When the conveyor is running the ECS continuously monitors the tray full and the collision avoidance sensor and commands that the conveyor stop if a projectile is detected at the collision avoidance sensor while the tray contains a projectile. The operator removes the projectile from the load tray.

The initial timing sensor on the stub conveyor is not directly involved in the download process. It is shown as an example of the built-in-test (BIT) process. The ECS monitors the initial timing sensor to ensure that it detects the projectile as it is downloaded. If the projectile is not detected the ECS stops the motors, turns on an indicator lamp to alert the operator and sends a "sensor failure" signal to the remote handset to clue in the operator. All the sensors with the exception of the collision avoidance and the grommet sensor have some BIT capability. These two sensors are checked on a periodic basis by the operator.

Projectile Upload Function

This function (fig. 15) involves the operator keying in an upload order via the remote handset. The conveyor starts as soon as the operator presses START on the remote handset. Simultaneously the magazines will index to bring an empty space into position to accept a projectile. While the magazines are moving, the ECS uses the empty carrier sensor to confirm that the empty spaces, according to the electronic inventory, are indeed empty.

Meanwhile the operator places a projectile onto the load tray and pushes it onto the conveyor belts. The conveyor belts transport the conveyor up into ARM-II/Uni. The grommet sensor ensures that the projectile has had the rotating band protective grommet removed. The profile sensor, in conjunction with the initial timing sensor, verify that the projectile has been placed correctly (fuze end first) on the conveyor. As the projectile is detected by the initial timing sensor, the conveyor is decelerated to a stop if neither magazine is ready or continues to transport the projectile into position for handoff. When the magazines are ready the conveyor moves the projectile into the handoff unit area.

The fuze light source and video camera are triggered and the fuze label is sensed when the fuze is detected by the fuze sensor. Shortly after, the projectile light source and video camera are triggered and the projectile label is sensed when the label is in position. The munition identification portion of the ECS proceeds to decode the labels to identify the fuze and the projectile.

The conveyor continues to run until the base of the projectile is detected by the initial timing sensor. The conveyor then decelerates until the base is located between the two position check sensors, which verify that the projectile is ready to be transferred. At that time the ECS will command the magazine selector to couple the handoff unit to a magazine. Both the magazine and the handoff unit moving together to take the projectile off the handoff conveyor and snap it into the empty carrier. The electronic inventory is updated.

Unicharge Download Function

This function (fig. 16) starts by the operator keying in a download order via the remote handset. The conveyor starts to run and the magazine indexes to bring the demanded unicharges in position to be transferred to the handoff conveyor. When the magazine has brought the unicharges to the right position, the ECS will command the download select to couple the download mechanism to the magazine. Both magazine and download mechanism moving together to take the unicharges out of the magazine and to place them onto the conveyor.

In the meantime the ECS has ensured that the conveyor is empty, via the conveyor clear sensors and has stopped the conveyor momentarily to accept the unicharges. The download mechanism opens the download door fully and deposits the unicharges on the conveyor. The conveyor belts start, the electronic inventory is updated and, once the unicharges are out of the way, the download door closes. When the conveyor is running the ECS continuously monitors the tray full and the collision avoidance sensors and commands that the conveyor stop if a group unicharges is detected at the collision avoidance sensor while the tray still contains unicharges. The operator removes the unicharges from the load tray.

Unicharge Upload Function

This function (fig. 17) involves the operator keying in an upload order, including the unicharge identification data, via the remote handset.

The unicharge chain-ladder starts as soon as the operator presses "start" on the remote handset. The chain-ladder continues to move to bring an empty space into position at the upload door to accept a group of five unicharges. Once an empty space is properly positioned the chain-ladder motion stops, the door latch is release, and a "door ready" light comes on to signal the operator.

Meanwhile the operator opens the unicharge packaging canister and removes the first packing disk. He then places the open canister on the staging tray next to the upload door. He presses on the upload door, once the ready light has come on, and the upload door opens. The operator pulls the five bare unicharges from the canister onto the upload door by pulling on the canvas strap that comes looped around the unicharges. The door is closed by the operator and the ECS, using the full bay sensors, verifies that the five unicharges have been loaded and latches the door closed. The electronic inventory is updated and the chain-ladder is positioned to the next empty space. If there are not five unicharges, the door does not latch and opens as soon as the operator releases it. At that point the operator can add unicharge(s) as required.

ARM-II/Uni Operator Controls and Interfaces

The operator controls and interfaces can be categorized into four groups. The first group are the controls and interfaces used to deploy and stow the conveyor. The operational requirements for the conveyor dictated that it be as long as possible and still be stowable within the envelope of the host vehicle. Additional length was permitted by supporting the conveyor on a carriage that slid forward during stowage (fig. 18). During deployment and stowage the conveyor is supported by an equilibrator. When stowed the conveyor is secured to the travel rest and during up/download operation the conveyor is resting either on its foot or its rubber pad at the outboard end. The operator controls that are involved in the deployment and stowage of the conveyor are shown in figure 19.

The second group of operator controls and interface are used during the (electrical) powering up of ARM-II/Uni and the upload and download processes. These controls and interfaces are shown in figure 20. The majority of the communication between the operator and the ECS take place on the handset (fig. 21). ARM-II/Uni has two handsets: a view handset at the crew station in the host vehicle cab (fig. 22) and a remote handset that is attached to the end of the conveyor during operation and stored in the cab for transport.

The planned function for the view handset in the cab is to provide "in-route" capabilities. The two in-route capabilities are allowing an order to be entered prior to arrival and docking thereby expediting the download process, and to allow interrogation of current inventories to provide information to other resupply, transport, command or user elements. The remote handset is the one that is generally used to command the ARM-II/Uni. The operation of both handsets is similar and will be discussed along with the "menus" later in this report.

The third group of operator interfaces are the emergency-stop and interlock (fig. 23). These were provided for safety considerations. The fourth group of operator interfaces are the backup manual drive for the magazines and conveyor that could be used in a emergency/degraded operation (fig. 24).

ARM-II/Uni Handset and Menus

The handset, in particular the remote handset, is the primary operator interface with the ARM-II/Uni. The handset (fig. 21) has a 75 by 125 mm (3 by 5 in.) liquid crystal display formatted such that the arrangement of information is consistent, regardless of the application (upload, download, menu selections, etc.). The display areas common to all of these applications include:

- Menu or operational task title, centered at the top of the display.
- Menu options/data field area in the central area.
- Procedure/prompt/message area at the bottom.
- Reserved area in the upper left for the "Control" indication.
- Single line cursor box including a caret (>) symbol to designate a selected Menu option or a selected munition.

The handset has a numeric/control-function keypad to accept commands. The functions of the individual keys is explained further in figure 25.

Menu for Download

The download operations are the same for both projectiles and unicharges. After power is turned on to the ARM-II/Uni at the crew station, an operator takes control at the remote handset by touching the TAKE CONTROL key. By default, to speed up the download process, the selected menu option automatically comes up as DOWNLOAD so that the operator needs only touch ENTER. The display then switches so the operator can decide between PROJECTILE or UNICHARGE. Operator touches ENTER to get projectiles or scrolls to UNICHARGE then touches ENTER to get unicharges.

The display changes to show the onboard inventory so that the operator can choose the type and quantity of the items to be downloaded. While the download of unicharges and projectiles must be entered as separate orders, the operator can enter a multiple order consisting of different types and/or lots of projectiles or for unicharges from different lots. Touching the START key initiates magazine and conveyor motion. The requested items are delivered in order that they arrive at the transfer or download mechanism. The sequence of displays for a projectile and a unicharge download order are shown in figures 26 and 27 respectively.

Menu for Upload

The upload operations are also similar. After power is turned on to the ARM-II/Uni at the crew station, an operator takes control at the remote handset by touching the TAKE CONTROL key. The operator scrolls to UPLOAD and touches the ENTER key. The display then switches so the operator can decide among PROJECTILE AUTO IDENT (where ARM-II/Uni automatically reads the projectile and fuze identification from the labels applied on the munition), PROJECTILE MANUAL IDENT (where the operator manually identifies the projectile and fuze using the handset), and UNICHARGE. For automatic projectile identification the operator needs to only touch START, which initiates magazine and conveyor motions. The display switches to indicate that the upload process is ongoing.

For the manual projectile identification and unicharge (which is always manual identification) the displays switches so that the operator can identify the type, then the lot, of the munitions being uploaded. While the identification is manual, the ARM-II/Uni system will count the munitions being uploaded. The operator has responsibility that the munitions being loaded is indeed that which was manually identified. Figures 28, 29 and 30 show the sequence of displays for a projectile automatic identification, projectile manual identification and a unicharge upload order respectively.

Additional Menu Options

The additional options available to the operator are inventory, menu format, lot number cross-reference and maintenance functions. The inventory option is used to view the onboard inventory (fig. 31). The onboard inventory is listed by munition type and lot number as well as by projectile and fuze combinations. The lot identification shown on the display is by a single letter designator. The single letter lot designator is also used on the download and upload menus. The primary reason that the single letter is used is so that the information of the item, such as a fuzed projectile, can all fit on one line (using 40 characters/line). The full 14 character lot number information is kept in the electronic inventory.

The menu format option is available to the different users for selecting the ammunition nomenclature between model numbers or DODIC numbers (fig. 32). In the upstream portions of the ammunition supply chain the ammunition is usually identified by the Department of Defense Item

Code (DODIC). The end user usually identifies the ammunition by the model number. ARM-II/Uni allows the format selection to be easily changed as well as allows separate formats for upload or download.

The lot number identifier cross-ref option is used to view the cross reference between the local one letter designator and the full 14 character lot number (fig. 33). A group of lot numbers and corresponding 1-letter designator were arbitrarily selected for the ARM-II/Uni tests. The identification labels on the projectiles and fuzes used in the ARM-II/Uni tests contained the full 14 character lot number.

The last menu option is used to obtain maintenance type information. The information includes total projectiles and unicharges uploaded, total ARM-II/Uni operation hours (analogous to a mileage odometer) and BIT status (fig 34).

Special Event and Message Display

The handset also displays special messages (figures 35 and 36) to help the operator properly diagnose and recover from events that are outside the normal operation. These events include the misread of projectile identification label, the pushing in of an emergency-stop button while operating, the operator placing a projectile incorrectly on the conveyor, and the detection of an equipment problem by the BIT process.

Menu Selection Flow

The flow through the menus starts with the MAIN MENU and, once the operation is completed, ends with MAIN MENU. This flow of the menu selections is shown in figures 37 and 38.

Maintenance Control Panel

The maintenance control panel (fig. 39) is not intended for use during normal upload/download operations. The function of this set of controls is to facilitate certain maintenance operations and to coordinate certain degraded (download) mode operations in case of the loss of higher ECS functions or the loss of power.

DESIGN REQUIREMENTS

The following is a list of requirements derived from the statement of work (SOW) or believed by Martin Marietta Armament Systems to be a necessary goal to meet the intent of the SOW, but not explicitly specified. The specification numbers refer to the paragraph numbers of the contractor A10284 Prime Item Development specification where these and additional requirements are documented. Reference to ARM-I is to a prior effort under contract number DAAA21-88-C-0161. Included is a discussion with regards to the ARM-II/Uni satisfying the requirement.

1. The ARM-II/Uni will be mounted on a GFE chassis (SOW 3.7.1). Spec. 3.1.2.1: The host vehicle for ARM-II/Uni will be the multiple launcher rocket system (MLRS) chassis - M987. The host vehicle (stationary) attitude during upload or download): (a) roll angle: ±20% (11.3 degrees) side slope, (b) pitch angle: ±20% (11.3 degrees) grade. The host vehicle transport profile: (a) roll angle: ±40% (21.8 degrees) side slope, (b) pitch angle: ±60% (31 degrees) grade, (c) speed: to 65 km/h (40 mph), (d) acceleration: 0 to 48 km/h (30 mph) in 20 seconds, and (e) deceleration: 32 km/h (20 mph) to 0 in 8.5 m (28 ft).

ARM-II/Uni was tested for upload and download operation at the ±20% slope and grade attitudes.

A physical control problem (handling) of the projectiles in the handoff conveyor area, when operating on a 20% side slope, was corrected by adding a section of high friction material to contact the outside diameter of the projectile. Another physical control problem of the projectiles between the load tray and the extendible conveyor, when uploading with the conveyor at maximum elevation and with ARM-II/Uni on a 20% grade, was corrected by the addition of telescoping guide rails on the extendible conveyor. With the addition of the high friction pads to the handoff conveyor and the guide rails to the extendible conveyor, ARM-II/Uni can upload and download projectiles over the ±20% side slope and grade envelope.

The two physical control (handling) problems with unicharges occurred during downloading when the ARM-II/Uni was on the 20% slopes or grades. This resulted in unicharges either getting "speared" on a guide on the handoff conveyor or getting jammed in the transfer forks of the handoff mechanism. Adding a lead-in to the guide and increasing the amount of time the conveyor belts stop to wait for the unicharges did not improved the situation enough to provide for operation at the 20% slope. Due to budget and time limitations, and that the unicharge performance was satisfactory at the reduced envelope of ±10% grade or slope, no corrective action was implemented other than restricting unicharge upload or download to 10% grade or slope maximum.

The transport profile was not tested by the contractor and only used as a design guide. The transport profile was tested at APG up to 40% side and grade, and an emergency stop at 55 km/h (35 mph) without any problems. A speed limit of 50 km/h (30 mph) was placed for safety reasons based on the BFVS behavior (unrelated to ARM-II/Uni) under an emergency stop. The APG test results indicate that the BFVS automotive characteristics and performance are not substantially different from the M993 Multiple Launch Rocket System with the M270 Launcher.

2. Input power will be 24 VDC (SOW 3.1.5). Spec. 3.1.2.1.3 - Input electrical power: (a) voltage: 25 ± 7 volts direct current (Vdc), (b) current: 300 amperes maximum. (The host vehicle provided for ARM-II/Uni has two 300-amp generators and four 12 volt 100 amp-hr batteries).

The electric voltage and current data was obtained as the various motors were operated. During these contractor tests, ARM-II/Uni was powered by an auxiliary power supply such that the supply voltage could be controlled. The current from the power supply to the ARM-II/Uni was monitored and initial results peaked at 530 ampere (table 1). Additional current draw was experienced when operating at low ambient temperatures such that the upload/download rate was reduced. To improve the performance at the lower operating temperatures, the conveyor gearbox lube was changed from SHC-634 (as shipped from the gearbox vendor) to SHC626, a light gearbox lube better suited for lower temperatures. With the lighter lube the peak current is estimated to be 450 ampere. The goal to keep current to 300 ampere could not be met, however the current required was within the capacity of the electrical system of the host vehicle.

The operation of ARM-II/Uni was tested at a low supply voltage setting of 18 VDC. Many ECU resets (restarts) were experienced and the conveyor rate decreased significantly, especially as more projectiles were placed on the conveyor. The ARM-II/Uni would not operate at 18 VDC. The ARM-II/Uni operated satisfactorily when the supply voltage was raised to 20 VDC (based on very limited testing at this voltage setting) The ARM-II/Uni operated satisfactorily with an elevated supply voltage of 32 VDC.

3. The ARM-II/Uni will interface with all self-propelled Howitzers (SPH), including Paladin, under all firing positions/conditions (SOW 1.0 (3)). Spec. 3.1.2.2.1. The ARM-II/Uni shall interface with: (a) SPH - M109A2/A3, (b) SPH - M109A6 (Paladin), (c) Cargo Carrier - M548, (d) FAASV - M992, (e) 2-1/2 Ton Truck, (f) 5 Ton Truck, and (g) Heavy Expanded Mobility Tactical Truck (HEMTT) - M977/M985.

ARM-II/Uni tested satisfactorily with a M109A2/A3 and a 2-1/2 Ton Truck (figures 40 through 42). The vehicle interface tests at APG were performed satisfactorily with the M109A6 (Paladin), the M977 HEMTT and M1089 (PLS). The TEXCOM test at Ft. Sill demonstrated the interoperability of ARM-II/Uni with the M109A6 (Paladin), the Palletized Loading System (PLS) flatrack - grounded), the M977 HEMTT, and the 5-Ton truck.

4. The ARM-II/Uni will handle the projectiles listed in SOW 3.1.1, 3.2.3. Spec. 3.1.2.3, .4: The ARM-II/Uni shall handle the projectiles (fuzed or with lifting plug) listed in table 2 and shall handled the fuzes (installed on projectiles) listed in table 3.

ARM-II/Uni was designed to handle all projectiles listed in the table and was tested using available inert M107, M483 and M549 projectiles. The tests were performed with lifting plugs and with fuzes. The lifting plugs used included the type G lifting plug and the shock attenuating plug with its wide flange. The inert fuzes used included the M577 and the M739.

ARM-II/Uni compares the projectile and fuze identification for compatibility (table 3) and alerts operator of incompatible combinations.

5. The ARM-II/Uni will provide separate storage for unicharge (SOW 3.1.1, 3.1.2). Spec. 3.1.2.5: ARM-II/Uni shall handle unicharge, model number XM230, ARDEC drawing number 12945131.

The unicharges are stored in a magazine separate and independent from the two projectile magazine. The unicharges are uploaded directly into the magazine using a unicharge upload door located at the rear of the magazine. The unicharges are downloaded using the same conveyor used for projectiles.

6. The ARM-II/Uni will increase the upload and download rate to 20 projectiles (of one type) per minute (SOW 3.2.1). Spec. 3.2.1.3.4 and 3.2.1.6.4.1: The ARM-II/Uni shall have an upload cyclic rate that can be manually adjusted up to 20 projectiles per minute. This rate is applicable when loading one type of projectile into an empty magazine and assumes a crew size that is capable of providing projectiles to the conveyor at rate. The ARM-II/Uni shall have a download cyclic rate that is manually adjustable up to 20 projectiles per minute. This rate is applicable when downloading from a magazine filled with one type of projectile and assumes a crew size that is capable of removing the projectiles from the conveyor at rate.

The projectile upload cyclic rate (machine rate with no hold ups from either the operators or from a multiple-attempt at automatic munition identification label read) into empty magazines was measured at 20.0 to 20.4 projectiles per minute.

While the upload rate can be slowed down by a four-position switch on the maintenance panel, the magazine selector clutch has a tendency to stick at half and slow rates. Since the normal operation is with the switch at fast rate and the machine upload rate does not affect the operator, the problem was not fixed due to time/budget considerations.

The projectile download cyclic rate from full magazines was tested at 18.0 to 18.1 projectiles per minute. The slower download cyclic rate was attributed to longer safety delays in the download process to ensure that the longest projectile would always clear the handoff forks. Possible corrective actions, such as increasing the nominal projectile magazines and/or conveyor motor speeds, were not implemented due to budget and time constraints especially since the projectile download effective rate exceed expectations.

Cyclic rate is defined as the machine rate with no hold ups from either the operators or from projectile-type searches. This rate can be measured using a magazines filled with projectiles of one type. The projectiles are then downloaded in sequence with no time spent in the magazines searching for the next projectile. Effective rate is defined as the machine rate with no hold ups from the operators but does include the time for the magazines to search for the next round. This rate is affected by the number of projectile types, their quantity and their distribution in the magazines.

7. The ARM-II/Uni will increase the download rate to a minimum of 12 projectiles per minute of a defined mix of four types of projectiles. Download rate requirement will not apply after the magazine becomes half empty. Spec. 3.2.1.6.4.2: The ARM-II/Uni shall have a download effective rate that is manually adjustable up to a minimum of 12 projectiles per minute average. This rate is applicable when downloading a minimum of number of projectiles while the ARM-II/Uni, initially filled with equal quantities of four (maximum) projectile types, is still at least half-full. It also assumes a crew size that is capable of removing the projectiles from the conveyor at rate.

A series of downloads were performed to determine the projectile download effective rate. The load mix consisted of four types of projectiles either randomly distributed throughout the magazines or grouped together by types evenly between the two magazines. The download order consisted of requesting eight projectiles, either all of one type or two each of the four types. The two times measured were point (elapsed time between first and last projectiles passing fixed point on the conveyor) and total (time from conveyor motion start to last projectile of the order on the load tray). These times are converted to rates by dividing the point time by the number of projectiles delivered minus one and by dividing the total time by the number of projectiles delivered. The rates based on point time and on total time are 16.8 and 12.8 projectiles per minute respectively (figs. 43 and 44).

The point time has very little "overhead" and is better measure of the projectile magazine search and transfer time. The download rate calculated on the point time is somewhat independent of the number of projectiles in the download order. The total time has the conveyor travel time included as an overhead. The rate based on the total time will tend to vary with the size of the download order. The rate will improve as the size of the download order increases and approach the rate based on the point time for very large download orders.

8. Spec: The ARM-II/Uni shall accept projectiles with projectile nose towards ARM-II/Uni and shall deliver projectiles with projectile base away from ARM-II/Uni (Same orientation, projectiles are not turned around in ARM-II/Uni.)

ARM-II/Uni receives and delivers projectiles with the fuze end towards ARM-II/Uni. There is a profile sensor that checks projectile orientation. If a projectile is oriented wrong, the conveyor will stop, the indicator light will come on, and the handset will display an error message and instructions to back the projectile out.

9. ARM-II/Uni can be operated by two people assigned to the ARM-II/Uni and a minimum of manpower at the loading point and Howitzer (ARM-I SOW C.3.4.4.1). Spec. 3.2.1.2.1: The conveyor shall be deployable and stowable by two operators. As a goal, the conveyor shall be deployable and stowable by one operator.

The conveyor was deployed from a stowed position, azimuth was adjusted, length extended and support foot dropped and locked in position by one operator in 45 seconds. The process was reversed and the conveyor stowed by one operator in 60 seconds.

The conveyor "tongue" weight was measured at 23 to 36 kg (50 to 80 pounds) when fully extended (without the conveyor-hold valve). The side force required to deploy/stow the conveyor varied with ARM-II/Uni attitude (side slopes or grade) from nearly negligible when level to a worst case of 32 kg (70 pounds) on a 20% side slope (driver side up).

The conveyor deployment and stowage was tested with a M109 self-propelled Howitzer. The conveyor was swung out and extended such that the conveyor rested on the floor of the Howitzer. This could be performed with one operator except that extending and retracting the conveyor was difficult. A second operator, in the Howitzer, helping to adjust the conveyor length made the task easy. The conveyor extension range of 1015 mm (40 in.) and the required clearance with the Howitzer spades during deployment prevented meeting the goal of a 610-mm (24-inch) tolerance on the separation distance between the vehicles. The ARM-II/Uni to Howitzer separation distance was 2740 to 3050 mm (108 to 120 in.).

A preferred operating configuration with the Paladin at Ft. Sill was using the conveyor with the support foot deployed on the ground with only the load tray inside the Paladin. This permitted a larger separation distance tolerance, allowed a simpler conveyor deployment and allowed more room in the Paladin for the operators to stow the projectiles in the bustle racks.

The conveyor deployment and stowage was tested by contractor with a (simulated) PLS (Palletized Loading System) platform which is 1830 mm (72 in.) up from the ground plane. The conveyor was swung out, partially extended (with the conveyor-hold valve set to support conveyor) and raised to maximum elevation with one operator. The same operator climbed onto the platform and finished extending the conveyor then setting it down to rest on the platform. The conveyor-hold valve should be then pushed in to release the conveyor. The conveyor maximum elevation angle is such that the ARM-II/Uni to PLS separation distance was 2740 to 3050 mm (108 to 120 in.). The goal of a 610-mm (24-inch) separation tolerance was not be achieved. Additional conveyor length and extendibility would be needed to achieve that tolerance.

10. Spec. 3.2.1.2.2: The conveyor height (defined to the center line of the projectile sitting in the load tray) shall have a minimum adjustable range from 760 to 2130 mm (30 to 84 in.) from a ground plane established by the host vehicle (MLRS Chassis - M987).

The tray height from ground (as measured to the center line of a projectile on the tray) had an adjustment from 355 to 2310 mm (14 to 91 in.) as determined by the conveyor resting on the ground or raised to its maximum elevation permitted by the equilibrator stroke. Note that resting the conveyor on the ground (without the support foot deployed) is not an operational position.

11. It is desired that during upload the ammunition identification be automatically read into the ARM-II/Uni inventory system (SOW 3.4.1). Spec. 3.2.1.3.3.1: The ARM-II/Uni shall read directly the projectile identification into the inventory system during the upload process. A coded label, to contractor's format, shall be placed on the projectile and shall contain the following information: (a) National stock number of projectile, (b) Lot number of projectile, (c) Projectile weight, (d) National stock number of fuze (if

projectile is fused), and (e) Lot number of fuze (if projectile is fused); or one label with projectile information shall be placed on the projectile and one label with the fuze information shall be placed on the fuze.

The automatic munition identification function was used during most parts of the upload testing. At the start of testing the reliability of fuze identification was quite low. Since changes could not be made easily it was decided to change the logic to identify the fuze as "unknown" if fuze data was not available. Note that if there is a problem reading the projectile identification, ARM-II/Uni stops and requires operator input.

Occasionally the time required to decode a projectile label was longer than the time allotted (allotted time is based on 20 projectile/minute rate). Whenever the decode time was longer than the allotted time the upload operation would stop and an error message would be displayed on the handset. These nuisance interruptions were eliminated by increasing the time allowed. Now a long projectile data decoding causes the upload process to hesitate only momentarily. The reliability of the projectile and fuze versus the number of times the labelled ammunition has been up/download is shown in figure 45. The reduction in reliability of the projectile identification can be attributed to the projectile labels being physically damaged during uploading and downloading. The high fuze identification reliability of 97% occurred when uploading at slow rate.

The ECS compares the projectile and fuze identification data for compatibility (table 4). Any combinations not in the table will cause the upload process to stop. The handset displays, on the lower part of the screen, a "wrong fuze" message for the operator. In addition to the this message, the projectile and fuze identification data are displayed in the upper part of the screen. The operator has the choice to "back out" to make a correction (for example, to change the fuze) or to load the bad combination. If loaded, the bad combination is identified in the inventory as "wrong fuze". Note that this re-identification overwrites the projectile and fuze identification inventory data. At a later time the operator can download the bad combination(s) using the normal download procedure.

12. The ARM-II/Uni shall have manual backup munition identification. Spec. 3.2.1.9.1: **The ARM-II/Uni shall have provisions to manually enter the projectile identification, and fuze identification as applicable, in case automatic projectile identification function is degraded (e.g., when the coded label is damaged or missing).**

The projectile upload menu has the options: "projectile auto ident" and "projectile manual ident". Upon selecting the manual identification option the operator is provided a series of displays (fig. 29) so that he can identify the projectile(s) to be uploaded. Once manual identification is complete and the conveyor starts, ARM-II/Uni will count the projectiles that are uploaded.

Even when ARM-II/Uni is in the automatic identification mode and a projectile label can not be read (damaged or missing), ARM-II/Uni will stop, indicator light will come on, and the handset will provide the operator the option to manually identify the projectile (fig. 35a).

13. ARM-II/Uni will have increased ammunition loading capacity, by at least 20% (by weight) over ARM-I (SOW 1(1), 3.1.3). Spec. 3.2.2.1: The empty weight of ARM-II/Uni shall be a maximum of 2360 kg (5200 pounds), for 61 rounds configuration; 1 round equals 1 projectile and five unicharges.

ARM-II/Uni is a 64 round configuration. The above maximum weight requirement then becomes 2475 kg (5456 pound), arrived at by multiplying the above weight by 64/61. The ARM-II/Uni weight, based on measured and estimate weights (table 5) of the components is 2380 kg (5250 pound). Also given in the table is the parasitic weight ratio (pwr), where this ratio is defined as

$$\text{Parasitic Weight Ratio} = \frac{\text{ARM-II/Uni Empty Weight}}{\text{Ammo Payload Weight}} .$$

The pwr is provided for some of the components also. For example the projectile storage unit, alone, divide by the weight of 64 projectiles yields a pwr of 41%.

14. ARM-II/Uni will be designed with projectile restraining device for the transportation of projectiles listed. Spec. 3.2.1.5: The ARM-II/Uni shall provide ammunition restraint such that the ammunition can be transported over a distance of 15 miles, in tests similar to ARM-I, without detrimental effects to the ammunition. As a goal, projectile travel restraint shall limit displacement to a maximum of 13 mm (0.5 in.) when subjected to a 6.0-g static force.

Early in the detail design process some tests were performed to demonstrate an axial restraint technique that would provide 2670 N (600 lbf), e.g., approximately 6 g's, of axial restraint to artillery projectiles of various lengths. The carrier alone provided approximately 1335 N (300 lbf) of restraint, so the object was to double this restraint level by providing features to enhance restraint. After investigating several possibilities, the selection was made in which rubber pads were bonded to the carrier slightly inboard of the projectile center line. This position provides a high normal force while minimizing friction during snap-out.

Four carriers fabricated to debug the manufacturing process were used for the test. The first step was to measure snap-in force and adjust roller preload until the desired level was achieved. Then dead load tests were conducted in which the carrier was suspended vertically nose down and weights attached to the lifting plug on the projectile. With this set-up, three different projectiles were tested: M107, M483, and M549. While all of these projectiles were restrained up to 2225 (500 lbf), significant slippage was observed with some projectiles at the 2670 N (600 lbf) level. To further improve projectile retention, higher friction polysulfone rollers were tried. These rollers provided 600 lbf axial restraint for all three projectiles, meeting the ARM-II/Uni requirement. To improve rolling resistance of the polysulfone rollers, nylon sleeves were pressed into the center, thereby providing a low friction hub without reducing friction at the outer diameter.

15. Environmental requirements same as FAASV per ARDEC drawing 8837375. Operating temperature for prototype -18° to 52° C (0° to 125° F; ARM-I SOW C.3.3.1.2). Spec. 3.2.5.1: The ARM-II/Uni shall perform herein during exposure to temperatures of 0° to 52° C (32° to 125° F). This narrower range is only for the non-militarized handset planned for this proof-of-principle. As a goal, the ARM-II/Uni shall perform during exposure to temperatures of -40° to 52° C (-40° to 125° F) and after being subjected to temperatures of -54° to 74° C (-65° to 165° F).

This requirement was used as a design input but not formally tested.

SENSORS AND POTENTIAL DEGRADED SYSTEM OPERATION

Equipment that automatically handles ammunition needs a number of electronic sensors and switches that detect the position of the ammunition and the status of the equipment. The sensors and switches provide signals that are analyzed by the ECU to initiate system functions and to continually check for potential unsafe conditions. As the amount of automation increases, the amount of information that the ECU needs and therefore the number of sensors increases

The ARM-II/Uni has a number of electronic sensors and switches to detect the position of projectiles and unicharges as they are moved into and out of the magazines and travel up and down the conveyor. Where possible continuous BIT was incorporated to detect any sensor or switch failure and subsequently stop the magazine(s) and conveyor to prevent damage to the system or injury to the operator. In some situations the system can be restarted by the operator and operated in a degraded condition (for example, the operator can switch from automatic projectile identification to manual projectile identification).

Some of the functions of ARM-II/Uni which are not essential for system operation were designed so that they may be disabled if necessary to continue operations. The ability to disable these functions was not given to the operator but can be quickly implemented by Martin Marietta support personnel (or if required at a later date, by properly trained military personnel) using an auxiliary maintenance terminal. On an objective system some of these or additional capabilities to operate in a degraded mode could be given to the operator in the form of battle overrides. A summary of the sensors, ARM-II/Uni degraded operations and possible objective system degraded operations is given in table 6.

Projectile Upload Sensors

Three optical sensors are used to detect the position of the projectile at various stages of the upload operation. Two of these sensors are essential and no degraded upload operation is possible, if they are not functional. A continuous check of these sensors and their power source are made whenever the system is uploading projectiles. If a failure occurs the magazines and conveyor are stopped and the operator is advised of the failure through a message on the handset. The failure then needs to be corrected before upload can continue. On an objective system these sensors would be candidates for redundancy.

Projectile Orientation and Grommet Sensors

The projectile orientation and grommet sensors detect a situation where the operator loads a projectile incorrectly on the conveyor. A faulty sensor could erroneously signal an error condition and prevent any upload, or it could fail to detect an operational error. The projectile orientation sensor will be continuously checked and the ARM-II/Uni stopped if it malfunctions. Since the grommet sensor does not normally activate during ARM-II/Uni operation it is checked periodically by the operator.

These sensors are not essential for uploading projectiles if care is taken to load the projectiles properly. The grommet sensor and the projectile orientation sensor are functions which may be disabled. The orientation sensor did fail during the operator training at Ft. Sill. The function was disabled by Martin Marietta personnel using an auxiliary maintenance terminal until a replacement part was installed a few days later.

Projectile and Unicharge Download Sensors

In the download mode the projectile position and unicharge conveyor clear sensors are used to control timing of the mechanism to prevent collisions between munitions while maximizing the download rate. These sensors are continuously checked and ARM-II/Uni stopped if a failure occurs.

There are two levels of degraded download operation. The first level can be implemented if electrical power is still available and motor controller is still functional. The selector gates are manually set so that the magazines can be downloaded. The magazine and conveyor are then controlled using the maintenance control panel (fig. 39). Since the ECU is bypassed, there will be no selection of items to be downloaded and no update of ARM-II/Uni inventory. The ability/training to use this degraded operation was not provided to the operator in the limited training provided.

The second level of degraded download operation is implemented if there is no electrical power available. Again the selector gates are manually set so that the magazines download. In this case the magazines and conveyor are driven mechanically with auxiliary power sources, such as air-powered hand-held wrenches. Magazines and conveyor could be hand-cranked by a very determined crew. An objective system could have provisions to de-couple the motors and gear box, and optimized manual-drive gear ratios to improve this manually powered degraded operation.

Unicharge Upload Sensors

Five optical sensors are used at the unicharge upload station to confirm that five unicharge increments have been loaded before the magazine is indexed and the inventory is updated. These unicharge counting sensors are automatically checked during unicharge upload and any malfunction prevents continuation of the upload process. On ARM-II/Uni, in a degraded mode activated through an auxiliary maintenance terminal, the ECU will disregard the signal from any sensor which the BIT indicates is not functional. In this degrade mode, ARM-II/Uni continues to operate as long as at least one of the five sensors is working, but it will not confirm that all five unicharge increments are loaded into each magazine bay.

The upload door has two (redundant) interlock switches (one in each of the two electrically operated latches). The plan was for a signal from either switch to be accepted as door is closed and that, if both interlock switches failed and did not provide a door closed signal, the unicharge magazine would not run for safety reasons. The BIT which checks the status of switches also prevents the unicharge magazine from running upon detection of a problem. Inadvertently no override was provided to allow continued operation if one switch failed. During the equipment tests, starting with the rough terrain test at Martin Marietta Armament Systems, there were incidents of switch function problems which hampered the unicharge upload. These incidents were caused by a misalignment of the two interlock switches and could be mitigated somewhat by the forceful closing of the upload door. An objective system could have a battle override setting to allow continued operations with only one switch operational.

Collision Avoidance Sensors

Two sensors located on the conveyor sense the presence of a projectile or unicharges on the load tray and on the conveyor a short distance from the load tray. If munitions are sensed at both these locations in the download mode the conveyor stops to prevent a collision. If either of these sensors fails the conveyor may fail to stop, or may stop on every round.

In case of sensor failure, the collision avoidance function can be disabled through the auxiliary maintenance terminal. The download operation then continues, however the operator now has to remove munitions from the load tray before the next munition come down the conveyor.

FABRICATION AND PRODUCIBILITY

The producibility considerations were kept in mind during the design of the ARM-II/Uni. The goal was to achieve a design that could be converted to an economical production design. Component material selections are considered industry standard, that is, no exotic or critical materials were used or are foreseen for a production design. Where cost effective for the proof-of-principle, commercial components were used in lieu of Military Standard (MS) parts. Also for cost consideration, some non-militarized components, such as the handsets, were selected. The criteria used in this selection was that the component could be militarized in a production program using existing technology. All manufacturing and inspection techniques required are of a mature technology. No new manufacturing techniques need be developed. This translates into a low risk production program.

DESIGN DOCUMENTATION

The ARM-II/Uni design documentation is included on the following Martin Marietta Armament Systems drawings and associated lists.

10048500 Artillery Rearm Module, 155-mm - Howitzer (top assembly)

10048504 Artillery Rearm Module, 155-mm - Howitzer - Layout

10048550 Artillery Rearm Module, 155-mm - Howitzer - Projectile Storage Unit

10048600 Artillery Rearm Module, 155-mm - Howitzer - Conveyor Group

10048700 Artillery Rearm Module, 155-mm - Howitzer - Unicharge Storage Unit

10048800 Artillery Rearm Module, 155-mm - Howitzer - Electrical Control System

The XM230 unicharge configuration used for the ARM-II/Uni design and test was that depicted in U.S. Army Armament Research, Development and Engineering (ARDEC) drawing 12945131, dated 5 December 1990.

TESTING SUMMARY

The testing performed on ARM-II/Uni fell into two general categories: subsystem and system tests. The subsystem tests were performed as the hardware became available. The tests included the pre-assembly fit checks as well as subsystem function tests such as the projectile carrier restraint test discussed earlier in the report. Once the fabrication and assembly of ARM-II/Uni was finished in August 1993, the system testing was started. These tests were performed to determine actual performance against system specification and design goals. The ARM-II/Uni system tests consisted of:

- the contractor's Engineering System Test and Final Acceptance Test performed over the August 12 through October 13, 1993 time period;

- the ARM II/UNI Safety/Human Factors Evaluation Test performed by the U.S. Army Combat System Test Activity (CSTA) at APG over the October 28, 1993 through January 7, 1994 time period; and

- the ARM II/UNICHARGE Customer Test (Technology Demonstrator Feasibility Test) conducted by the Test and Experimentation Command (TEXCOM), Fire Support Test Directorate, Ft. Sill, OK, over the January 17 through February 11, 1994.

The total number of cycles with available munitions during the three tests was 8080 projectiles and 11,185 unicharges. The number of munitions cycled versus time is shown in figure 46.

Contractor's Engineering System Test and Final Acceptance Test

These tests were started on August 12, 1993 and were performed at the Martin Marietta Armament Systems facility in Burlington, VT and at the Ethan Allen Firing Range in Jericho, VT. These system tests consisted of mechanical and electrical system checks, host and docking vehicle compatibility tests as well as rough terrain transport test.

The total number of cycles with available munitions during the tests was approximately 2500 projectiles and 1180 unicharges. The results of these tests are documented in the Test Results Report (data item A045) submitted on January 1994. A summary of the test results is provided in table 7.

At completion of the test, new identification labels were put on the projectiles and fuzes. The ARM-II/Uni was shipped to APG with the 64 inert projectile/fuzes and 55 inert unicharges in the magazines.

There were some anomalies in the operation of ARM-II/Uni during the testing. These are grouped into mechanical, electrical and software for discussion.

Mechanical Problems and Corrections

A physical control or handling problem existed during the transfer of projectiles into the magazines when on a 20% side slope. This was corrected by adding a section of high friction material to contact the outside diameter of the projectile. The conveyor portion that contacts the rotating bands was kept as a low friction material to facilitate any required projectile axial movement by the repositioner cam during the handoff to the magazine.

A second physical control problem existed with projectiles going from the load tray to the extendible conveyor when uploading with the conveyor at maximum elevation and with ARM-II/Uni on a 20% grade. When operating at this attitude a projectile pushed from the load tray onto the extendible conveyor would bounce off the conveyor belt onto the ground. This problem was corrected by the addition of telescoping guide rails on the extendible conveyor. With the addition of the high friction pads to the handoff conveyor and the guide rails to the extendible conveyor, ARM-II/Uni can upload and download projectiles over the ±20% side slope and grade envelope.

Two physical control problems occurred with unicharges during downloading when the ARM-II/Uni was on the 20% slopes or grades. During the side slope (driver side down) operation the left-most unicharge sometimes is retarded as it rubs against the side guide of the download ramp. When the conveyor starts up, the next four unicharges push the late unicharge into the unicharge guide where it is "speared". Adding a lead-in to the guide and increasing the amount of time the conveyor belts stop and wait for the unicharges did not improved the situation enough for operation at the 20% slope. Unicharge download operation were restricted to 10% slope.

At the 20% grade (vehicle cab down) unicharges sometimes jammed while coming through the projectile area of the handoff mechanism. The "V" formed by the handoff conveyor belts is somewhat shallow (15° dictated by the projectile handoff function) and does not restrain the unicharges adequately. A unicharge can shift forward (towards the cab) and snag on the high friction section of the projectile guide. This unicharge is then turned catching in the transfer forks of the handoff mechanism. The following unicharges then press against it by the continued conveyor motion. Unicharge download operations were restricted to 10% grade.

The reliability of the automatic fuze identification was initially 72% to 82%. The problem appeared to have mechanical (camera view, focus and lighting, and trigger beam) and software (when and how data from camera is processed) causes. Since changes could not be readily made during the testing, the logic was changed to identify the fuze as "unknown" if fuze data was not read correctly instead of stopping ARM-II/Uni with an error message. Note that if there is a problem reading the projectile identification, ARM-II/Uni stops and requires operator input. At the end of the contractor testing, the camera view and lighting were adjusted, and the size of the trigger beam reduced which improved the fuze read reliability.

Three mechanical problems surfaced as the result of the rough terrain test. The first problem was that the conveyor main drive chain became loose. The tensioner had loosened, presumedly from the road vibrations. The tensioner was re-tightened and test continued. Later lockwiring provisions were added to the tensioner and it was lockwired for the APG and Ft. Sill tests. No problems were experienced with the tensioner during these tests. The second problem was that the drive/resolver gear cluster for the front projectile magazine also came loose and disengaged from the resolver. The front projectile magazine would cycle but not deliver any projectiles as no position feedback was going to the ECU. The gear cluster was re-engaged with the resolver, tightened and pinned in place.

The third problem occurred as a result of the low ambient temperatures while ARM-II/Uni was stored at the EAFR before and after the rough terrain test. The low temperatures thickened the gearbox lube such that the increased torque required resulted in diminished rate and electrical power requirements that exceeded the (software set) current limits. Later the gearbox lube for the conveyor and projectile magazines were changed to SHC626, a lighter gearbox lubricant better suited for the lower ambient temperature.

Electrical Problems and Corrections

The first electrical problem consisted of random ECU resets or restarts during operations. The ECU resets can be grouped into three classes: power-on reset, low voltage reset and timed-out reset. The power-on reset is normal, that is once at power-on. If the supply voltage gets below a certain level, the ECU stops functioning. To prevent ARM-II/Uni from starting back up in the middle of some process once the voltage is restored, the ECU is reset just like power-on. Lastly, to monitor the software processing, certain events taking place in software are watched by a "watch-dog" sequence and timed against an external (hardware) clock. If the time is exceeded, it is assumed that the software processing went astray and the ECU is reset.

The causes for random ECU resets can be negative power supply voltage spikes, electrical hardware (the external clock, the ECU enclosure wiring and ECU board subassembly, ECU chips), and software (program error such that processing does go astray). One of the first ECU reset problems was the occasional incident of continuous resets on power-on. This was diagnosed as a temperature effect on the external clock and an ECU software initialization process time close to the time-out constant. The initialization software was changed to include additional signals to the watch-dog.

The cause of most of the ECU resets experienced was not established. The primary candidate is electrical hardware involving both the chips and the ECU boards. Additional testing with different boards, if available, and with a logic analyzer attached would be required to find the root cause.

The second electrical problem involves not being able to stay within the maximums current goal and to meet the low voltage goal for ARM-II/Uni. This problem is for the most part a mechanical problem. The currents needed to power the conveyor and the magazine, especially the conveyor, were much higher than anticipated. A significant part of the power losses was in the conveyor gear box. As mentioned previously, improvement was made by changing to a lighter gearbox lubricant. This power problem increased at low voltage and the conveyor speed slowed significantly as projectiles were placed on the conveyor. On the electrical side, the ECU could not operate satisfactorily at the 18 VDC, with many ECU resets experienced.

Software Problems and Corrections

One of the first software problem involved the preselecting one of the projectile magazines for downloading whether or not it contained the nearest projectile to be downloaded. The logic error was found and corrected. Other software problems involved the displaying the handset screens and the receiving of input from the handset. These were methodically diagnosed and corrected.

Some software problems involved the recovery process from an interrupted process (for example, an emergency stop inadvertently pushed in during an upload transfer). For the most part these were diagnosed and corrected, except for the recovery from an interrupted upload or download of unicharge. The recovery from an interrupted unicharge process requires a power down and up of the ARM-II/Uni.

Another suspected software problem involves the fuze identification reliability. Part of the reliability problem appears to be related to a longer than anticipated fuze data decoding. While the fuze label is seen by the fuze camera before the projectile label is seen by the projectile camera, the fuze data is sometimes provided to the ECU's input buffer after the projectile data. The ECU logic is triggered by the arrival of the projectile data. As this timing part of the logic could not be easily changed, other parts of the logic were changed to identify a fuze as "unknown" if the data was not available.

Other software problems were encountered and corrected over the debugging process that took place during the engineering systems test which stretched over several months. These changes were numerous and were the result of the normal debug process needed to adapt the newly developed software to operation in the real world environment. These changes are expected and are part of the system integration process. On a development program such as this changes required to correct software design or code are not normally documented until after formal testing begins.

Safety/Human Factors Evaluation Test at CSTA, APG

The objective of the APG test was to sufficiently test the safety of the ARM-II/Uni and host vehicle to support a limited safety release for troop use at Ft. Sill. The test was started on October 28, 1993, and included automotive operations and soldier/machine interfaces testing.

The test was successful and ARM-II/Uni was deemed to be safe for the upcoming operational/feasibility testing at Ft. Sill subject to the following conditions: operators wear gloves, hearing protection and steel-toed footwear; vehicle not driven on slopes greater than 40% slope and at speeds not to exceed 48 km/h (30 mph); only inert ammunitions be transported, uploaded or downloaded; and, operated in conjunction with the M109A6 (Paladin), M977 (HEMTT) and M1089 (PLS) provided the terrain is reasonably level.

The additional number of cycles with available munitions during the APG tests was approximately 3000 projectiles and 950 unicharges. The ARM-II/Uni was shipped to Ft. Sill with the 64 inert projectile/fuzes and 55 inert unicharges in the magazines on January 10, 1994.

There were some anomalies in the operation of ARM-II/Uni during the testing. Again these are grouped into mechanical, electrical and software for discussion.

Mechanical Problems and Corrections

One mechanical problem involved the "spearing" of a unicharges when operating on a 20% side slope (driver side down). This problem was observed during contractor testing. Unicharge operating envelope was restricted to 10%. A second problem occurred during uploading projectiles while on a 20% side slope (driver side up). In this case the projectile bounced and rocked on the stub conveyor causing late sensing by the initial timing sensor. This caused the projectile to be stopped on the stub conveyor late and the end of the fuze being struck by the returning transfer forks. On future designs the initial timing sensor should cover more of a vertical plane instead of a narrow beam. For ARM-II/Uni the operating envelope was restricted to 10% for testing at Ft. Sill.

The engager roller on the projectile magazine selector had to be replaced during the test. The roller was subjected to severe duty arising from incorrect electrical/software timing. The timing was properly set.

Cracks in about four of the polysulfone/nylon rollers on the projectile carriers were discovered. The problem was initially thought to be caused by the press fit at assembly. It was later diagnosed as the polysulfone roller being exposed to an incompatible cleaning fluid (MEK) used when bonding on the rubber pads to the carriers. Spare rollers were obtained to be available for the Ft. Sill test. Also at the completion of the APG test four of the rubber pads had to be rebonded to the projectile carriers.

The stub conveyor belts were observed to slip or jump on the outboard gearbelt pulley under heavy load. The stub conveyor belts not only transport the projectiles along the stub conveyor but also transmit all the power to drive the fixed and extendible conveyors. The cause of the slippage is felt to be belt elongation, which requires further study. The slippage was mitigated by spacing the projectiles roughly 600 mm (24 in.) apart. After the APG test the conveyor belts were cleaned, in place, with soap and water. Some of the drive chains were tightened.

The two emergency stop buttons on the load tray where occasionally pushed in by accident as the operator handled munitions at the tray. Guards were fabricated and installed after the APG test to mitigate these nuisance emergency stops.

During the runs to try out the improvements on the fuze identification the rubber topping on one of the stub conveyor belts became delaminated from the belt core. It is suspected that some FOD ("foreign object damage") wedged between the belt and a conveyor gear alignment guide. Both stub conveyor belts were replaced.

Electrical Problems and Corrections

The handset failed to respond at the start of the APG test. During the troubleshooting/failure analysis an ECU circuit board was incorrectly installed at APG by Martin Marietta personnel and damaged several components. The ECU was returned to Burlington, VT and fixed; the original cause for the response failure was not established.

Upon return from a 160 km (100 mile) road test the high level power (for example, electrical power to the motors) was absent. The problem was narrowed to tripped circuit breaker or intermittent circuit. All circuit breakers were reset and system worked fine. There were no repeat problems of this kind. Future designs should consider additional vibration and shock isolation for some electrical components.

The fuze identification reliability continued to be in the 70-80% range. At the completion of the APG testing, this was improved by changing the fuze camera settings and by installing new (faster) fuze-decoding software in the identification decoder. New identification labels were put on the projectiles and fuzes for the Ft. Sill test.

Software Problems and Corrections

The delivery of the wrong quantity of projectiles was one of the software related problem. The logic error was isolated and the software was corrected. The second software related problem was that occasionally a projectile would be stopped on the conveyor too deep (pass the second position sensor) and still be transferred into a magazine. Some fuzes were damaged by

:

striking the end of the carrier. After the completion of the APG test this projectile-too-deep anomaly was analyzed and found to involve the logic conversion of the conveyor resolver information. The problem was corrected prior to the start of the TEXCOM test.

Technology Demonstrator Feasibility Test at TEXCOM, Ft. Sill

The purpose of the Ft. Sill test (94-CT-FS-1154) was "To examine the concept feasibility of the Artillery Rearm Module (ARM) II/Unicharge technology demonstrator. The test results will be used by the Office of the Project Manager for Ammunition Logistics (PM, AMMOLOG) to develop requirements for future field artillery resupply vehicles."

The test was started on January 18, 1994, and included a three day pre-test training of the test personnel by the contractor, a three day pilot test and the record test. The record test included: planned events to determine cyclic rate, to evaluate the inventory and delivery accuracy of the ARM-II/Uni, and to ascertain the interoperability of ARM-II/Uni with the M109A6, PLS, HEMTT and the 5-ton truck, and an operator questionnaire and post-test interview. Additional events (called test excursions) included performing the break-bulk, projectile fuzing and uploading the projectiles and unicharges.

The ARM-II/Uni was received from APG with 64 inert projectile/fuzes and 55 inert unicharges. An additional 210 inert unicharges were available for the TEXCOM tests. Two hundred of these came packaged five to a canister with a fabric strap around the group, to facilitate removing the unicharges from the canister, and a fiber cushion to take up the headspace in the canister. The configuration of these 200 included an inert igniter bag covered with a red thin-film cover at each end (fig. 47). The bags were retained in the cone shaped cavity by common cord. All the inert unicharges used during tests were ballasted to the proper weight.

The number of cycles with available munitions during the TEXCOM test was approximately 2545 projectiles and 9055 unicharges, bringing the system total to 8080 projectiles and 11185 unicharges (fig. 46.). The test was completed on February 11, 1994. Included in this report is a discussion of some of the problems that occurred, grouped into mechanical, electrical and software categories. For detailed result of the test please see the TEXCOM test report.

Mechanical Problems and Corrections

During the pre-test training the conveyor would sometimes stick in the fully extended position. It was discovered that the conveyor extension stops had been assembled incorrectly. Since the stops were not readily accessible, temporary stops were added to the guide rails and the test continued.

At high conveyor elevation, e.g., when docked with a HEMTT, the fixed/extendible conveyor belts rubbed against the conveyor support structure unless the conveyor azimuth was set to 0°. The rubbing caused belt damage and in one case delamination of the rubber topping from the belt core. The elevation joint spacing is adjustable for the drive chain tension. A new section of chain (longer) was installed and the joint spacing accordingly increased. The delamination portion of the belt was rebonded to the core with adhesive.

The performance of cable-operated azimuth release became problematic. The cable linking the release mechanism to the azimuth release lever was removed. A short cable with a ring was installed and the azimuth release function was performed near the azimuth joint.

The munition identification labels consist of 2-D matrices printed on white polyester film having an acrylic-based pressure sensitive adhesive for bonding to the projectile or fuze. To provide some measure of protection, from dirt and handling, a layer of Scotch Labelgard(tm) tape was applied over the label. The cold weather during the pre-test training was followed by warmer and high humidity weather resulting in the cold munitions becoming dripping wet from the condensation. The moisture softened the adhesive on the Labelgard such that the protective tape detached from the munitions. All the tape was removed and the labels cleaned of residual adhesive and the test continued without any Labelgard. A spot check of the label reading reliability early in the test indicated 100% projectile and a 85-96% fuze read reliability. Another spot check later in the test indicated a 94% projectile and a 75% fuze read reliability. A good portion of low fuze reliability can be attributed to dirty/poor contrasting labels. Without the protective tape the fuze labels became dirty quickly as the label is in the handhold area. Near the end of the tests the projectiles were relabelled and the read reliability returned to 100%.

During the pilot test it became evident that the 200 new unicharges would not stay bonded together. The test personnel rebonded all the new unicharges before the record test. Also the thin-film cover over the igniter bag was found to be susceptible to being easily damaged during handling. The adhesive bond appeared marginal. Once the cover became separated, the igniter bag tended to droop out of the cone shaped cavity. It is felt that the drooping of the igniter bag put axial pressure on the stack of five unicharges. This caused increased side pressure on the unicharge guides in the magazine and download ramp. Toward the end of the test about 5% of the bags actually came loose and fell off of the unicharges.

Towards the end of the test a few unicharges were crushed during download in the unicharge download ramp area. The side guide of the ramp was bent to provide more of a lead-in effect which fixed the problem. It is theorized that the increased axial pressure (addressed above) caused friction between the unicharge and the guide which caused the unicharge to be crushed.

Electrical/Software Problems and Corrections

At the system checkout the projectile orientation sensor (a proximity switch) sent, intermittently, false indication signals to the ECU causing the system to stop and giving a "sensor not clear" error message. The sensor was removed and the projectile orientation test was disabled (battle-over-ride) with the auxiliary handset. The first two days of pre-test training was performed in this condition and a new sensor was installed on the third day.

During the pre-test training, the ECU reset problems, both at power-on and during unicharge download, continued to plague the operation. The continuous or multiple resets at power-on seemed to have been aggravated by the cold ambient temperature, approximately 0° C (32° F) and low vehicle voltage. Some of the resets during up/download operations also appeared to be related to low vehicle voltage and condition improved by increasing engine speed to high idle.

The ECU resets during unicharge download where troublesome. During most of the unicharge download timeline the unicharge download door is mechanically engaged in the gate cam. If an ECU reset occurs, it is likely that it will occur during an ongoing download of a unicharge group. After the power down/up required to recover from the ECU reset, the ECU will not know that the group of unicharges is coming. The ECU will not stop the conveyor belts and the group of unicharges will be dropped onto the moving belts. Usually the left-most unicharge lags the others coming down the unicharge ramp and gets pushed sideways by the other four unicharges into the guide where it is "speared" by one of the guide rods.

Prior to the start of the pilot test, various combinations of ECU boards (the ARM-II/Uni boards and a set borrowed from another project), new and old PROM chips (all with the same version 12 software) were tried out. The best overall operation was achieved with the new PROM chips on the ARM-II/Uni boards. The remainder of the test was accomplished with this configuration. Throughout the test there was only one reoccurrence of an ECU reset during operation. There was also one incident of the remote handset failing to communicate with the ECU. ARM-II/Uni had to be powered down/up to resume operation. The cause of this problem was not identified.

CONCLUSIONS

Based on the ARM-II/Uni fabrication, development and integration tests and performance tests, it is concluded that the ARM-II/Uni proof-of-principle:

1. Meets the intent of the SOW requirements as described in the DESIGN REQUIREMENTS section of this report;

2. Demonstrated the feasibility of significantly reduced manpower and time to handle 155 mm projectiles;

3. Demonstrated the feasibility of automatic ammunition identification with the accompanied reduced time and error potential of operator keying-in data;

4. Demonstrated at least a doubling of the ammunition delivery rate of the previous ARM-I effort;

5. Demonstrated the storing, transport and delivery of bare XM230 unicharges (inert) to the self-propelled Howitzer;

6. Demonstrated that automated artillery ammunition handling rate can be increased by improving the magazine configuration. The projectile effective rate was more than doubled by incorporating dual magazines, high speed and reverse search modes, access to each projectile carrier as it passes the transfer unit, independent conveyor drive and using sensors to monitor the position of munitions and the status of equipment; and

7. Demonstrated the usefulness and safety aspects of the monitoring the proper operation of the sensors with continuous built-in-test (BIT) processes. In turn, it also demonstrated the usefulness for "soft" degraded mission continuation in the form of battle overrides that can disable either some BIT process or some non-essential sensor functions in an emergency.

RECOMMENDATIONS

Based on the ARM-II/Uni fabrication, development and integration tests and performance tests of phase II, the following recommendations are submitted to ARDEC for consideration and approval.

1. Future projectile handoff mechanism of an ARM-II/Uni nature should have a position feedback to the electrical control unit. The feedback signal is essential for the recovery after an interrupted transfer process.

2. Future designs that incorporate an initial timing sensor on a relatively short stub conveyor should be more of a vertical plane instead of a narrow beam to compensate for projectile rocking and bouncing.

3. Future (bare) unicharge conveyors of an ARM-II/Uni nature should have generous lead-in ramps and additional side guides to maintain positive control of the unicharge, especially in when passing by adjacent mechanisms. Small length to diameter ratio of the unicharge allows it to be easily turned about its center of gravity.

4. Future unicharge upload door of an ARM-II/Uni nature should have additional clearance between the unicharges and the magazine door opening to facilitate the manual upload operation.

5. Future (bare) unicharge storage units of an ARM-II/Uni nature should have a more robust low-friction applied finish. The applied finish rubbed off onto unicharge and ended up on the conveyor belts reducing the friction between belt and munition.

6. Future conveyor systems should have provisions that allow the conveyor belts be easily replaced in the field.

7. Future automatic ammunition labels should be applied to an area of the projectile which is less susceptible to label damage from both manual and machinery handling. The labels should be weather-proof from heat, cold and 100% humidity.

8. Future serial interfaces in the ECU should provide separate interrupts for the projectile and fuze label reader data. This would allow the software to delay projectile/fuze identification until all data is received and prevent the race condition which resulted in many unidentified fuzes. Planned increases in speed of the label decoding system will help prevent these delays form reducing the upload speed of the system.

Table 1. ARM-II/Uni system input power

Mode	Current* (ampere) @ 24 VDC
Standby (ECU only)	13
Motor hold	25
Conveyor (empty)	155 (estimated at 80 with SHC-626)
Conveyor (5 projectiles)	250 (estimated at 170 with SHC-626)
One projectile magazine (in high-search)	140
Two projectile magazines (in high-search)	280
Unicharge upload	80
Unicharge download (with conveyor)	175
Conveyor (full) and two projectile magazine in high speed search	530 (estimated at 450 with SHC-626)

* Current data filtered at 1.0 Hertz; data with SHC-634 in the gearboxes.

Table 2. ARM-II/Uni projectile list

DODIC Number	Model Number	Type (Description)	Drawing Number
D501	M692	ADAM-L	9298315
D502	M731	ADAM-S	9298316
D503	M718	RAAM-L	9317586
D505	M485	ILLUM	9214510
D506	M116A1	HC/BE	8885162
D509	M741	RAAM-S	9317588
D513	M804	PRACTICE	9331794
D514	M741A1	RAAM-S	11786242
D515	M718A1	RAAM-L	11786217
D528	M825	SMOKE	E15-12-259
D529	M795	HE	9329573
D544	M107	HE(DC)	75-14-449
D547	M116	SMK GRN	9227998
D548	M116	SMK HC	9227998
D549	M116	SMK RED	9227998
D550	M110A1	WP	9217030
D551	M116	SMK YLW	9227998
D562	M449A1	ICM	8875850
D563	M483A1	DPICM	9215220
D579	M549A1	RAP	9235999
D864	M864	BASE BLEED	9272016
(TBD)	XM898	SADARM	9395803

Table 3. ARM-II/Uni fuze list

DODIC Number	Model Number	Type (Description)	Drawing Number
N278	M564	MTSQ	10534285
N285	M577A1	MTSQ	9352381
N286	M582	MTSQ	(TBD)
N289	M762	ET	12551000
N290	M767	ET	9258605
N291	M732A2	PROX VT	11716451
N340	M739	PD	9258605
N463	M728	PROX VT	11718400
N464	M732	PROX VT	11716451
N659	MK399	MOD 1 (MOUT)	5918048
(TBD)	XM773	MOFA	9258605

Table 4. ARM-II/Uni projectile/fuze compatibility *

		Fuze DODIC	N278	N285	N286	N289	N290	N291	N340	N340	N463	N464	N659	N
Projectile		Model	M564	M577A1	M582A1	M762	M767	M732A2	M739	M739A1	M728	M732	MK399	XM773
DODIC	Model	Desc.	MTSQ	MTSQ	MTSQ	ET	ET	PROX VT	PD	PD	PROX VT	PROX VT	MOUT	MOFA
D501	M692	ADAM-L		X		X								
D502	M731	ADAM-S		X		X								
D503	M718	RAAM-L		X		X								
D505	M485	ILLUM		X		X								
D505	M485A1	ILLUM		X		X								
D505	M485A2	ILLUM		X		X								
D506	M116A1	HC/BE		X		X								
D509	M741	RAAM-S		X		X								
D513	M804	PRACTICE	X		X				X	X		X		
D514	M741A1	RAAM-S		X		X								
D515	M718A1	RAAM-L		X		X								
D528	M825	SMOKE		X		X								
D529	M795	HE	X		X		X	X	X	X		X	X	X
D544	M107	HE(DC)	X		X		X	X	X	X	X	X	X	X
D547	M116	SMK GRN		X		X								
D548	M116	SMK HC		X		X								
D549	M116	SMK RED		X		X								
D550	M110A1	WP	X		X		X		X	X				X
D551	M116	SMK YLW		X		X								
D562	M449A1	ICM		X		X								
D563	M483A1	DPICM		X		X								
D579	M549A1	RAP			X		X	X	X	X				X
D864	M864	BASE BLD		X		X								
D	XM898	SADARM		X		X								

* This table documents the projectile/fuze compatibility used in the ARM-II/Uni software only. It is not indended to convey overall projectile/fuze compatiblity.

Table 5. ARM-II/Uni weight budget

Description	Qty	kg	lb	pwr(a)
Artillery Rearm Module (with payload)	1	6140	13530	
Artillery Rearm Module (empty)	1	2380	5250	63%
Projectile Storage Unit	1	1190	2625	41%
Structural Assembly (545 lb)	2	495	1090	
Drive Components (230 lb less motor)	2	210	460	
Serpentine Component List (420 lb)	2	380	840	
Handoff Assembly	1	107	235	
Unicharge Storage Unit	1	500	1095	58%
Box Assembly	1	270	595	
Drive Components (less motor)	1	59	130	
Chain Ladder List	1	157	345	
Download Transfer Assembly	1	11	25	
Electrical Control System	1	250	542	(fixed)
Electrical Control Unit	1	11	24	
Hi-level Unit (59 lb)	2	54	118	
Motor (29 lb)	4	53	116	
Enclosure	1	34	75	
Power Distribution Box	1	21	46	
Crew Station & Remote Handset	1	2.2	5	
Maintenance Panel	1	4	8	
Label Reader (Cntr, Lights, Cameras)	1	17	37	
Sensor List	1	1.4	3	
Actuator List	1	5	10	
Cable List	1	45	100	
Conveyor Group (manual)	1	300	656	(fixed)
Handoff Conveyor	1	22	49	
Drive Components (less motor)	1	40	87	
Stub Conv/Support Assy	1	89	195	
Equilibrator Assembly	1	23	50	
Transfer Conveyor (less docking head)	1	89	195	
Load Tray Assembly	1	36	80	
Pallet Structure (b)	1	150	332	(fixed)
Vehicle Structure Assy (c)	1	168	370	(fixed)
Payload		3760	8280	
Projectile @ 100 lb/ea	64	2906	6400	
Unicharge @ 5.7 lb/ea	330	854	1880	

(a) pwr = parasitic wgt ratio = (empty wgt) / (payload wgt)
(b) 130 mm (5 in.) pallet assembly directly under storage unit
(c) vehicle (MLRS) adapting structure; not included in ARM-II/U wgt.
(d) shaded values indicate measured wgt; others are calculated.

Table 6. ARM-II/Uni Sensors and potential degraded operation

SENSOR	ARM -II/U DEGRADED OPERATION	OBJECTIVE SYSTEM DISCUSSION
Projectile Position (Upload) Initial Timing; Limit #1; Limit #2	None - replace sensor	Candidates for redundant sensors
Projectile Orientation (Upload) & Grommet Detection	Disable with Aux Maint Term [(a)]- operator resp. for correct upload	Candidate for operator set battle-overide
Five Unicharge Detect (Upload)	Set to one with Aux Maint Term - operator resp. for full unicharge row	Candidate for operator set battle-overide
Uni Door Interlock (Upload)	Redundant - signal for either of two switches accepted as good	
Label Reader Trigger (Upload)	Operator enter munition ID	Candidate for hand-held reader
Projectile Position & Uni Conveyor Clear (Downld)	Go to MANUAL download - bypass computer. Download all.	Candidate for various levels of degraded operation, included some inventory control
Collision Avoidance (Downld)	Disable with Aux Maint Term - operator resp. for collision avoid.	Candidate for operator set battle-overide
Empty Element Detect	None - replace sensor	Candidate for redundant sensor

[(a)] Aux Maint Term is a hand-held device that plugs into ECU

Table 7. Summary of ARM-II/Uni test results

Parameter/ Test Point	Requirement/ or Goal	Results (Remarks)
Projectile cyclic rate		
Upload	20/minute	20.0 to 20.4
Download	20/minute	18.0 to 18.1 (No corrective action planned as Effective Rate is OK)
Proj. effective rate		
Download	12/minute	16.8 to 17.0 (projectiles pass a fixed point) 12.5 to 13.4 (start to last projectile on load tray)
One proj. download		
Best position		9 seconds
Worst position		22 seconds
Unicharge Cyclic Rate		
Download	60/minute	61.1
One unicharge 5-group download: Best pos.		12 seconds
Worst position		173 seconds
Conveyor Deployment	One operator	One operator to ground and PLS, Easier with two operators with Howitzer.
Separation Distance	± 12 inches	± 6 inches (Limited with Howitzer by 40" conveyor extension and clearance with the Howitzer spades; limited with PLS by maximum conveyor elevation angle.
Automatic Munition Identification		
Projectile		97% reliability.
Fuze		Initially 72-82% reliability, improved to 85-96% @ Ft. Sill
Host Vehicle Attitudes	20% Grade/ Side Slope	20% for projectiles; limited to 10% for unicharges.
Elect. Power Supply	18-32 VDC/ 300 ampere	20 VDC minimum; estimated 450 ampere

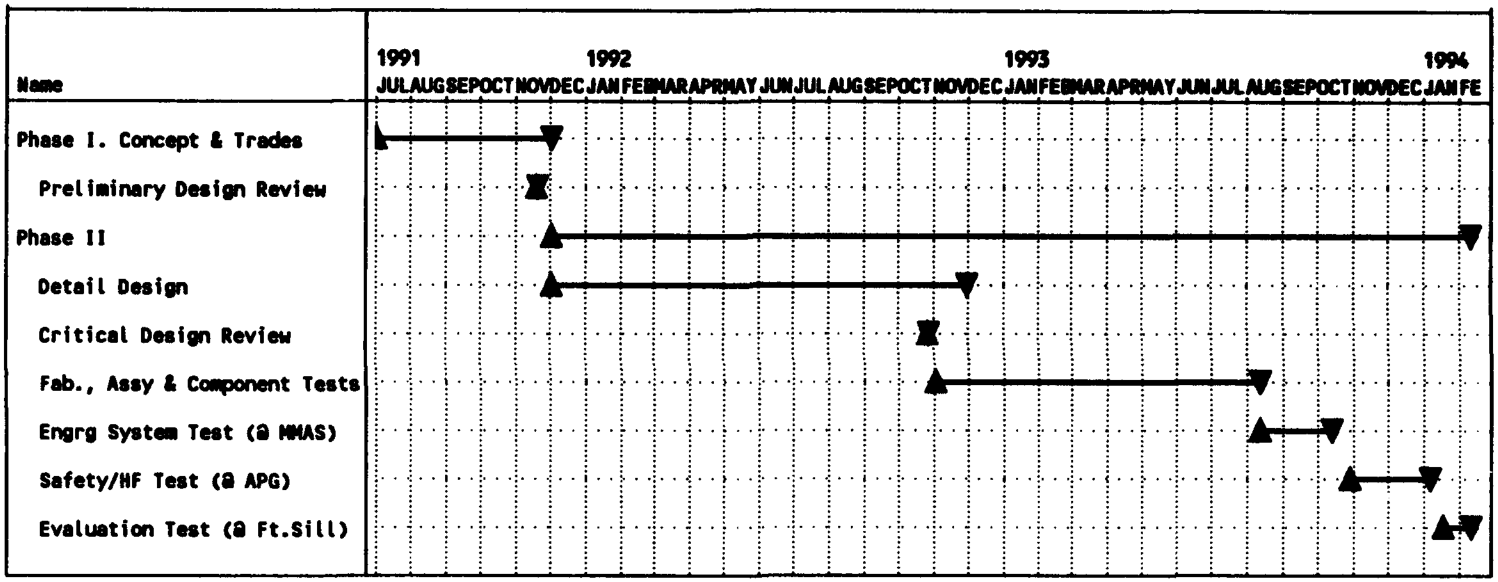


Figure 1. ARM-II/U project timeline and milestones

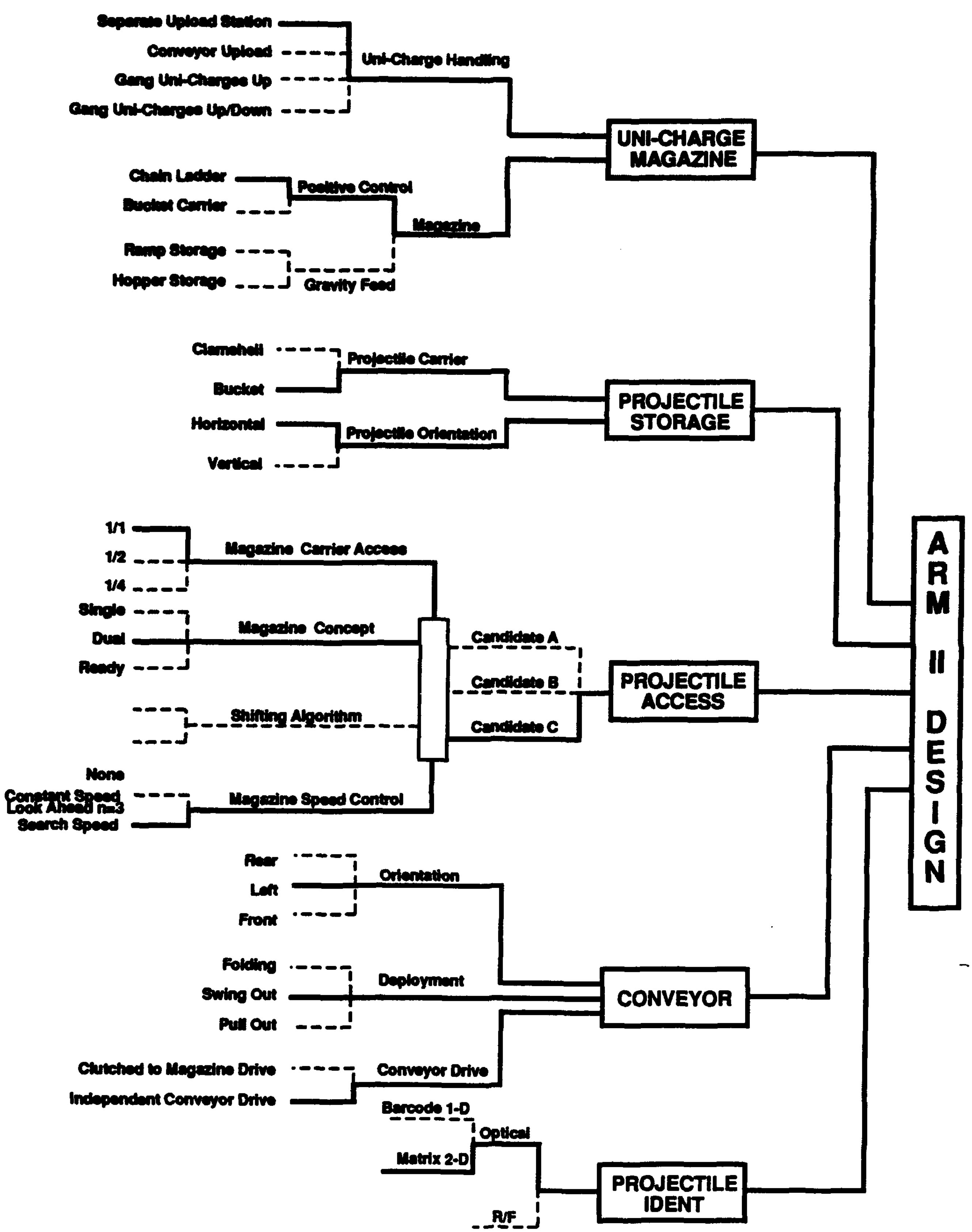


Figure 2. ARM-II/U concept trade study

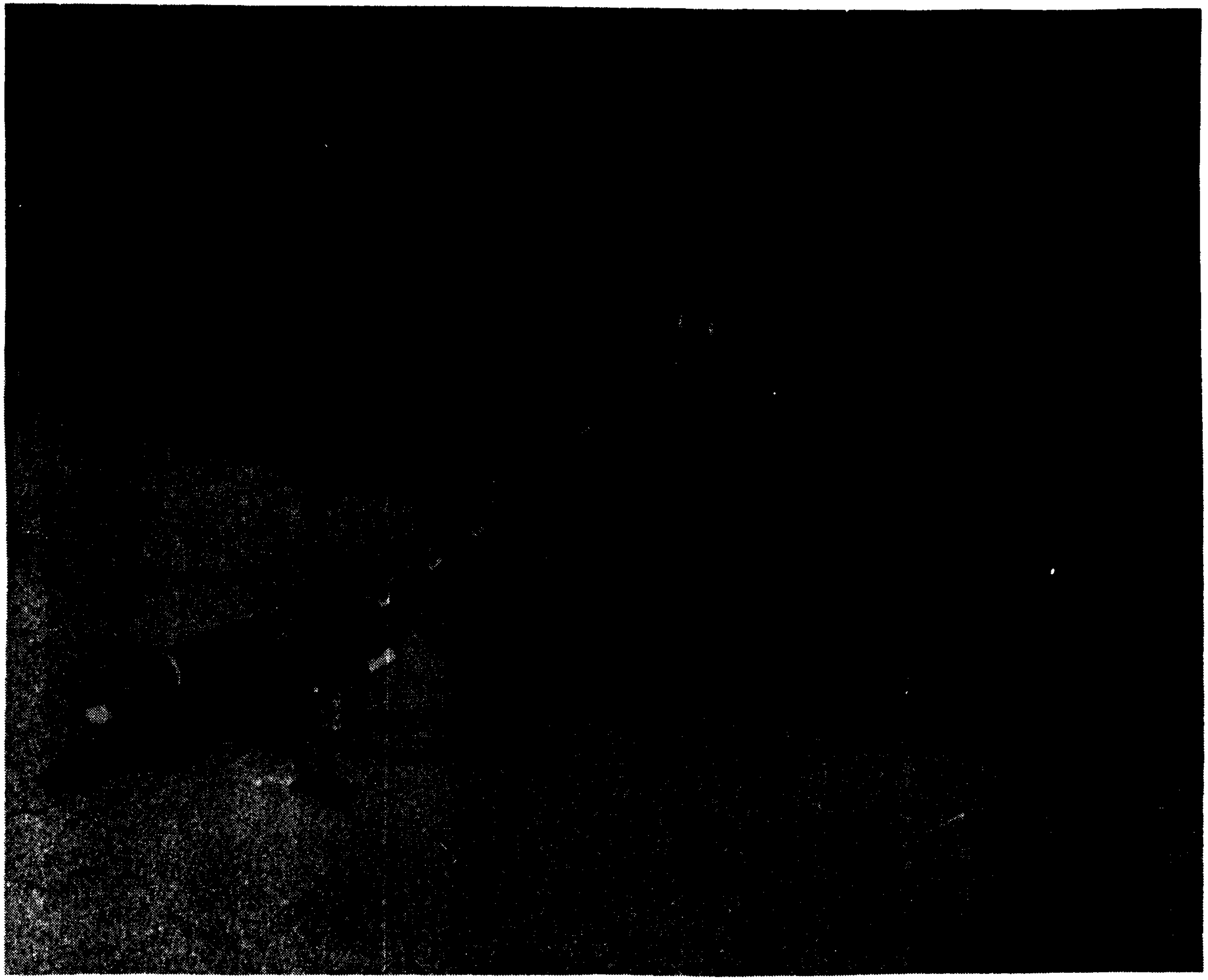


Figure 3. ARM-II/U assembly (10048500) on BVFS

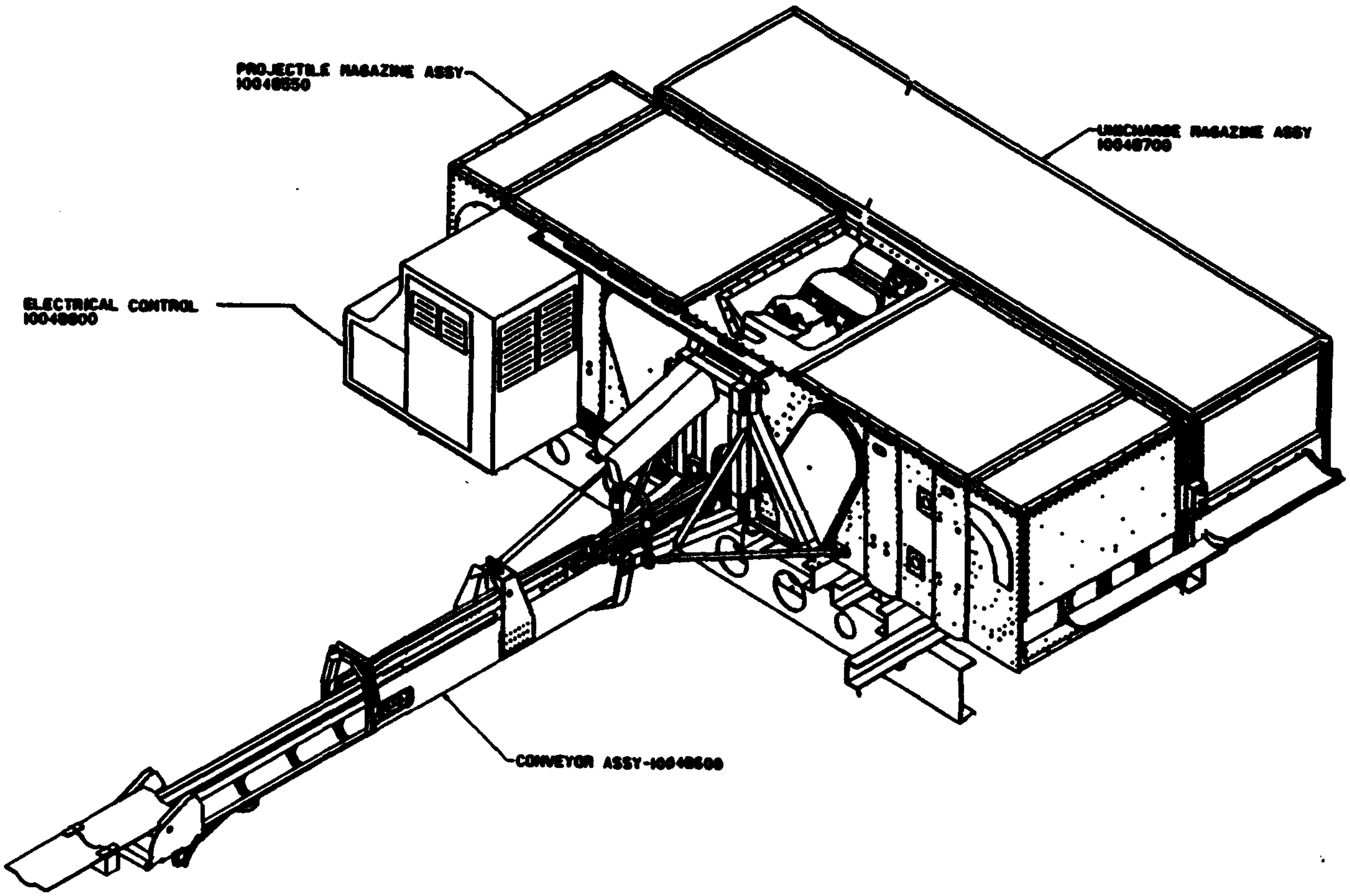


Figure 4. Major components the ARM-II/U assembly

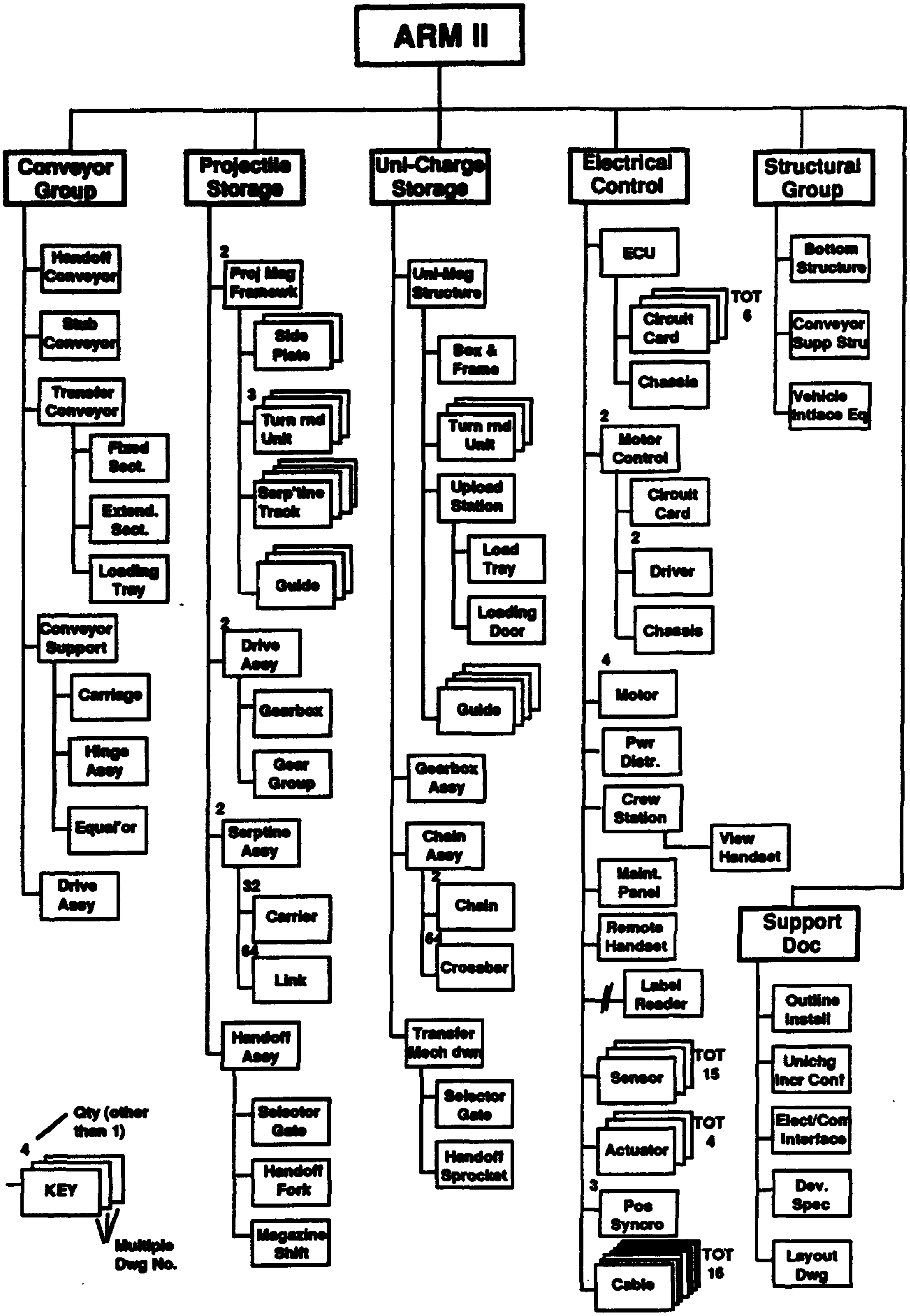


Figure 5. ARM-II/U assembly and subassembly tree

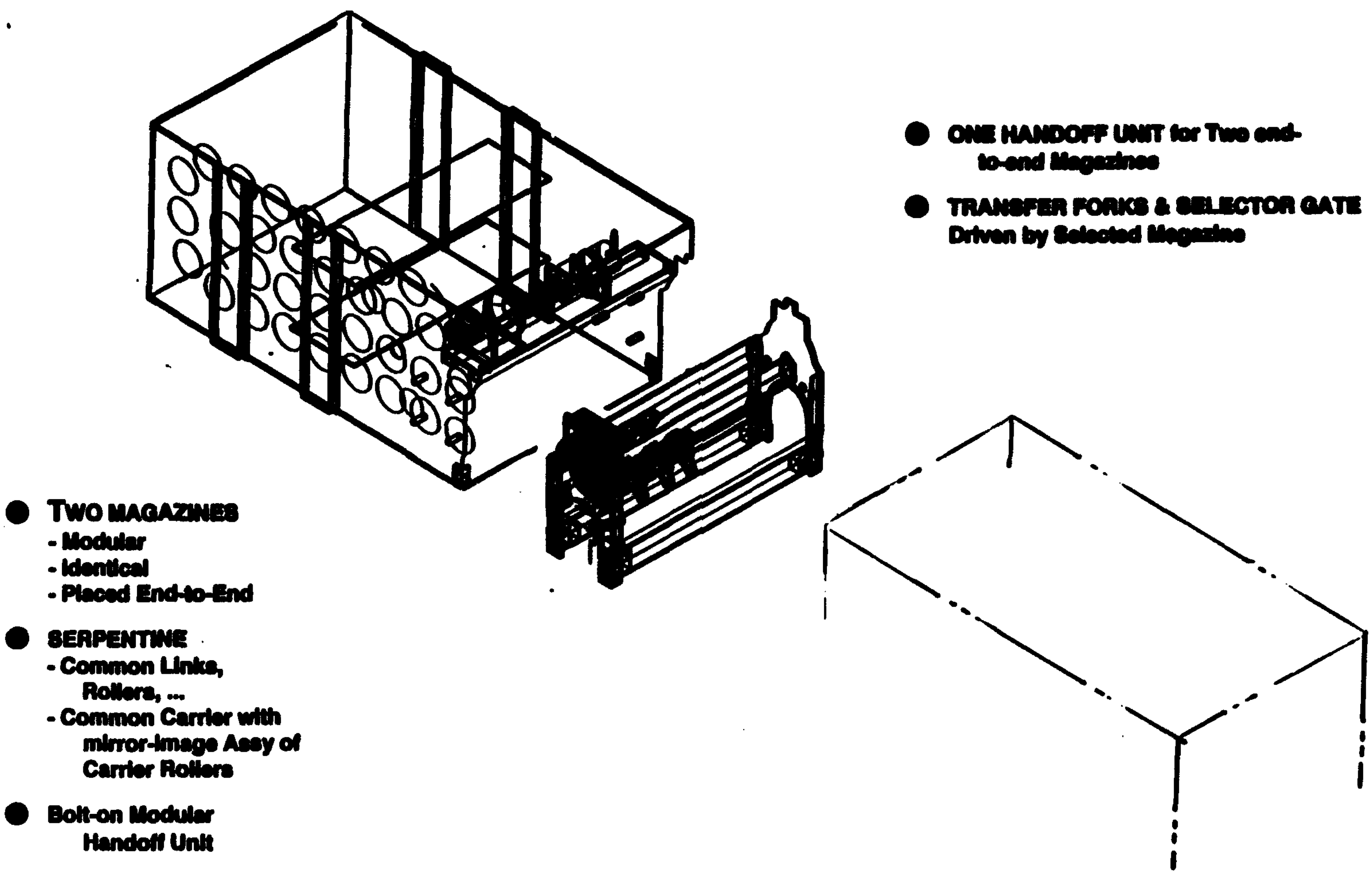


Figure 6. ARM-II/U projectile storage unit

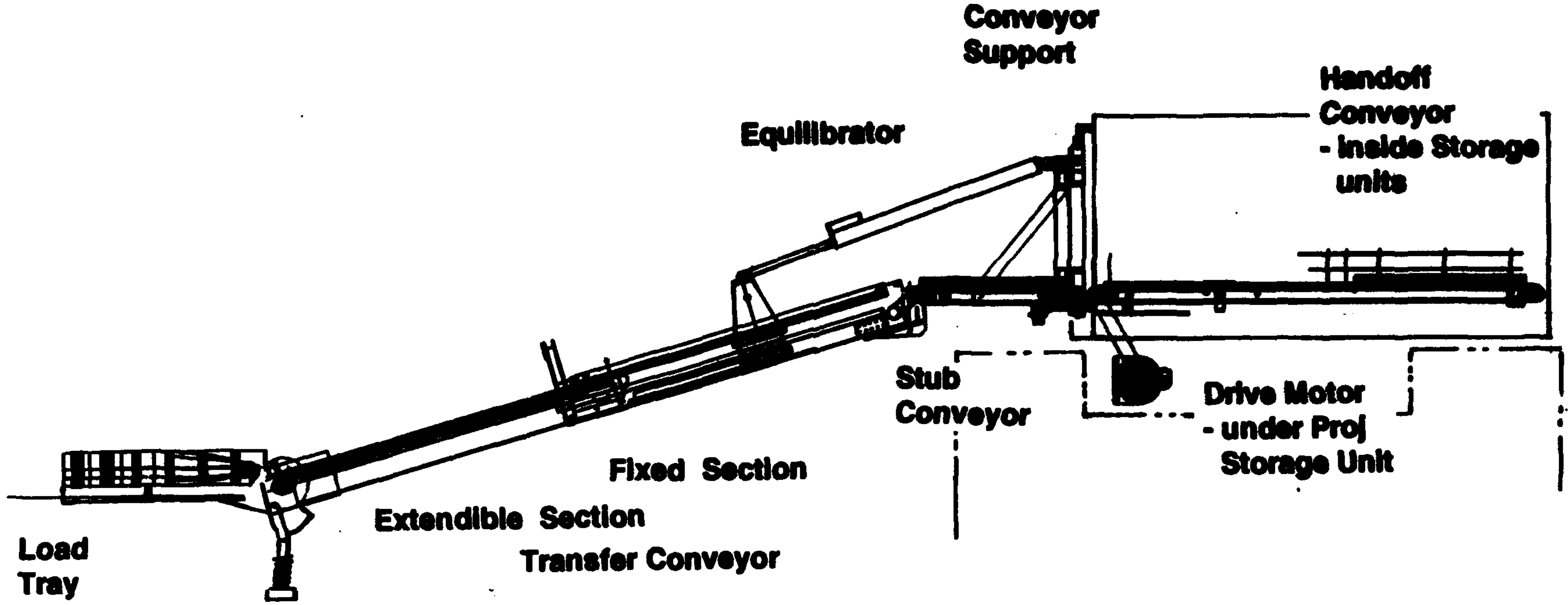
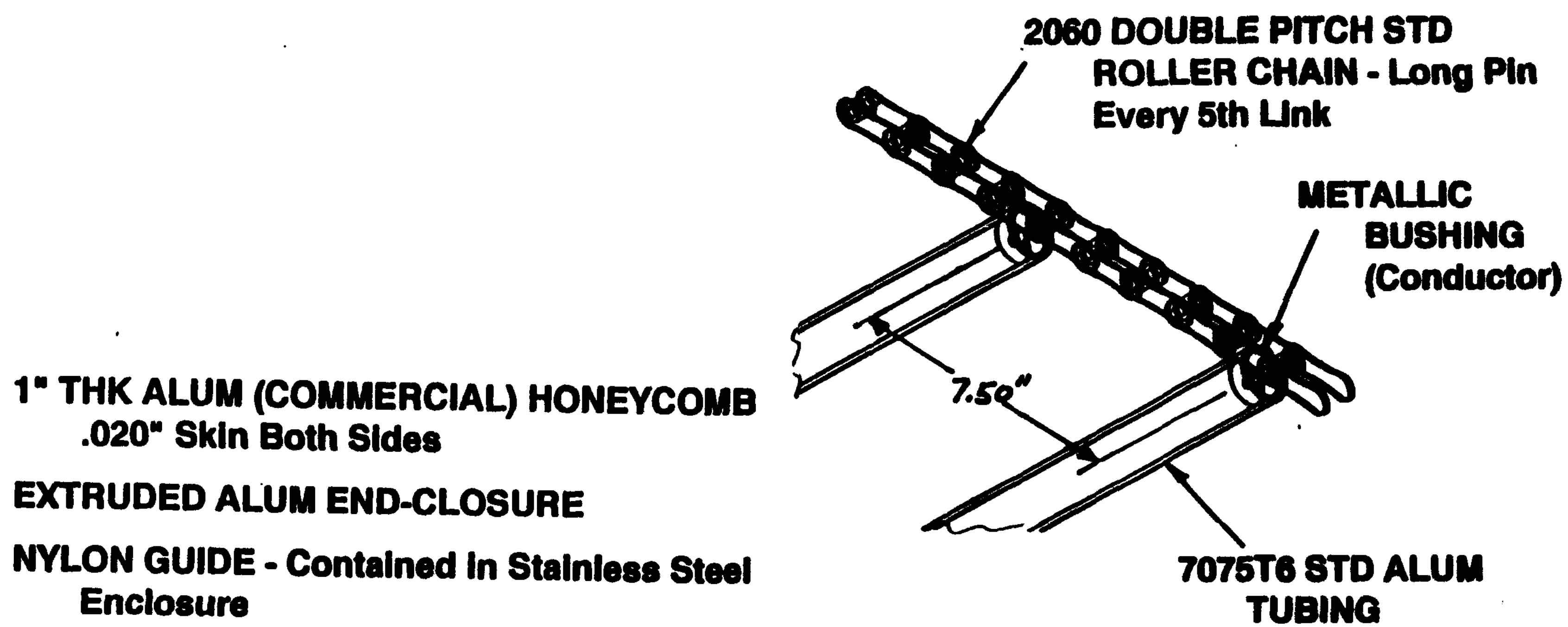


Figure 7. ARM-II/U conveyor subassemblies



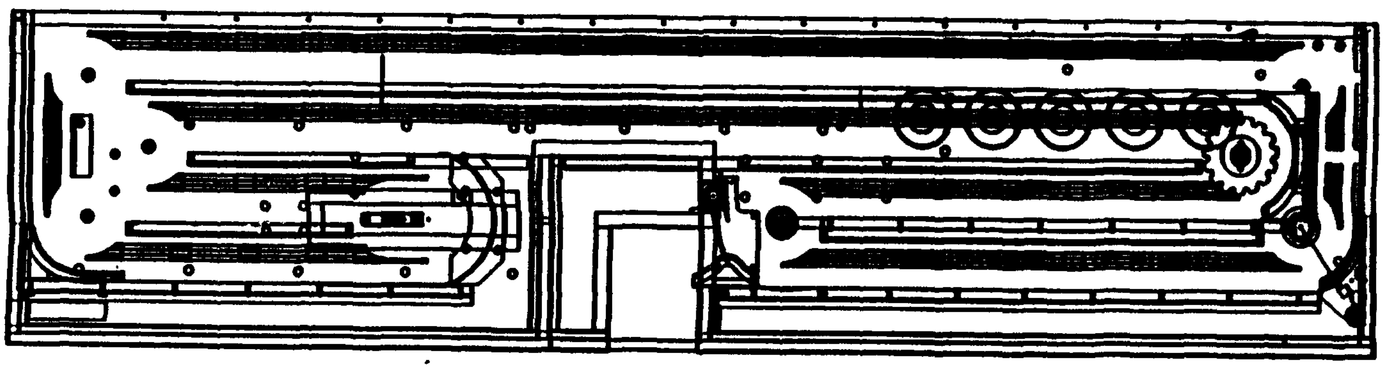


Figure 8. ARM-II/U unicharge box and chain-ladder subassembly

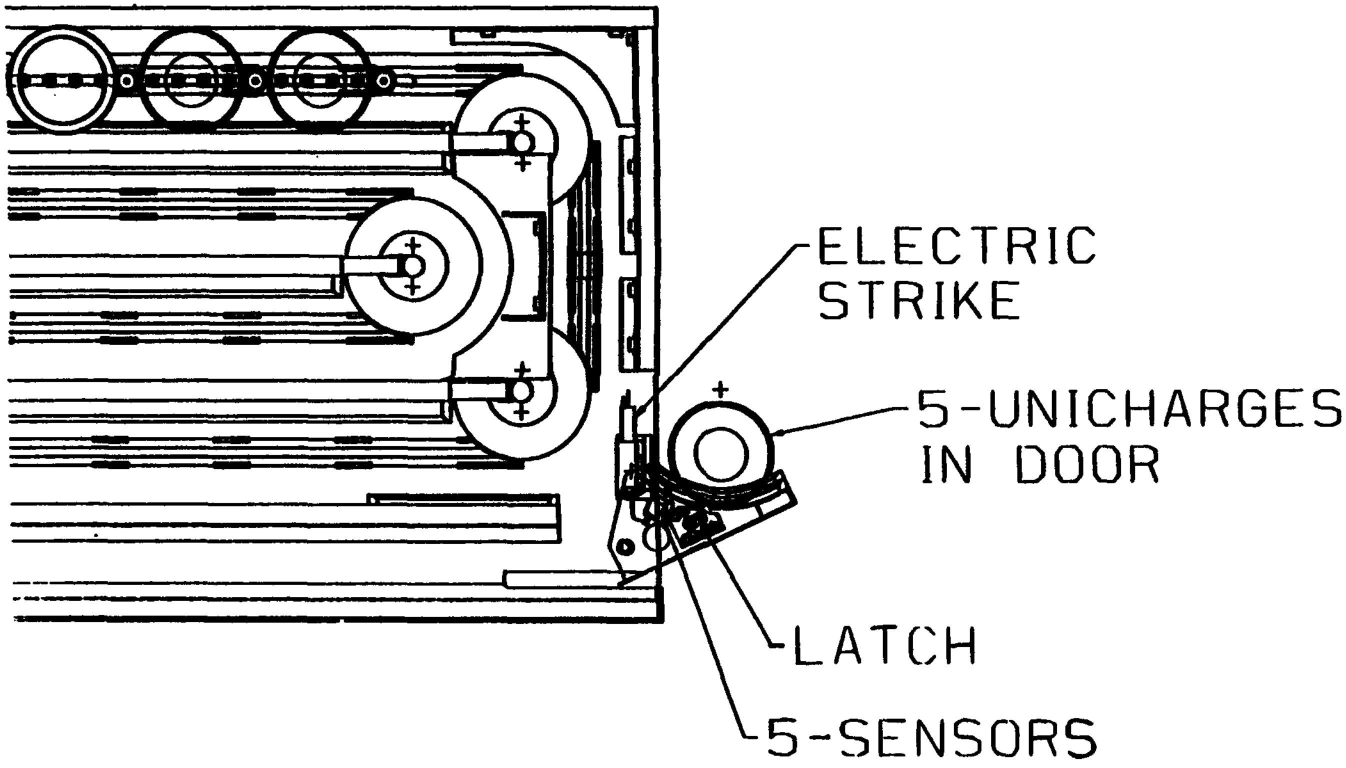


Figure 9. ARM-II/U unicharge upload door

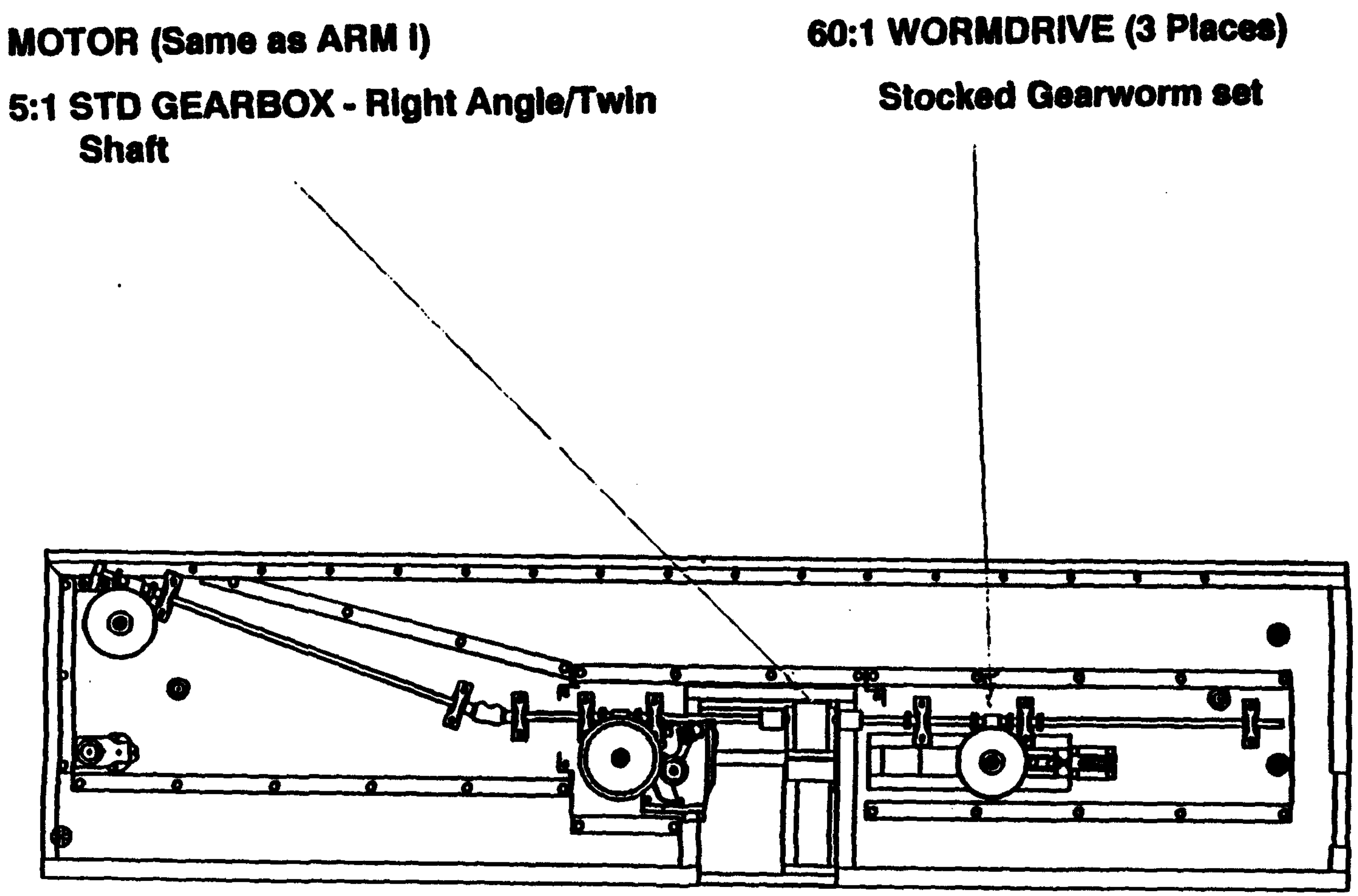


Figure 10. ARM-II/U unicharge drive train

- **SINGLE GATE - Top**
- **GATE ACTUATION (Yes/No) on Electrical Signal**
- **GATE MECHANICALLY TIMED to Chain Ladder**
- **CAM DESIGN - Controls**

  Unicharge Fall to Conveyor

  (5 at a time)

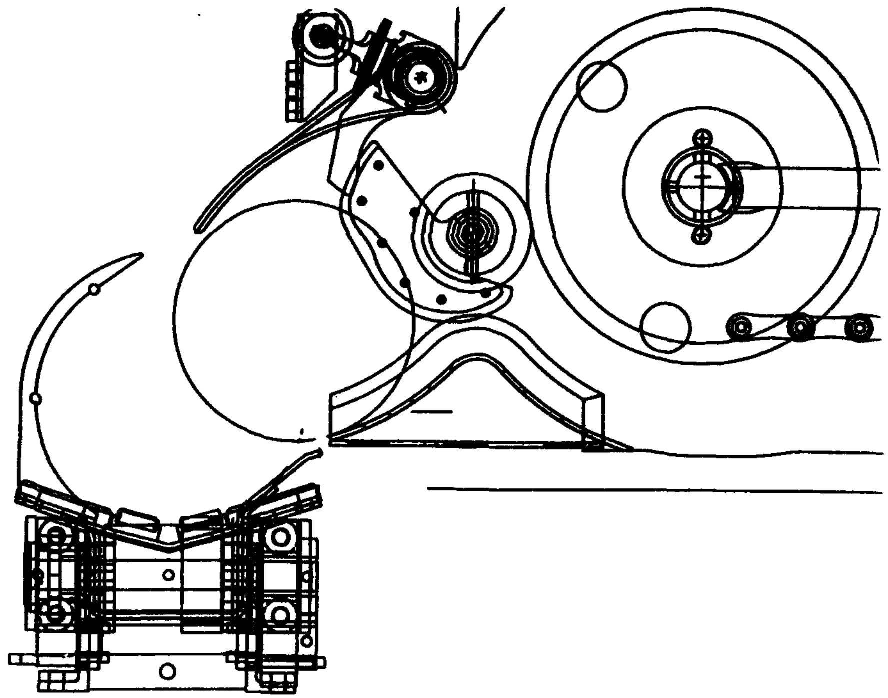


Figure 11. ARM-II/U unicharge download mechanism

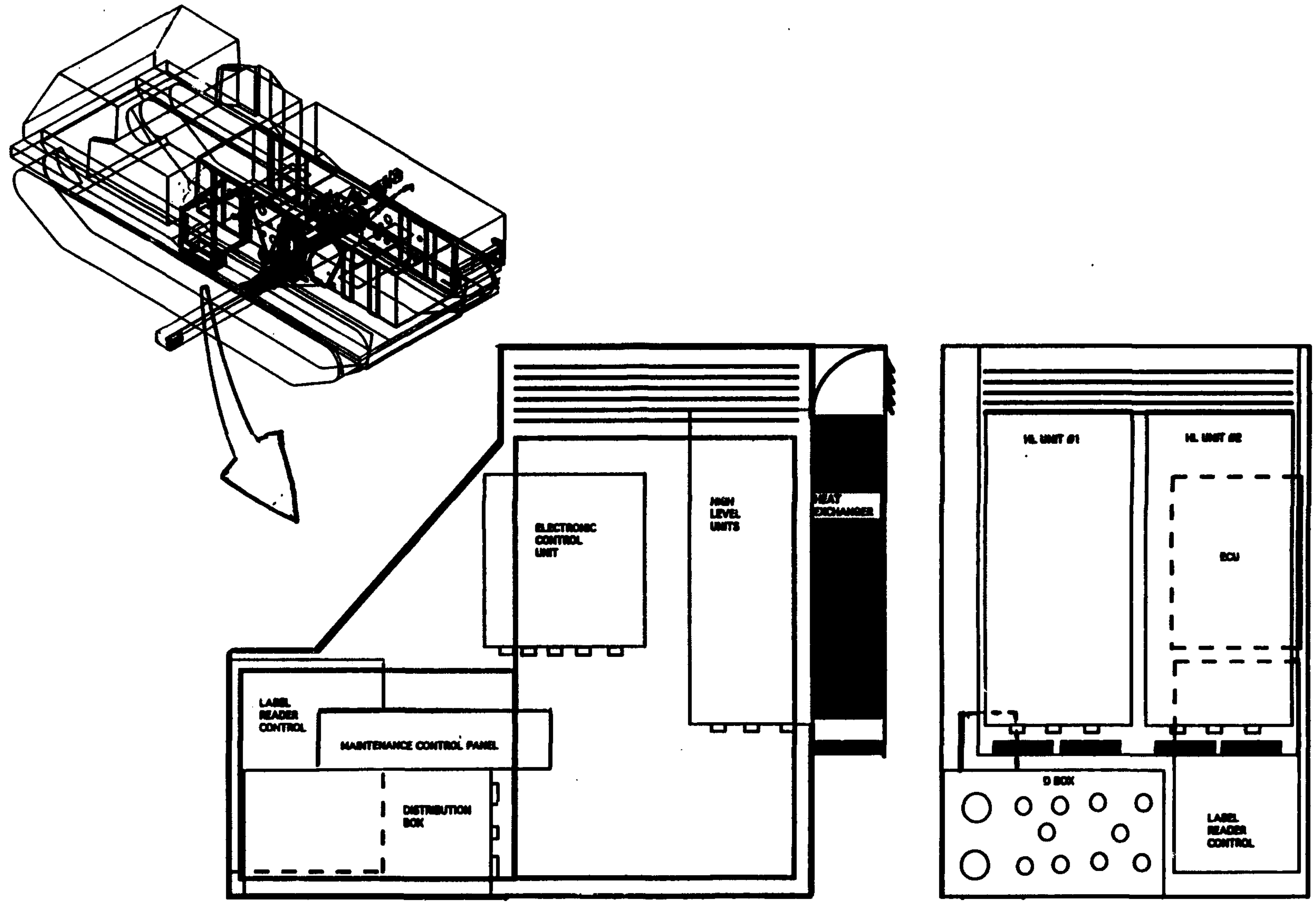


Figure 12. ARM-II/U electrical control system enclosure layout

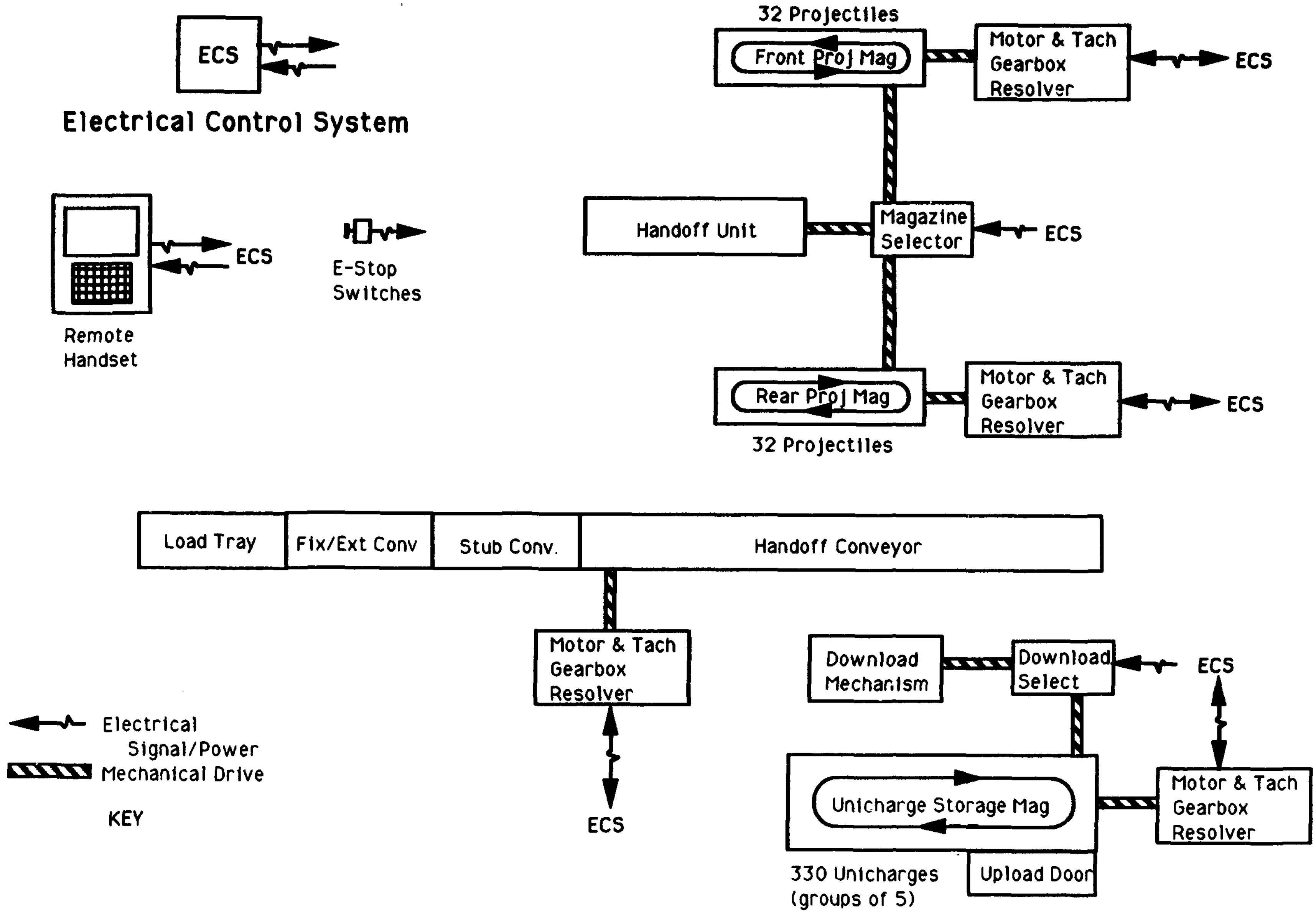


Figure 13. ARM-II/U Block Diagram

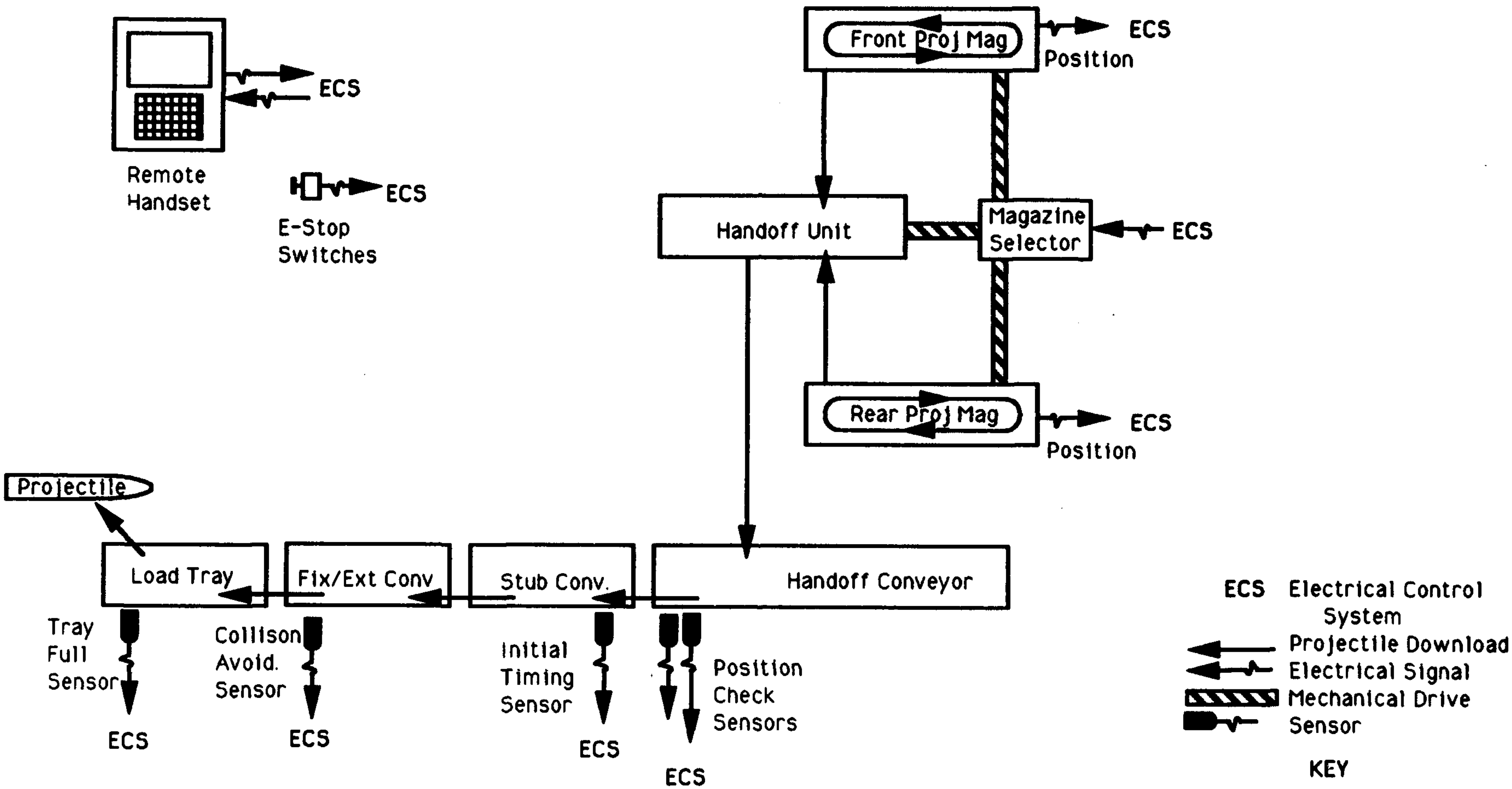


Figure 14. Projectile download functional diagram

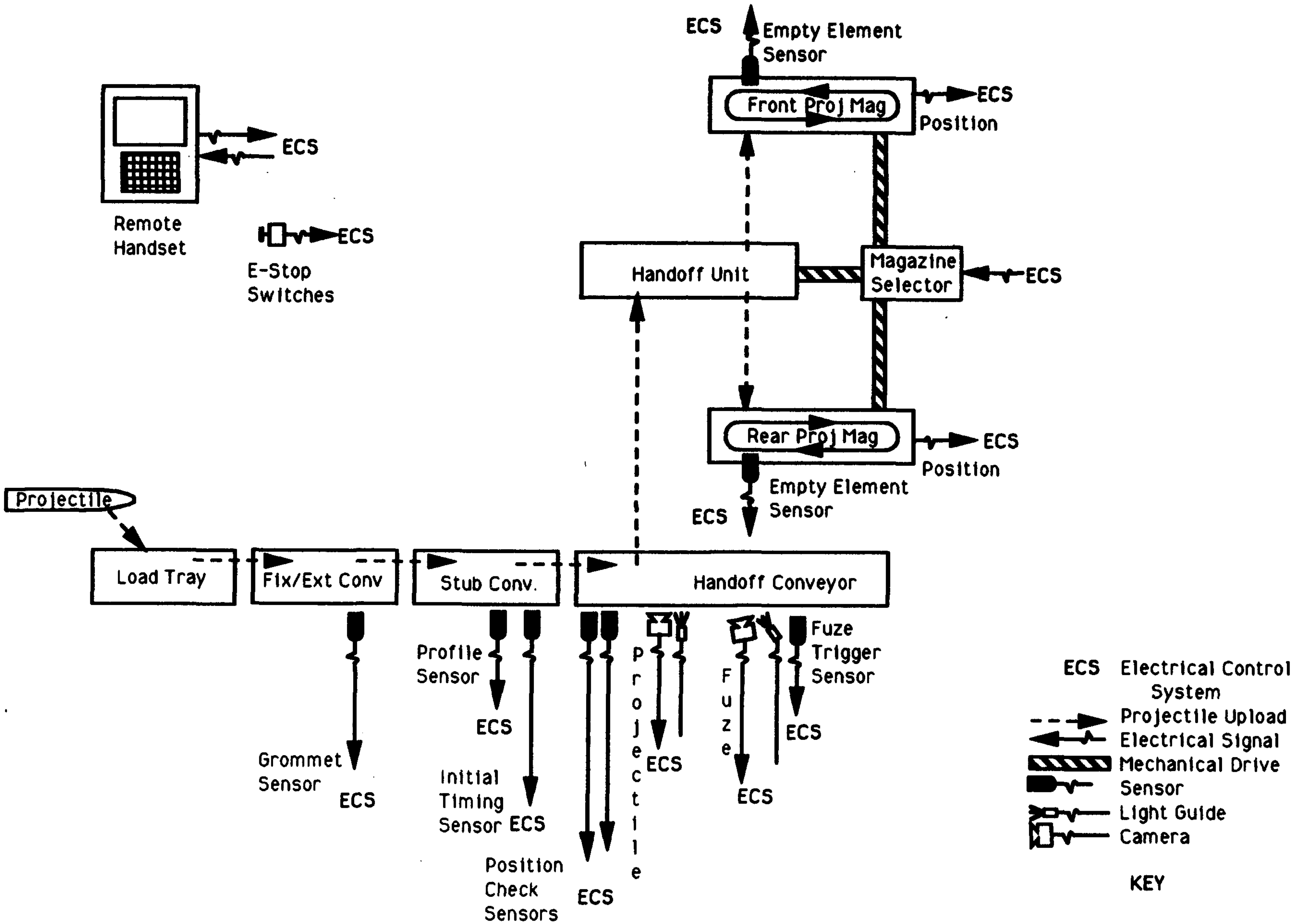


Figure 15. Projectile upload functional diagram

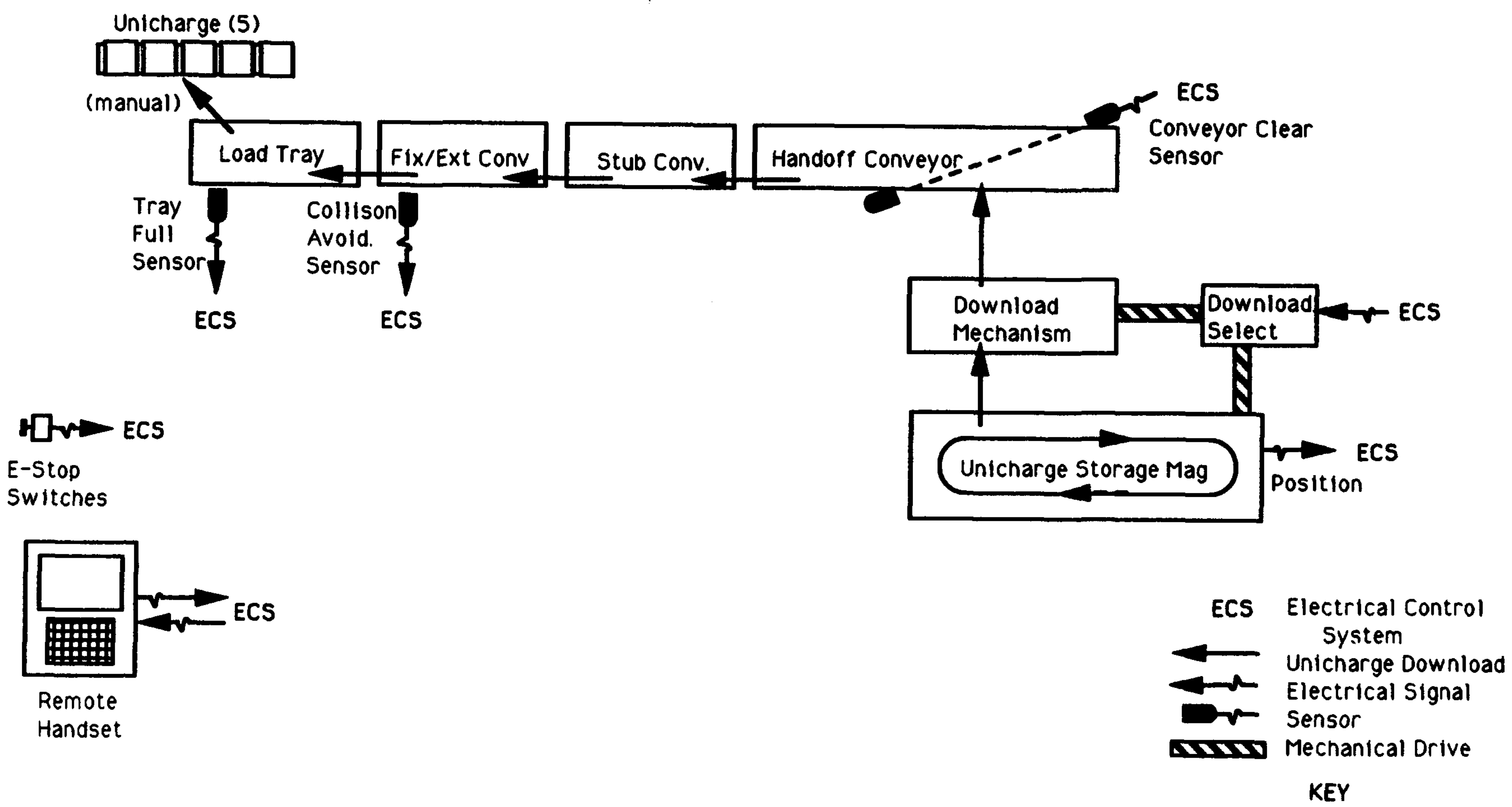


Figure 16. Unicharge download functional diagram

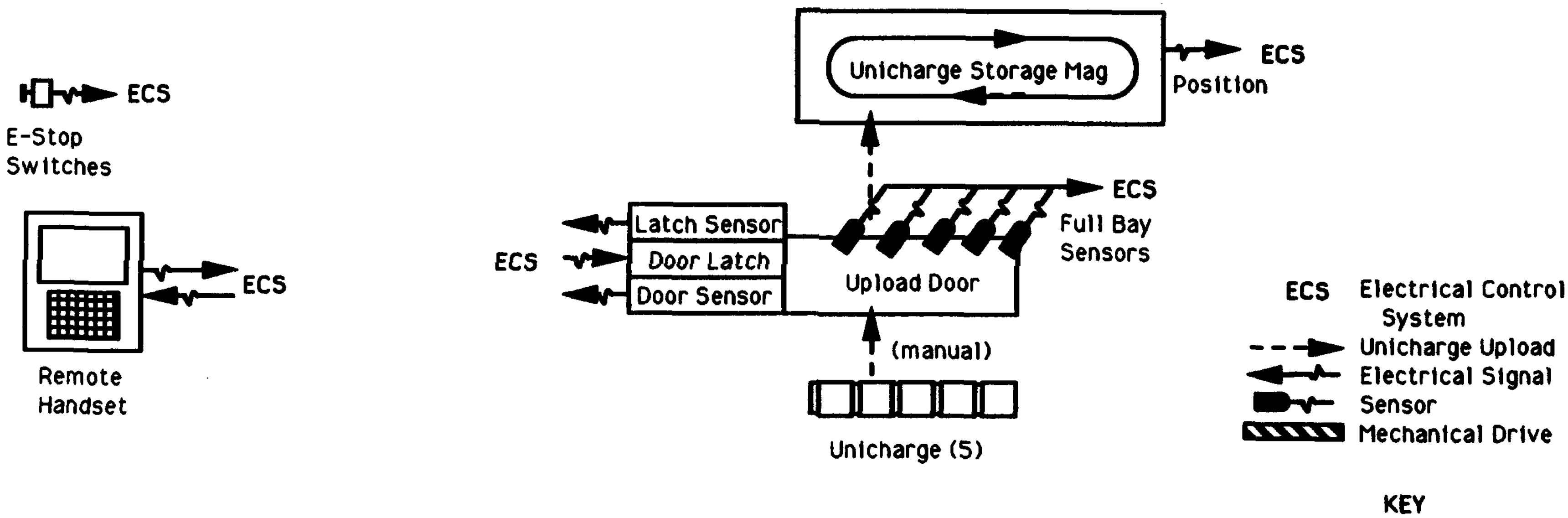


Figure 17. Unicharge upload functional diagram

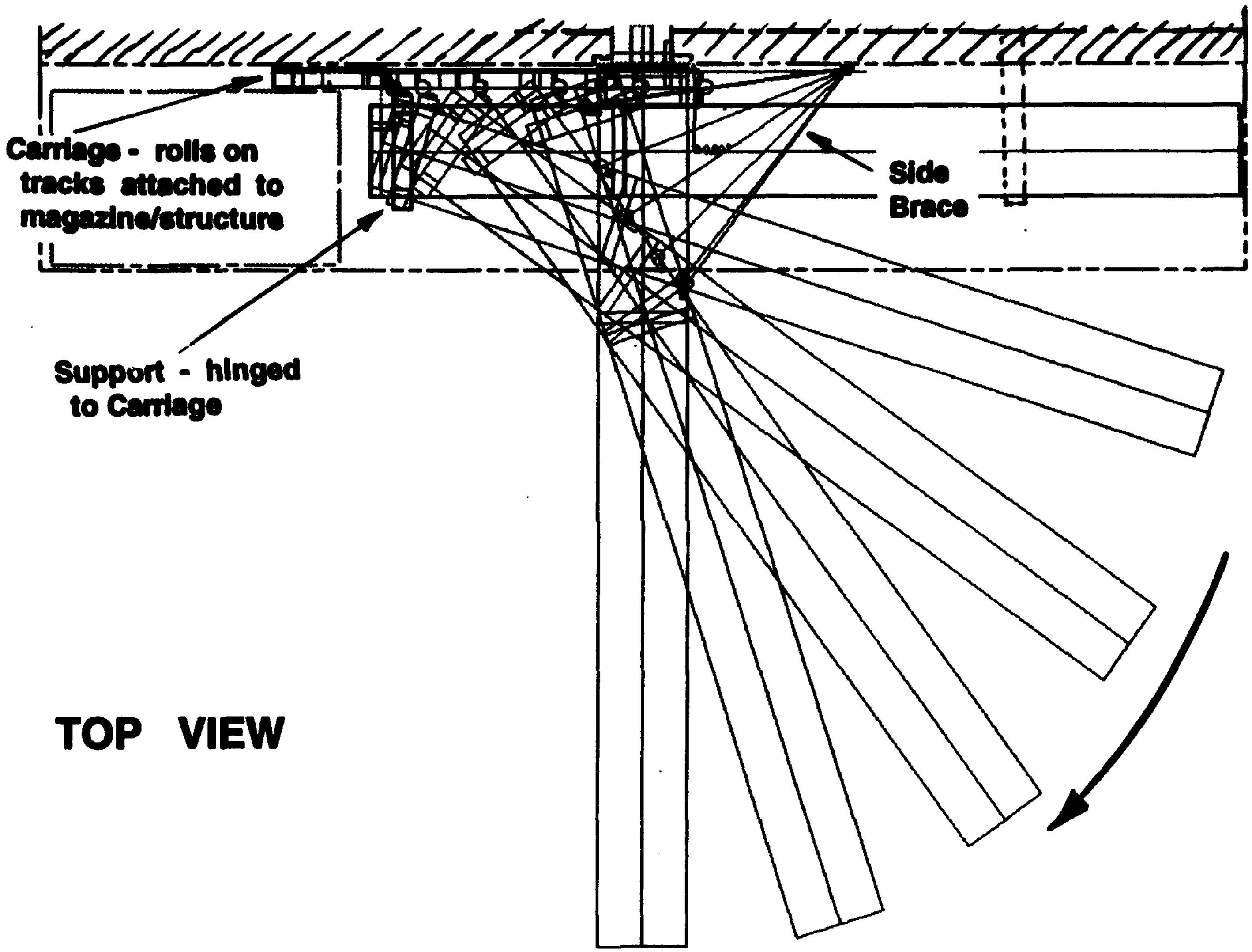


Figure 18. Conveyor carriage and hinge support

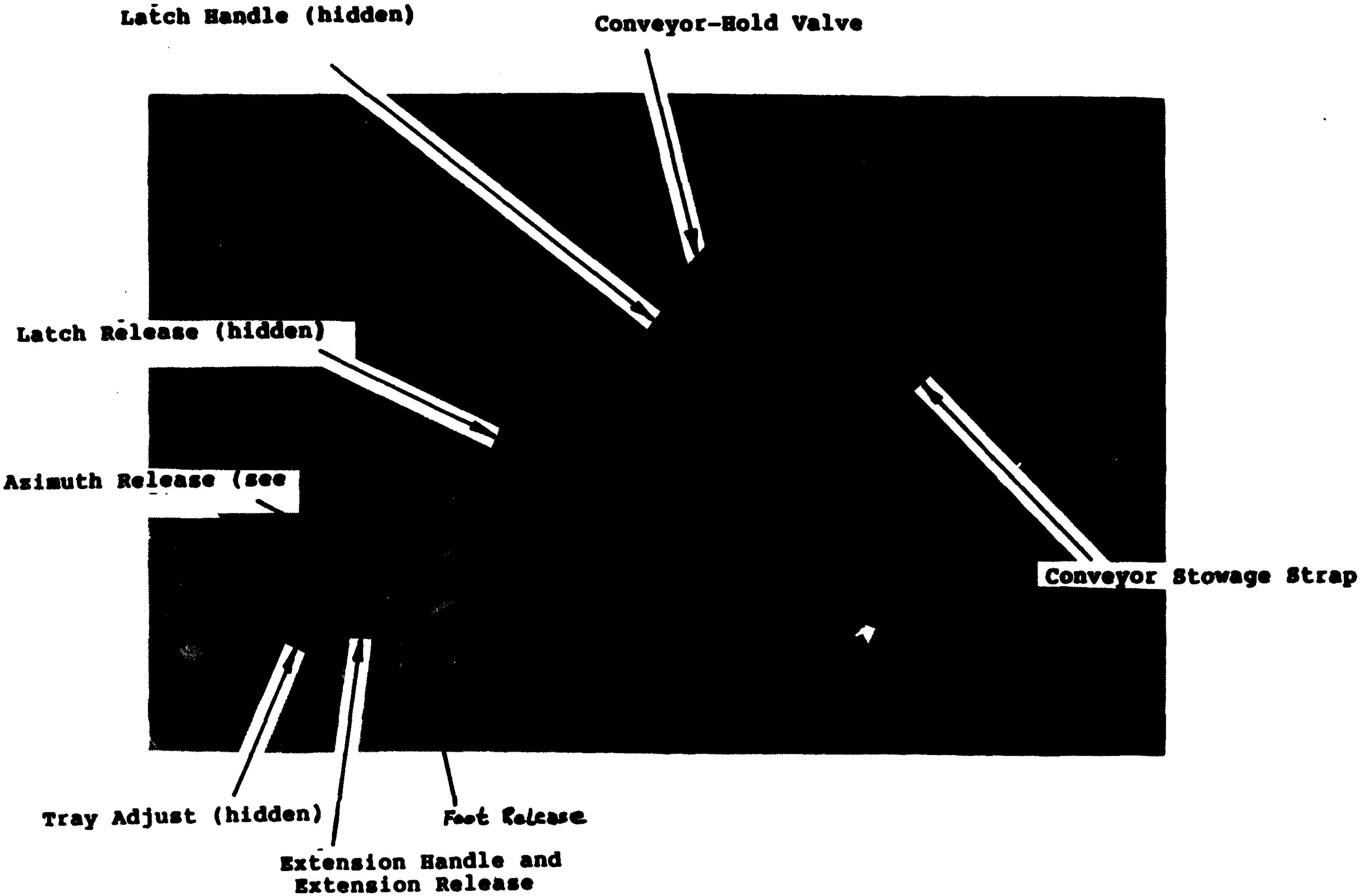


Figure 19. Operator controls and interfaces (group 1-conveyor deployment)

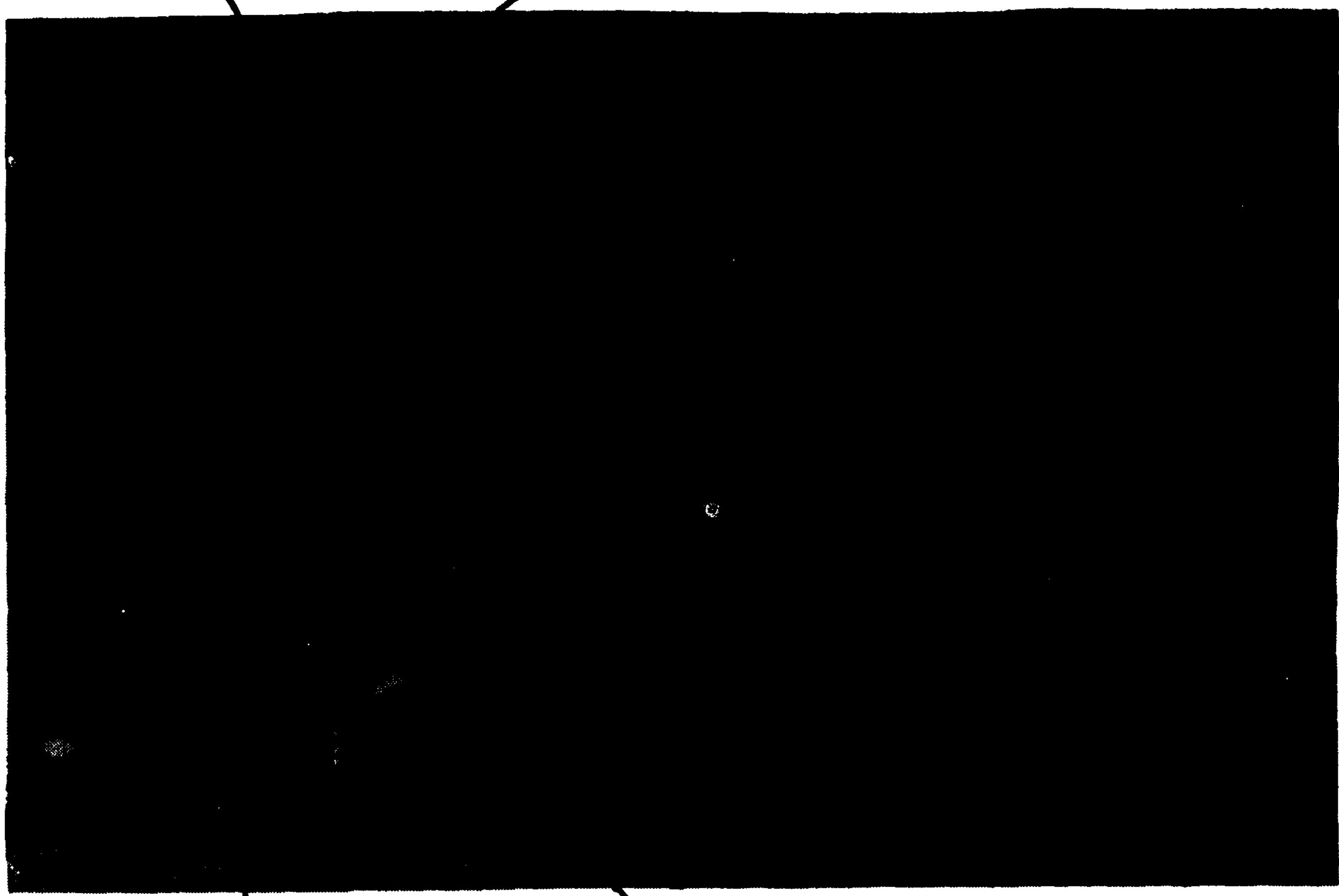


Figure 20. Operator controls and interfaces (group 2-up/download)

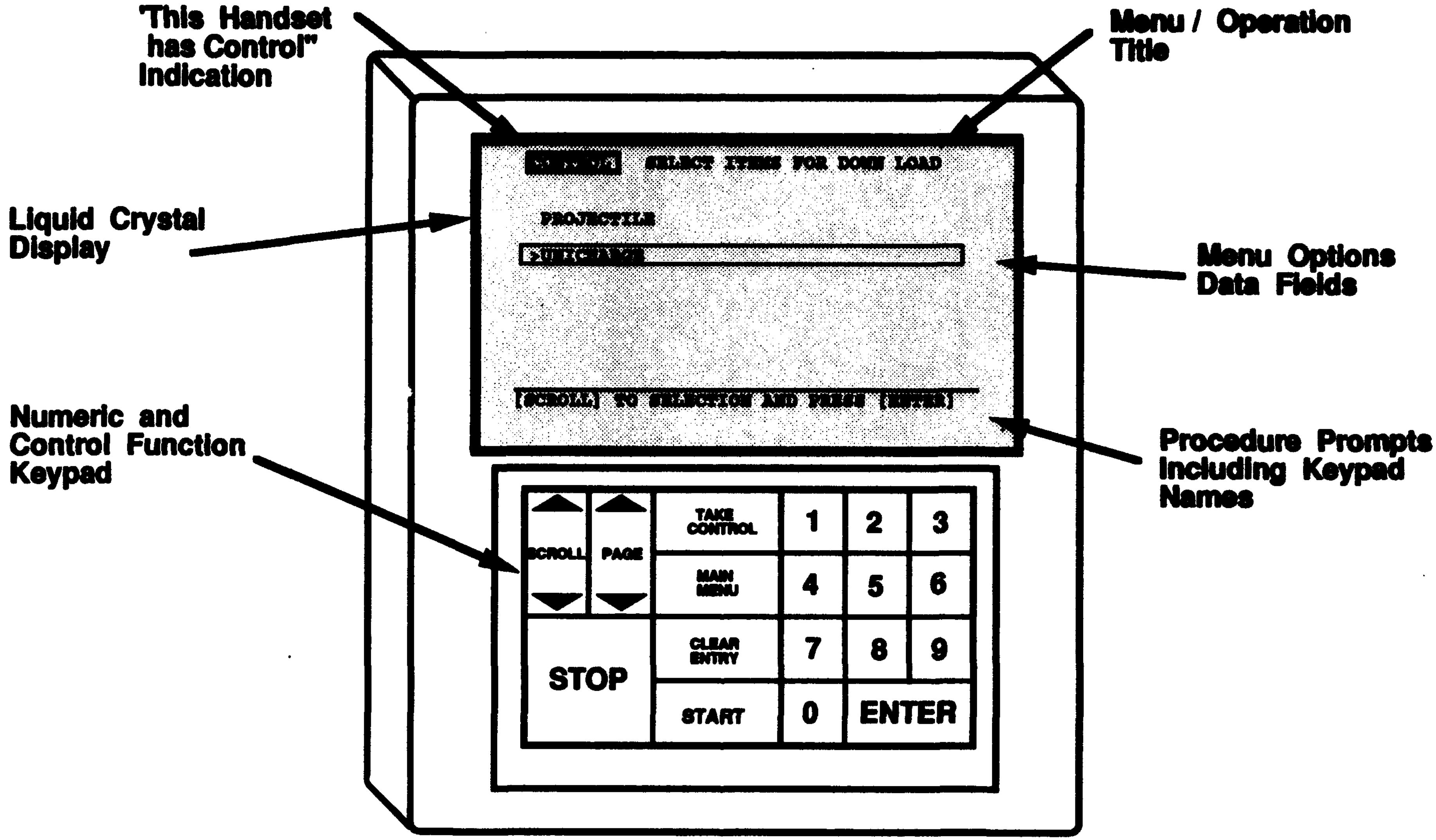


Figure 21. Handset display and keypad layout

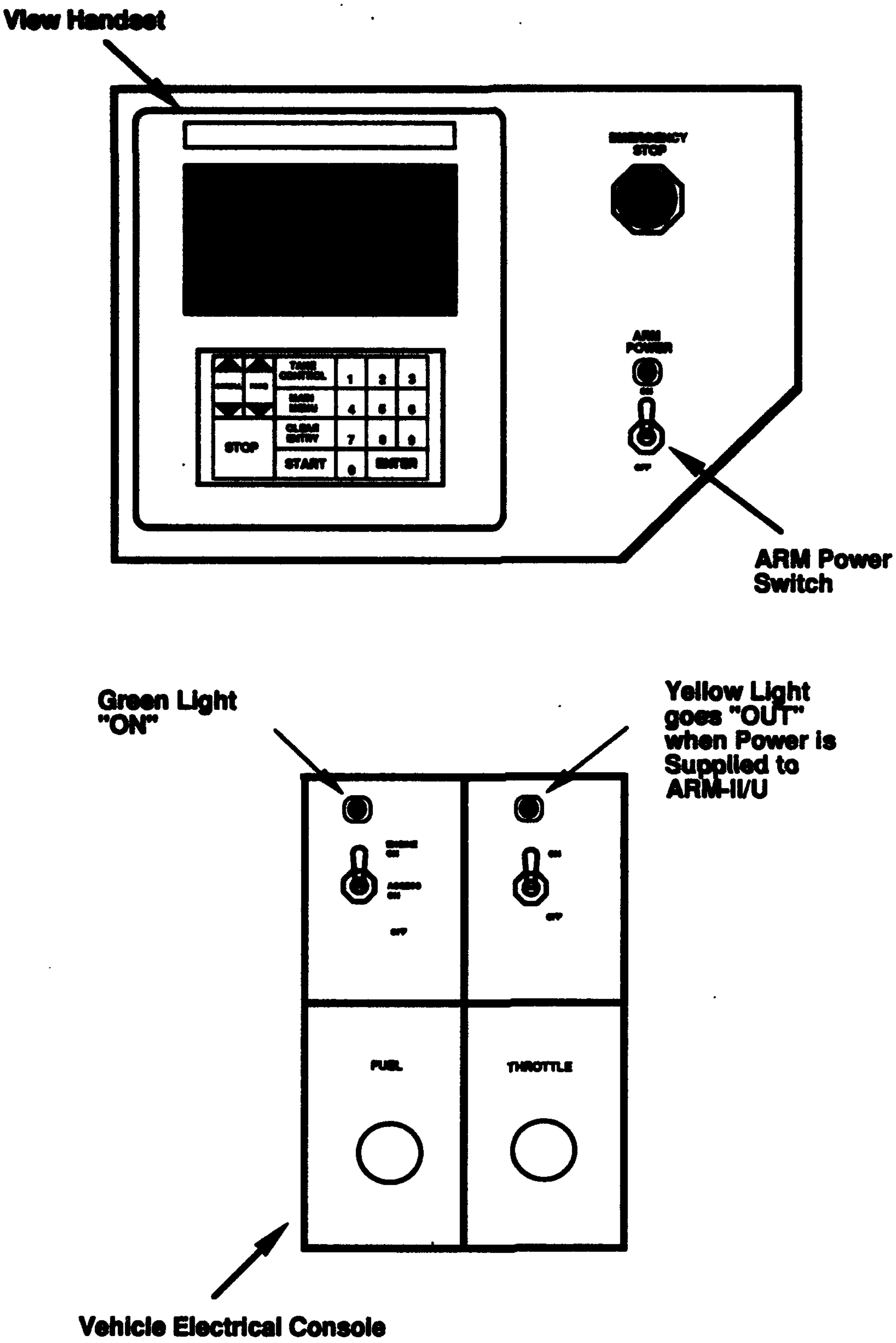


Figure 22. Crew station (in vehicle cab)

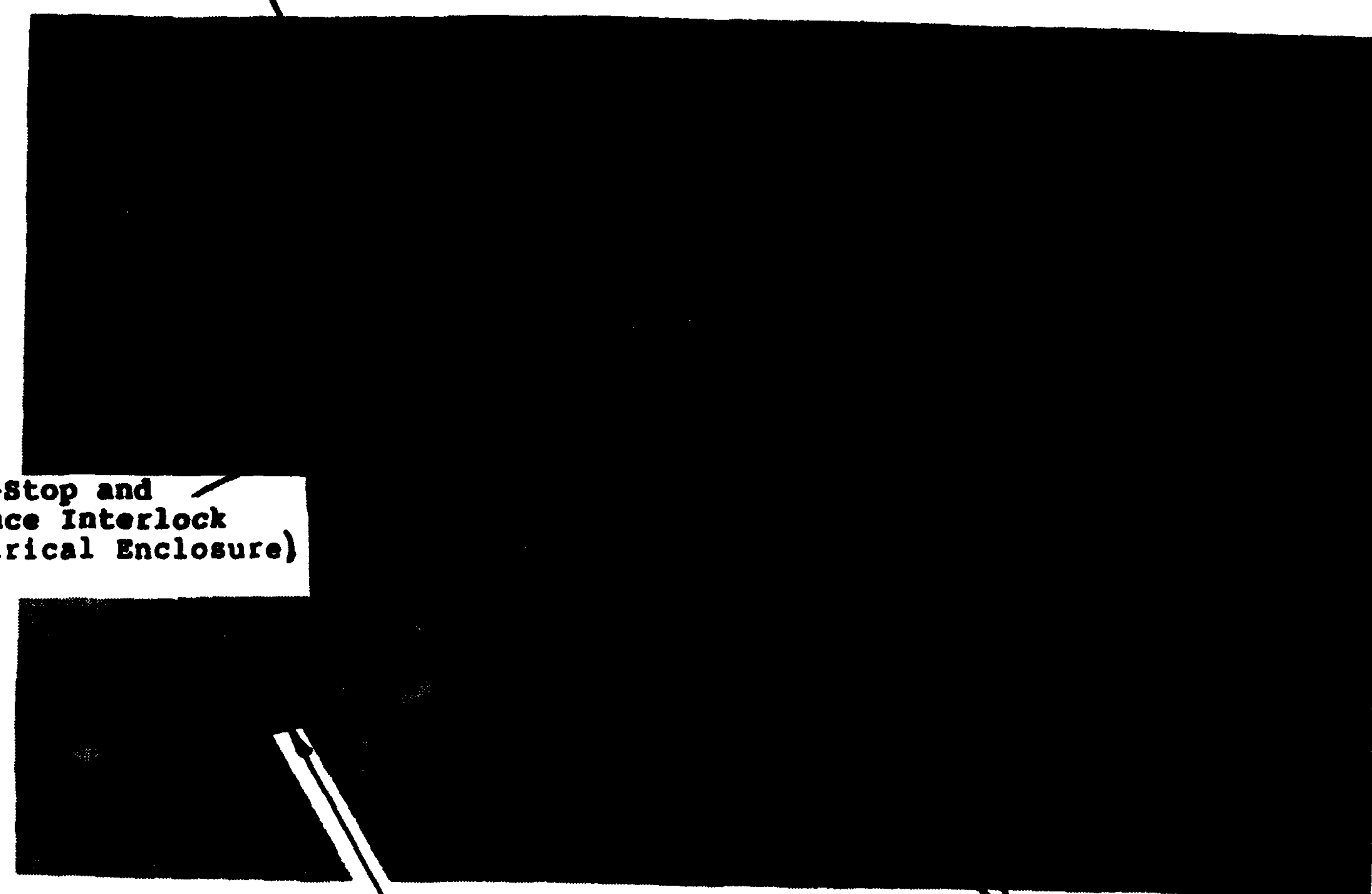


Figure 23. Operator controls and interfaces (group 3-emergency stop and interlocks)

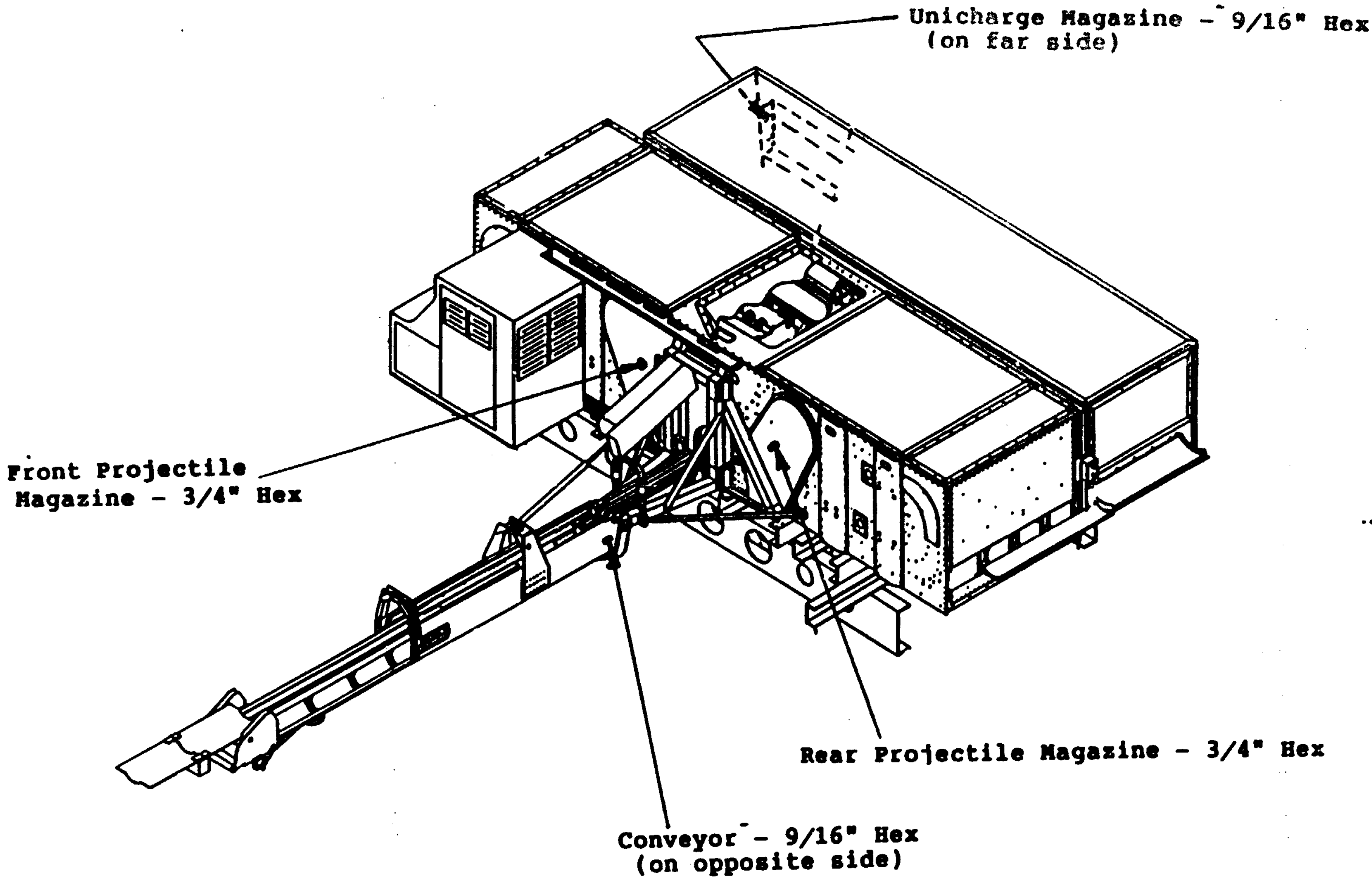
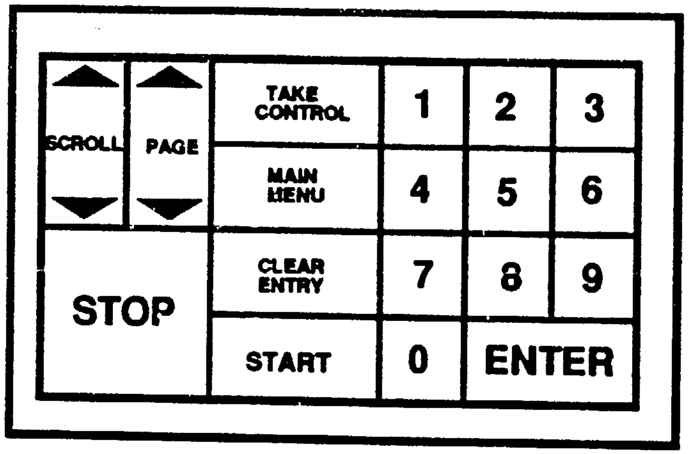


Figure 24. Operator controls and interfaces (group 4-backup manual drive)



HANDSET KEYPAD FUNCTIONS

[SCROLL] Moves Cursor Box Up/Down To Indicate "Selected" Menu Option

[PAGE] Displays Forward/Back Pages in Multi-Page Listing

[TAKE CONTROL] Gives This Handset Control of System Operation Functions (Upload / Download)

Numerics [0], ... , [9] Identification of (Download) Order Quantities

[ENTER] Second Step of Option Selection from Menu. Finalizes Current Selection

[CLEAR] Erases Displayed Quantity in "Order" Column

[MAIN MENU] Returns Display to Top Level Menu (Unless Download is in Process at This Handset)

[START] Starts Conveyor and Magazine Motors at the REMOTE HANDSET Only

[STOP] Stops all Motors and Actuators

FIGURE 25. Handset Keypad Functions

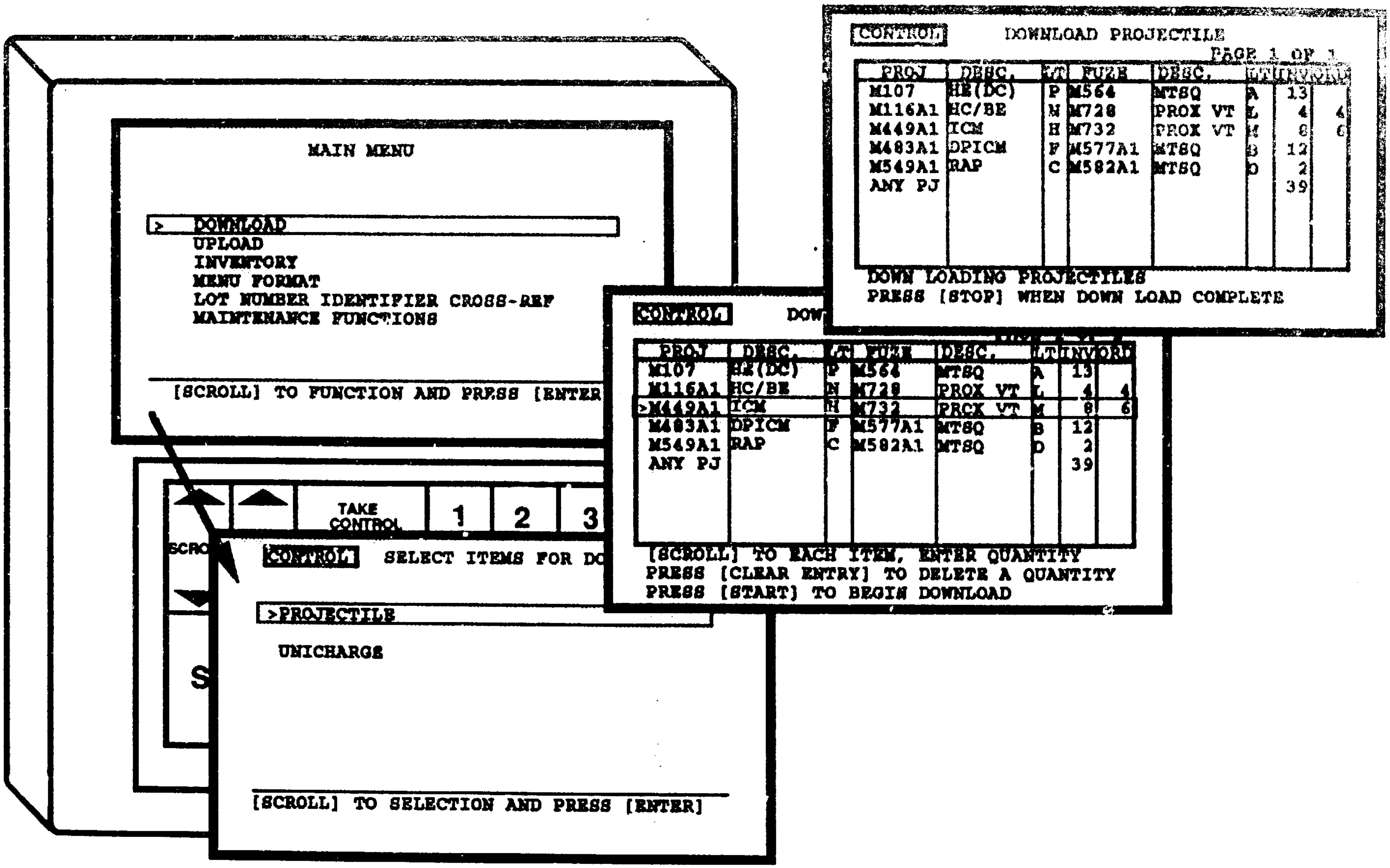


Figure 26. Projectile download menus

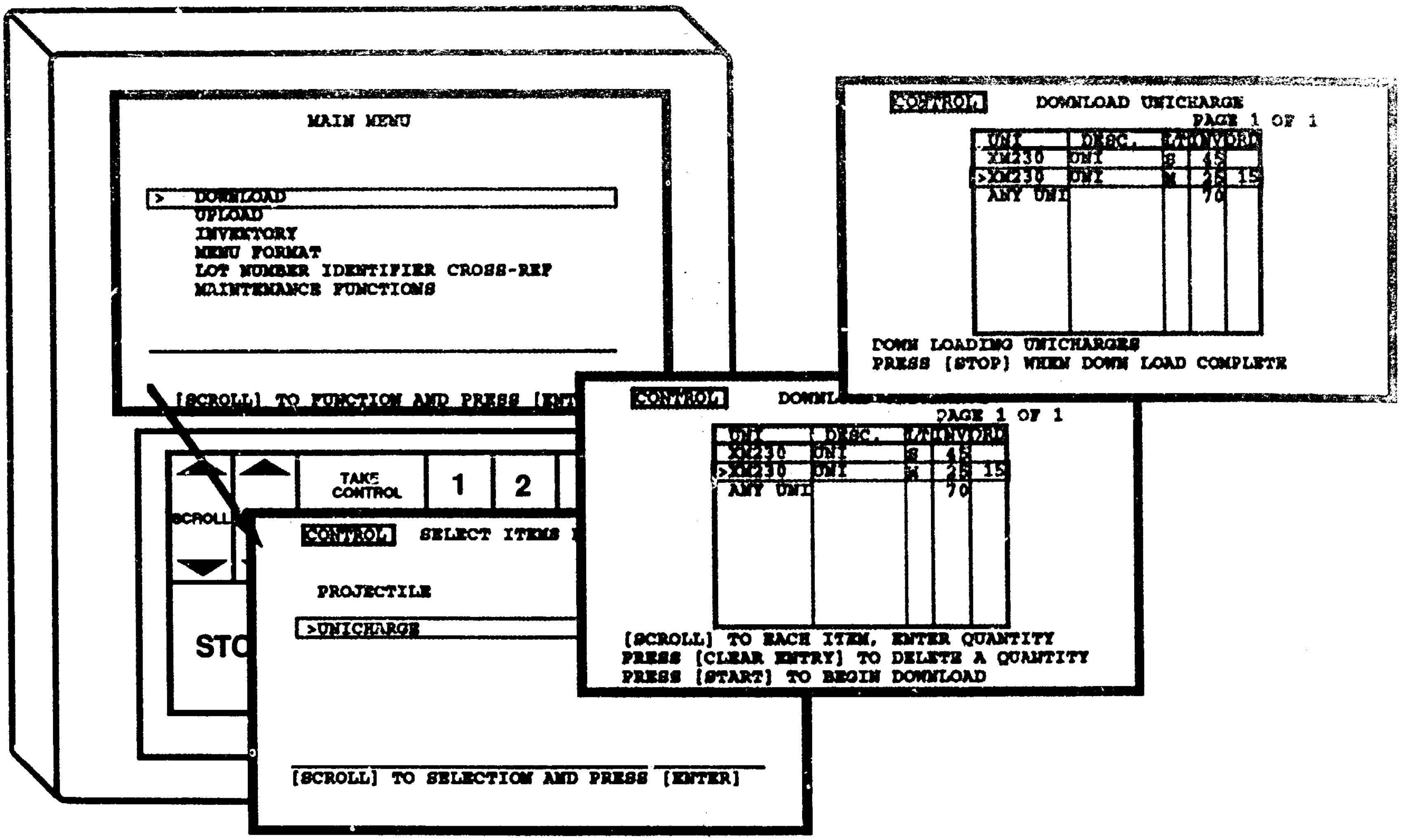


Figure 27. Unicharge download menus

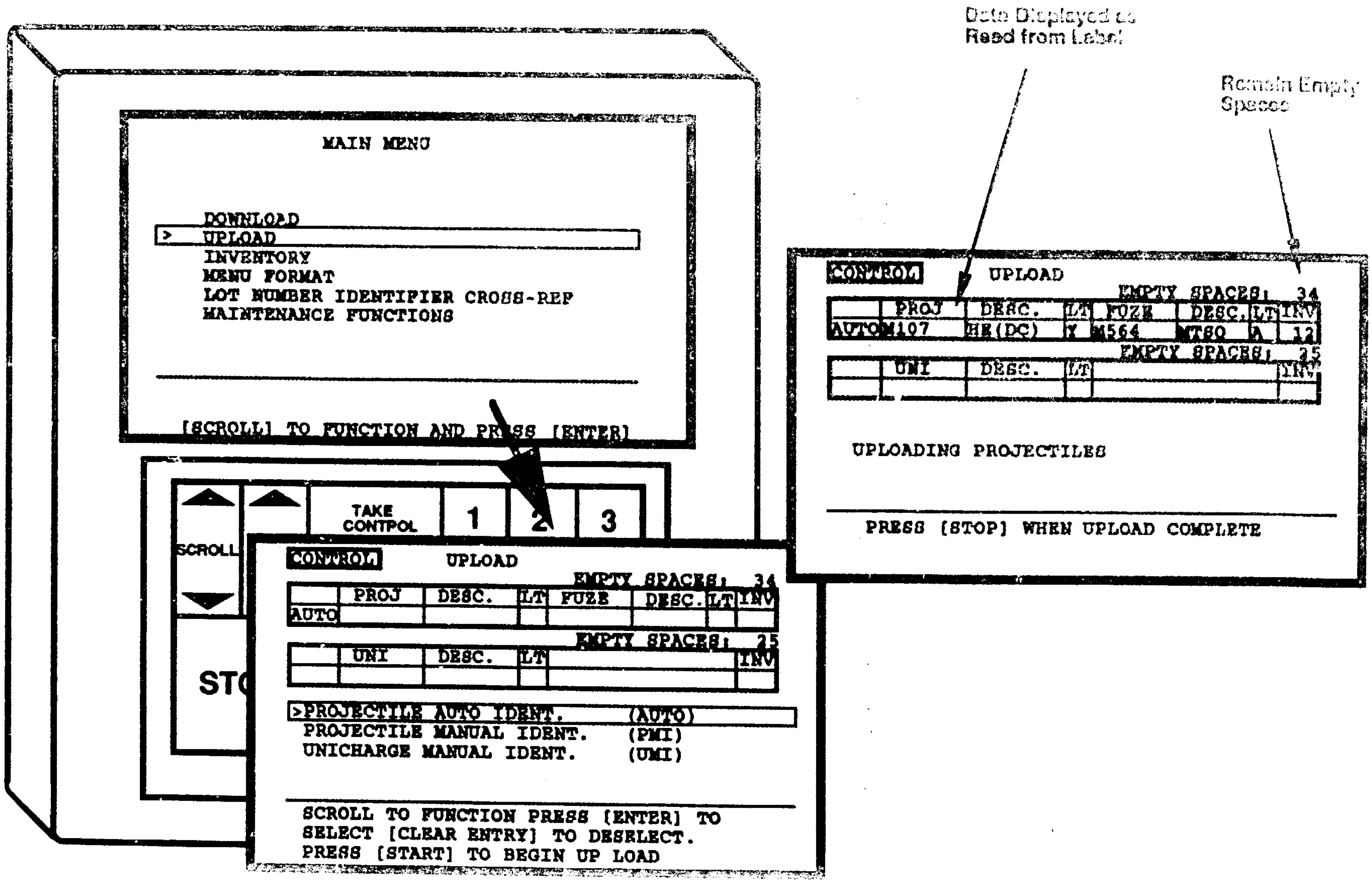


Figure 28. Projectile upload, with automatic identification, menus

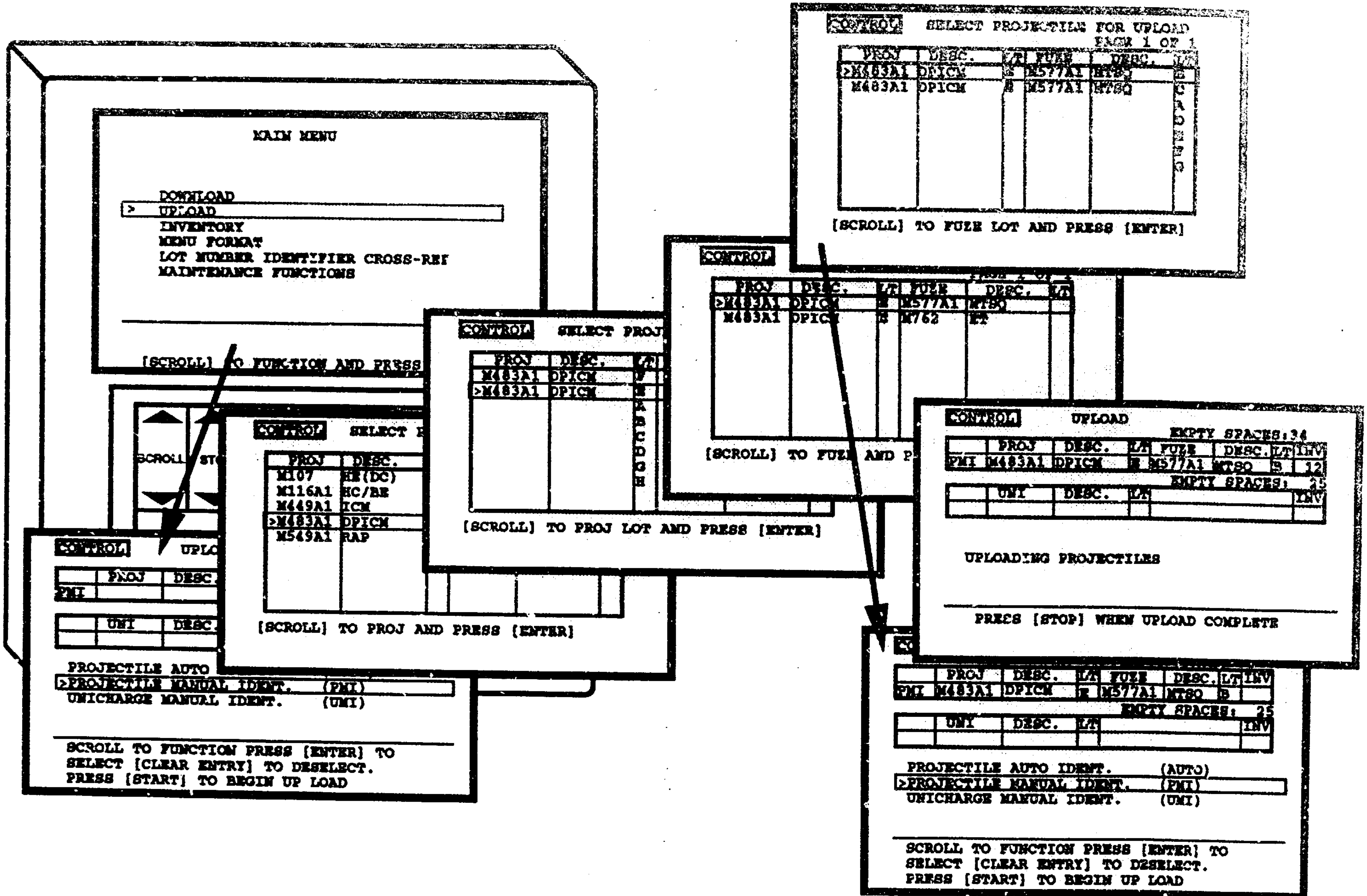


Figure 29. Projectile upload, with manual identification, menus

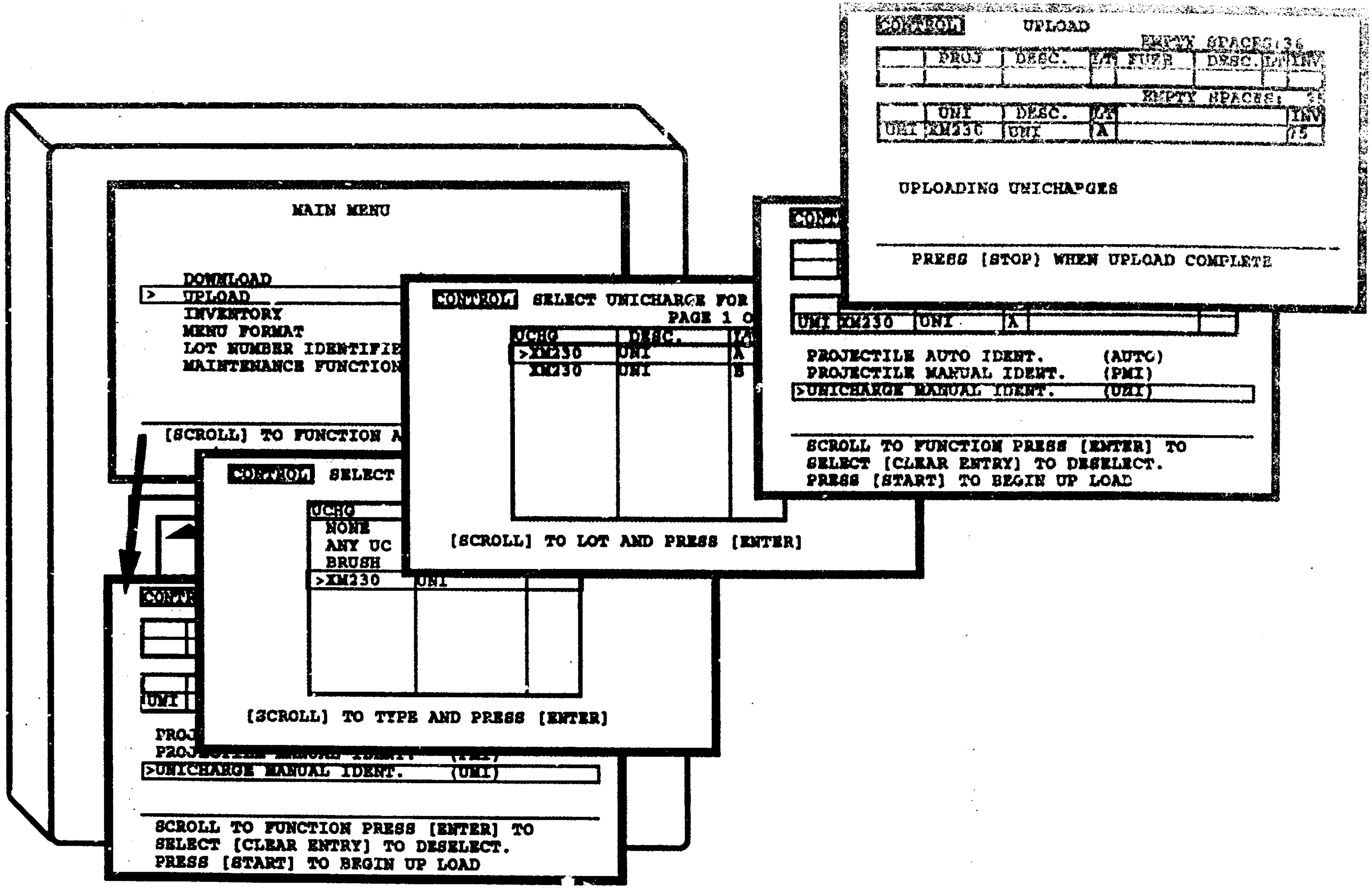


Figure 30. Unicharge upload menus

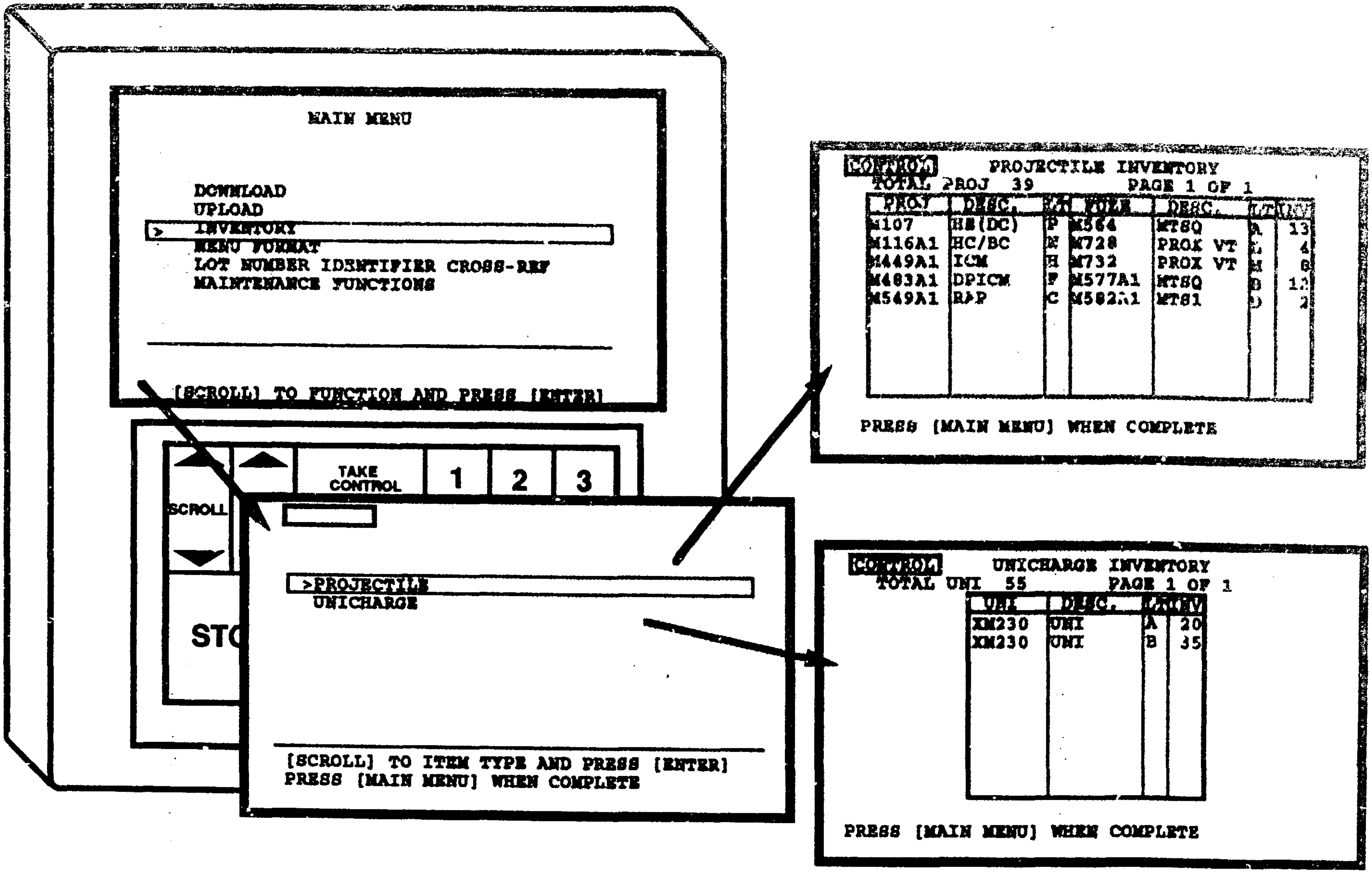


Figure 31. Inventory menus

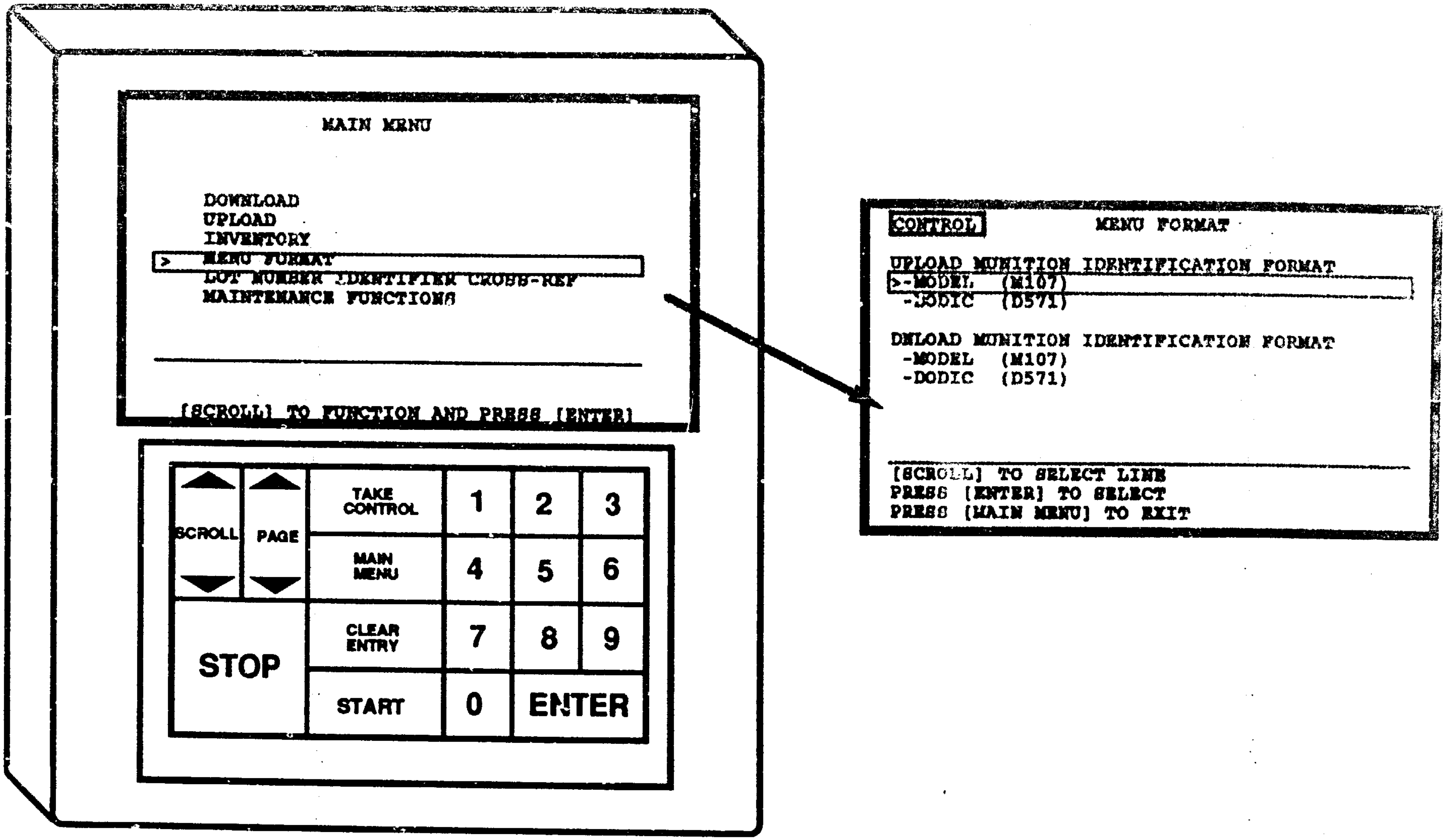


Figure 32. Munition identification format menus

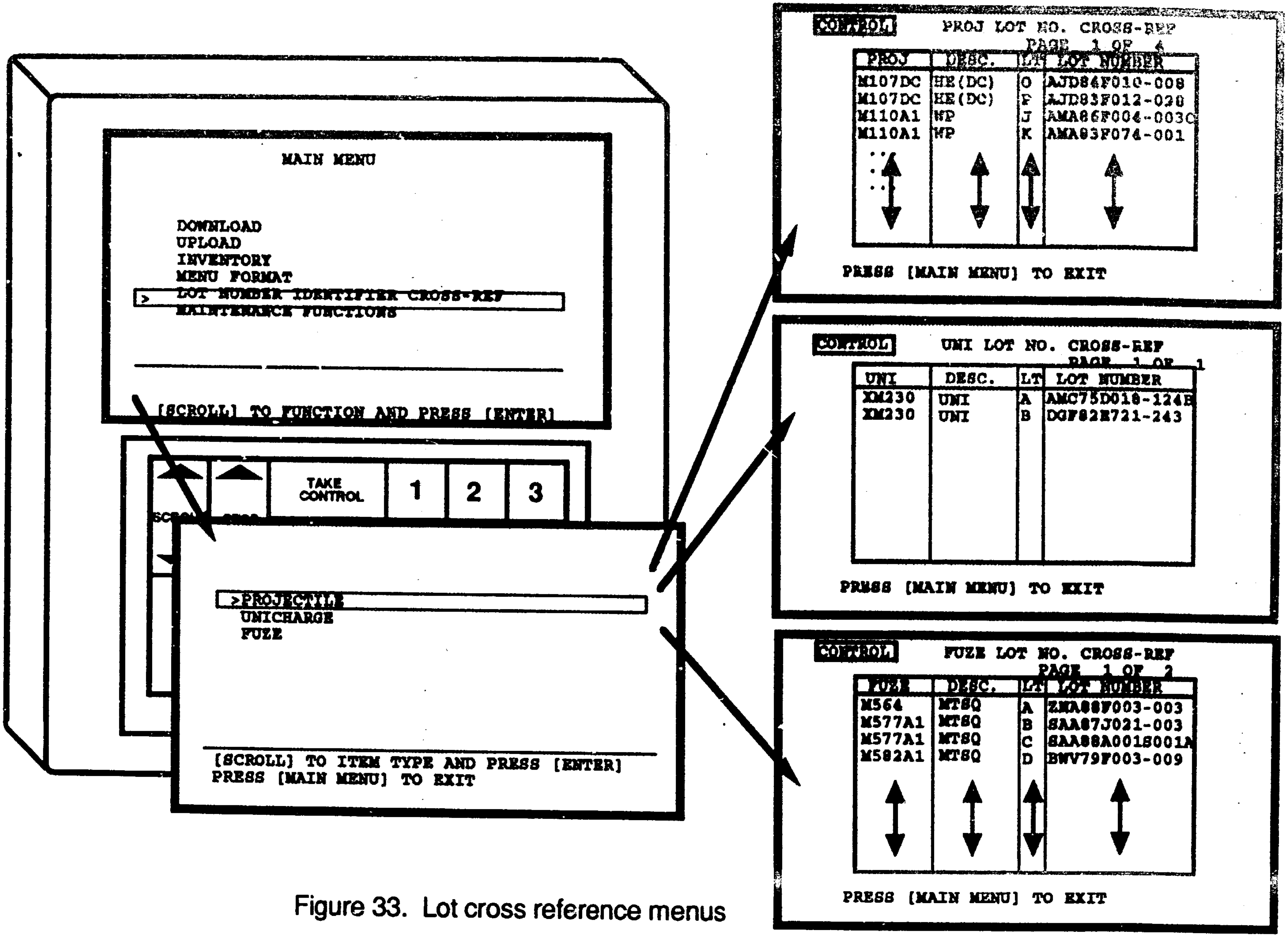


Figure 33. Lot cross reference menus

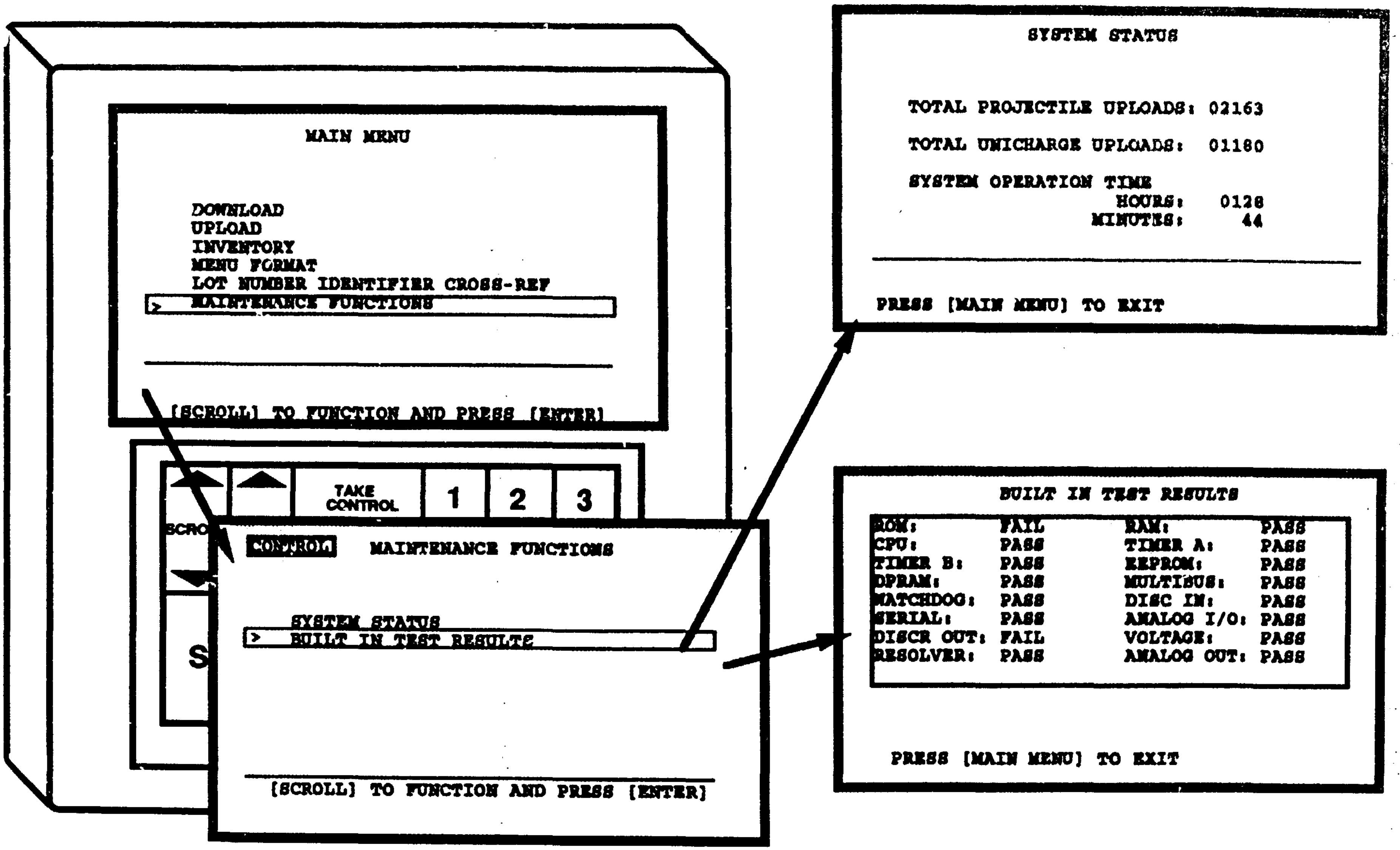


Figure 34. Maintenance menus

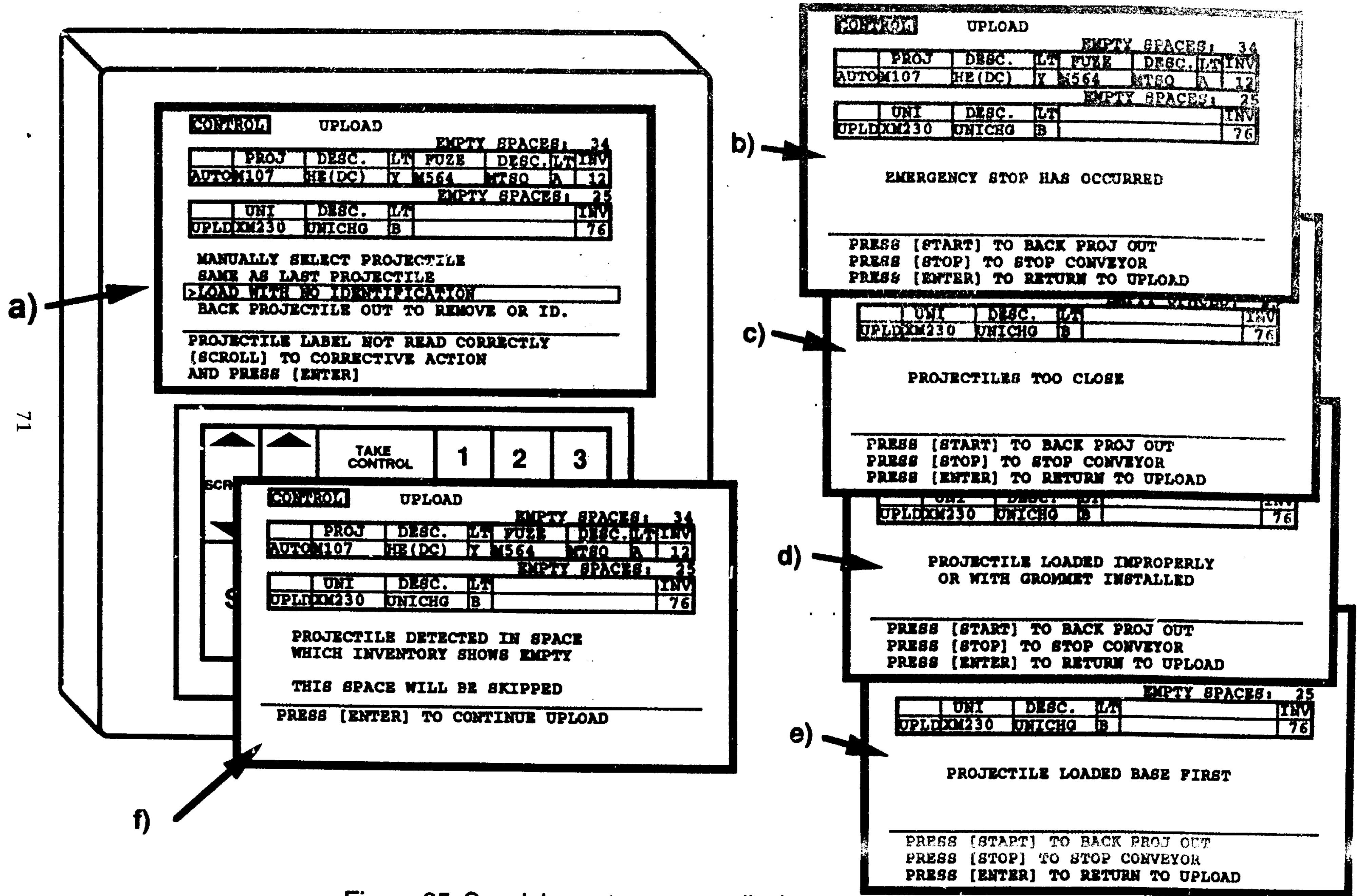


Figure 35. Special event message displays

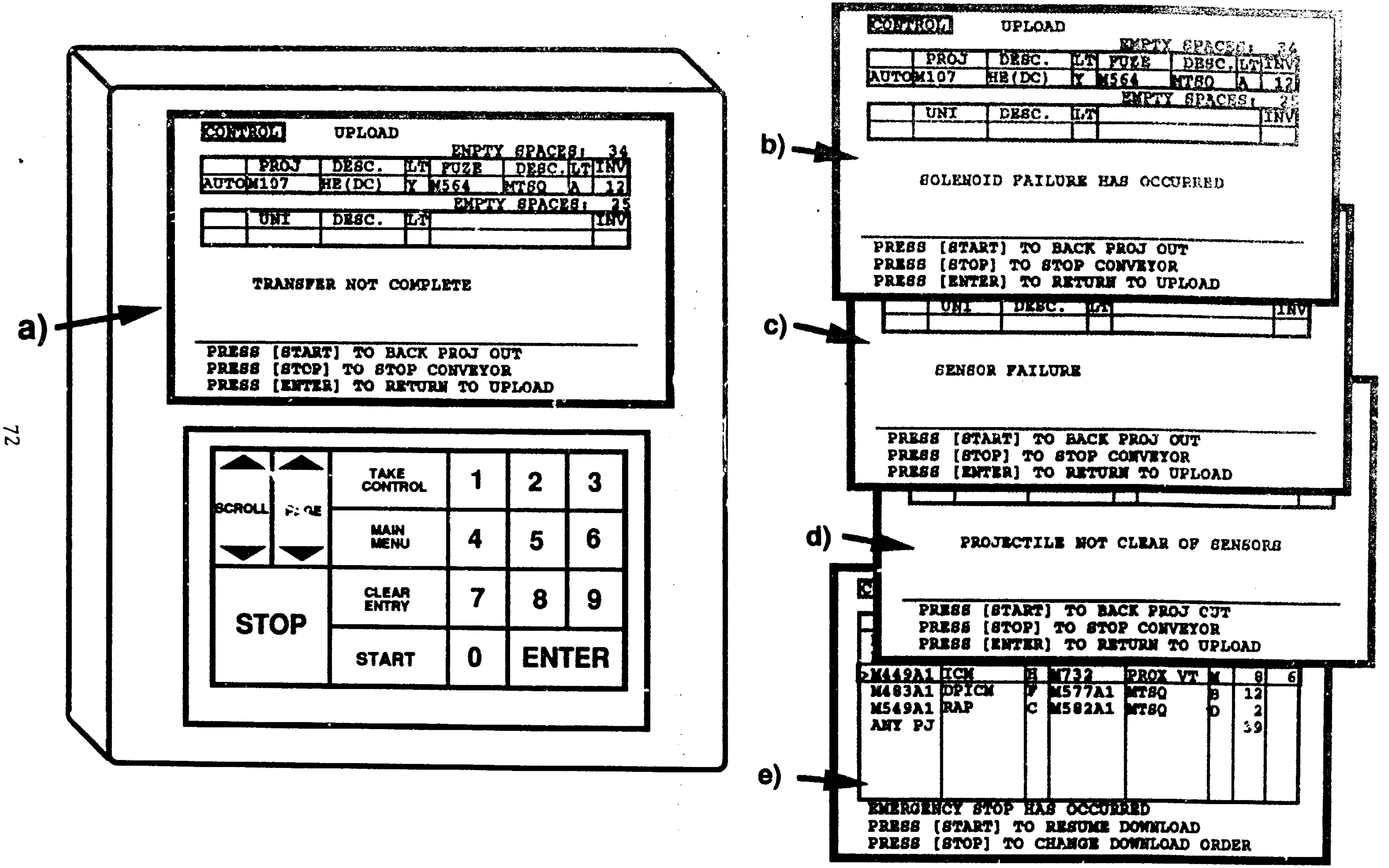


Figure 36. Special event message displays (continued)

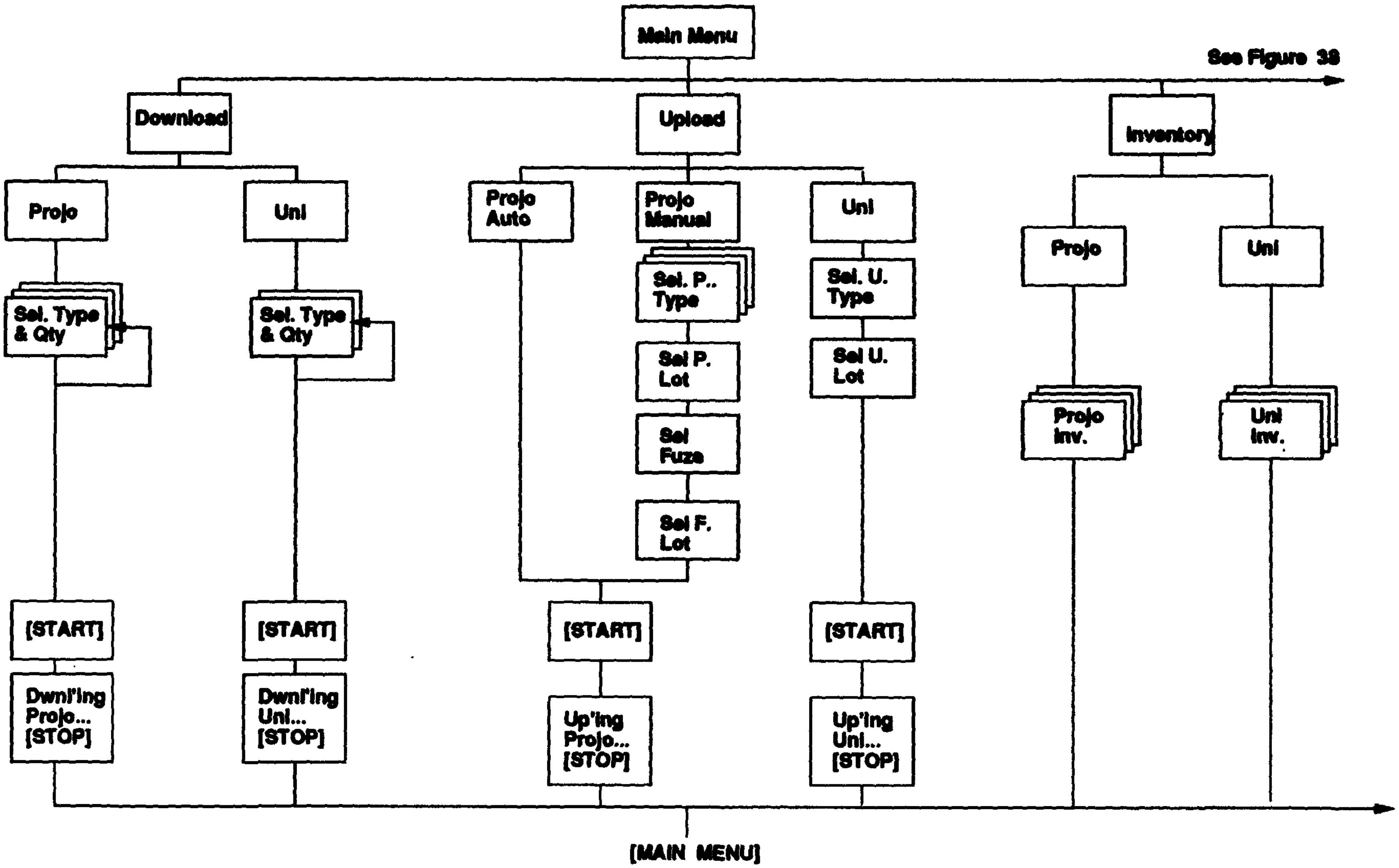


Figure 37. Menu flow diagram (part 1)

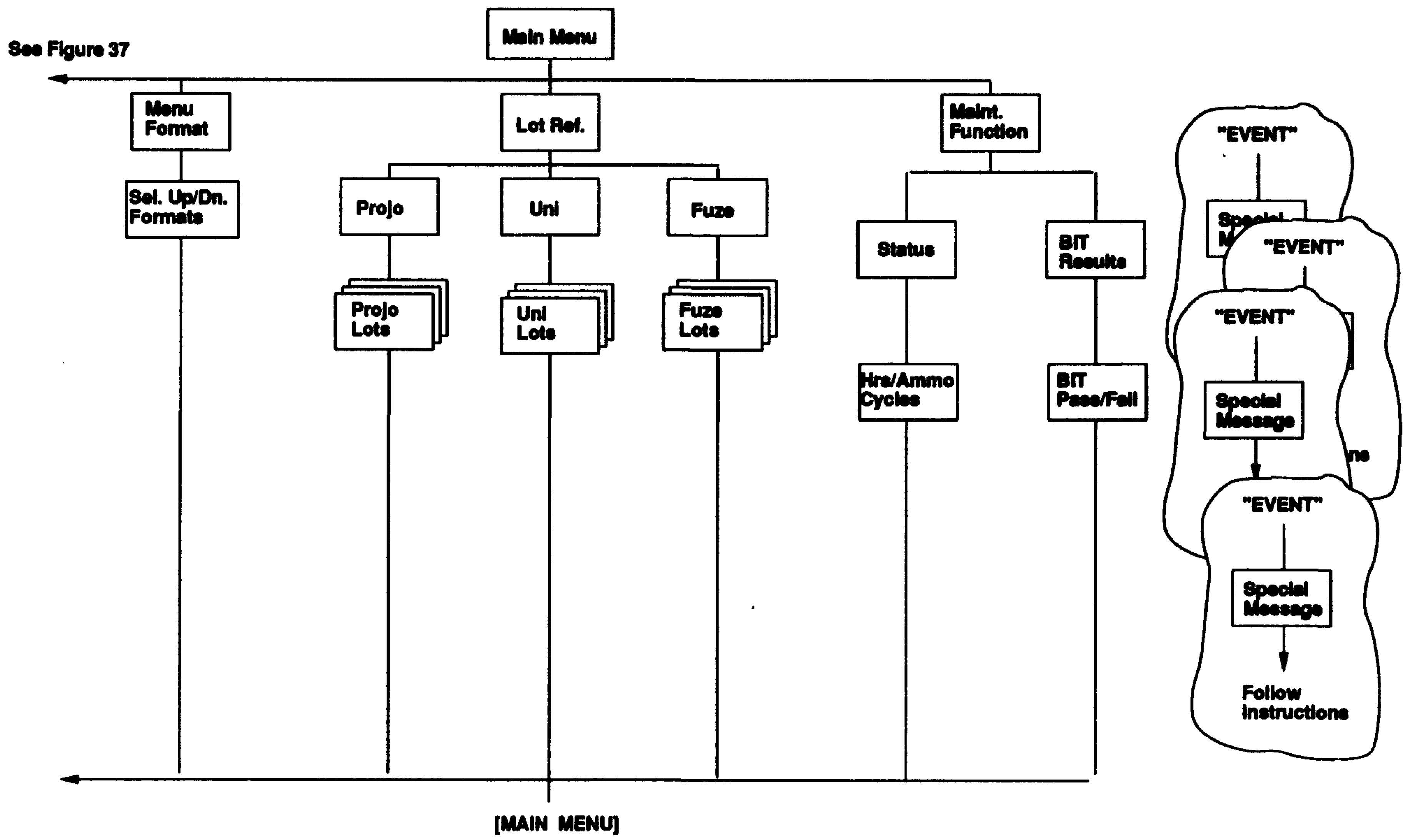


Figure 38. Menu flow diagram (part 2)

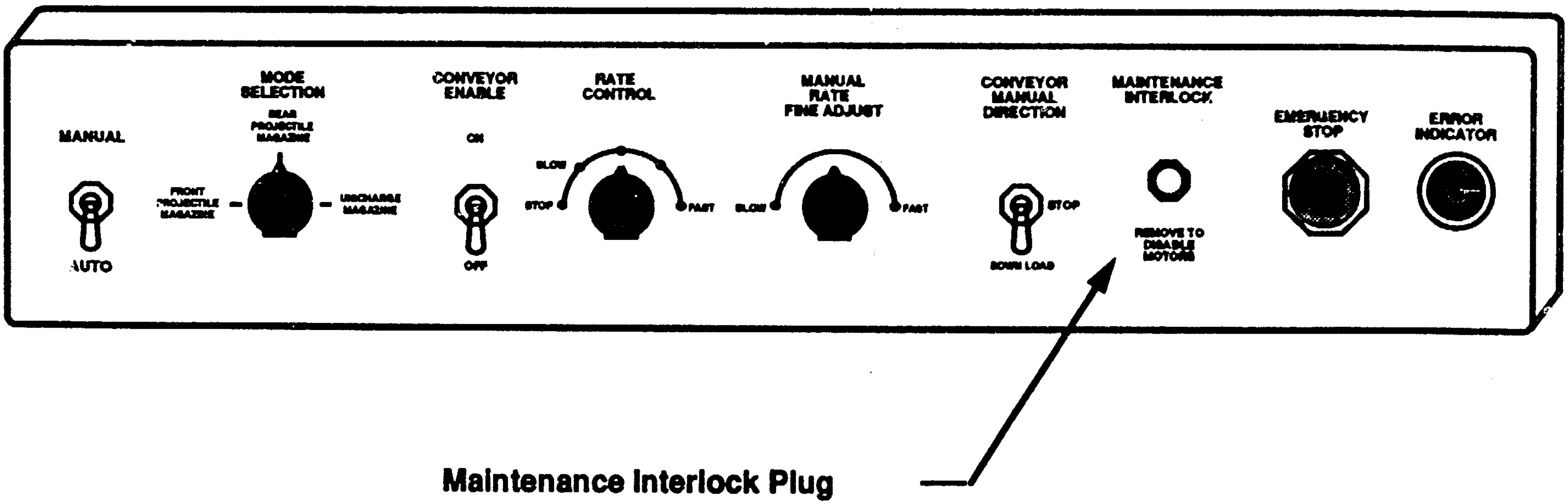


FIGURE 39. Maintenance control panel

Figure 40. ARM-II/U docking with a M109 Howitzer

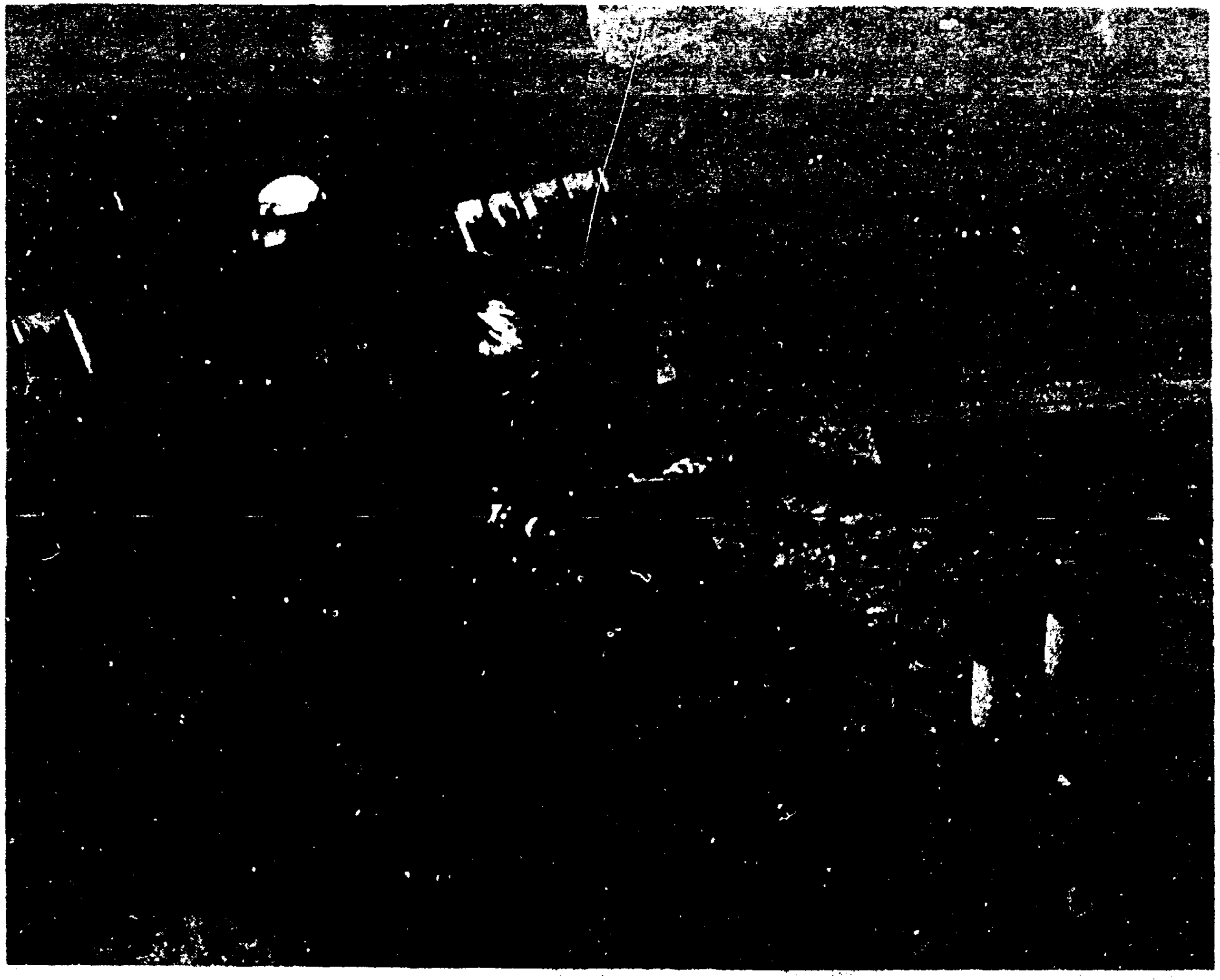


Figure 41. ARM-II/U conveyor deployed to floor of Howitzer

Figure 42. ARM-II/U docked with a 2-1/2 ton truck

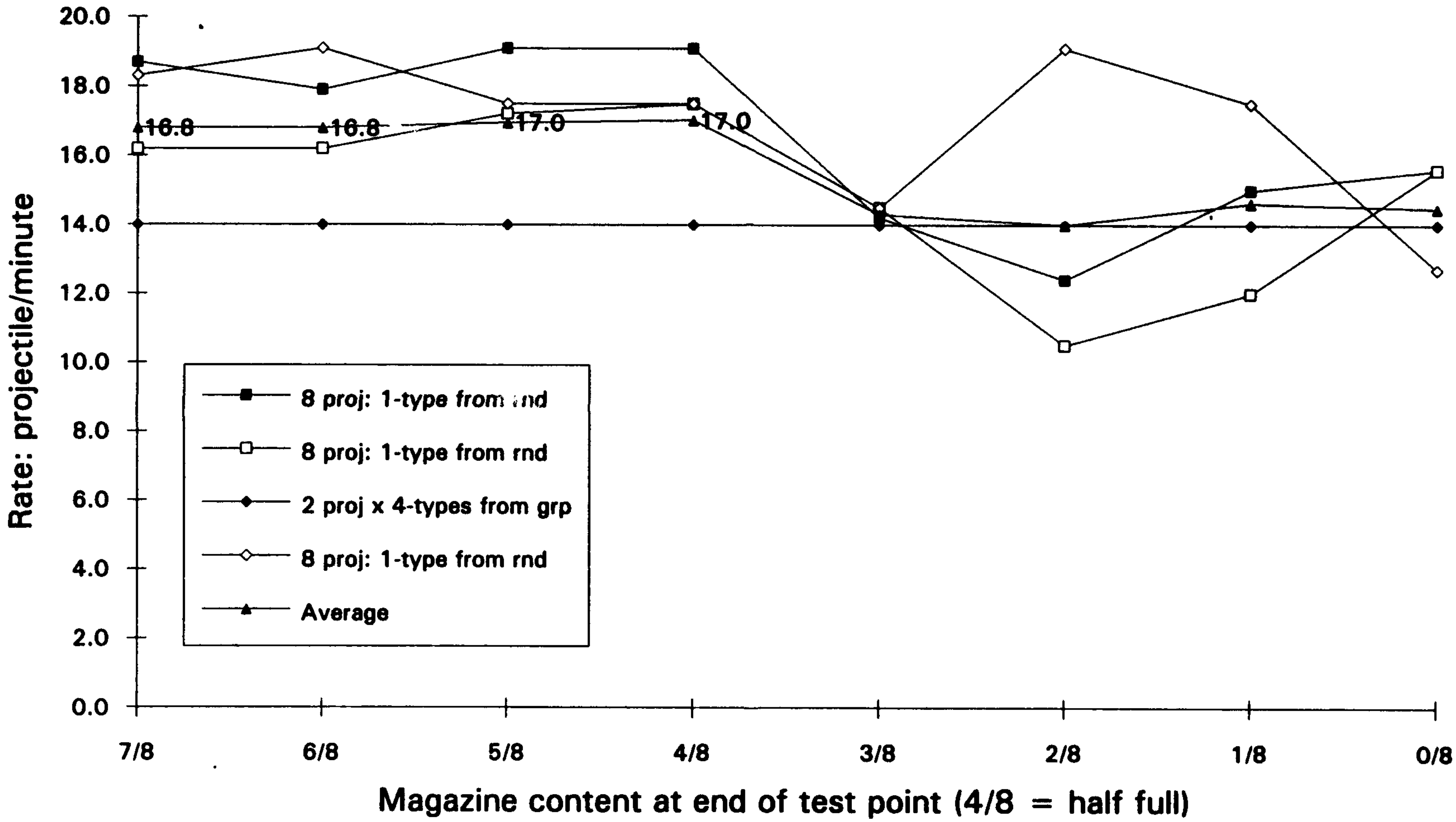


Figure 43. ARM-II/U download rate (projectiles pass a given point)

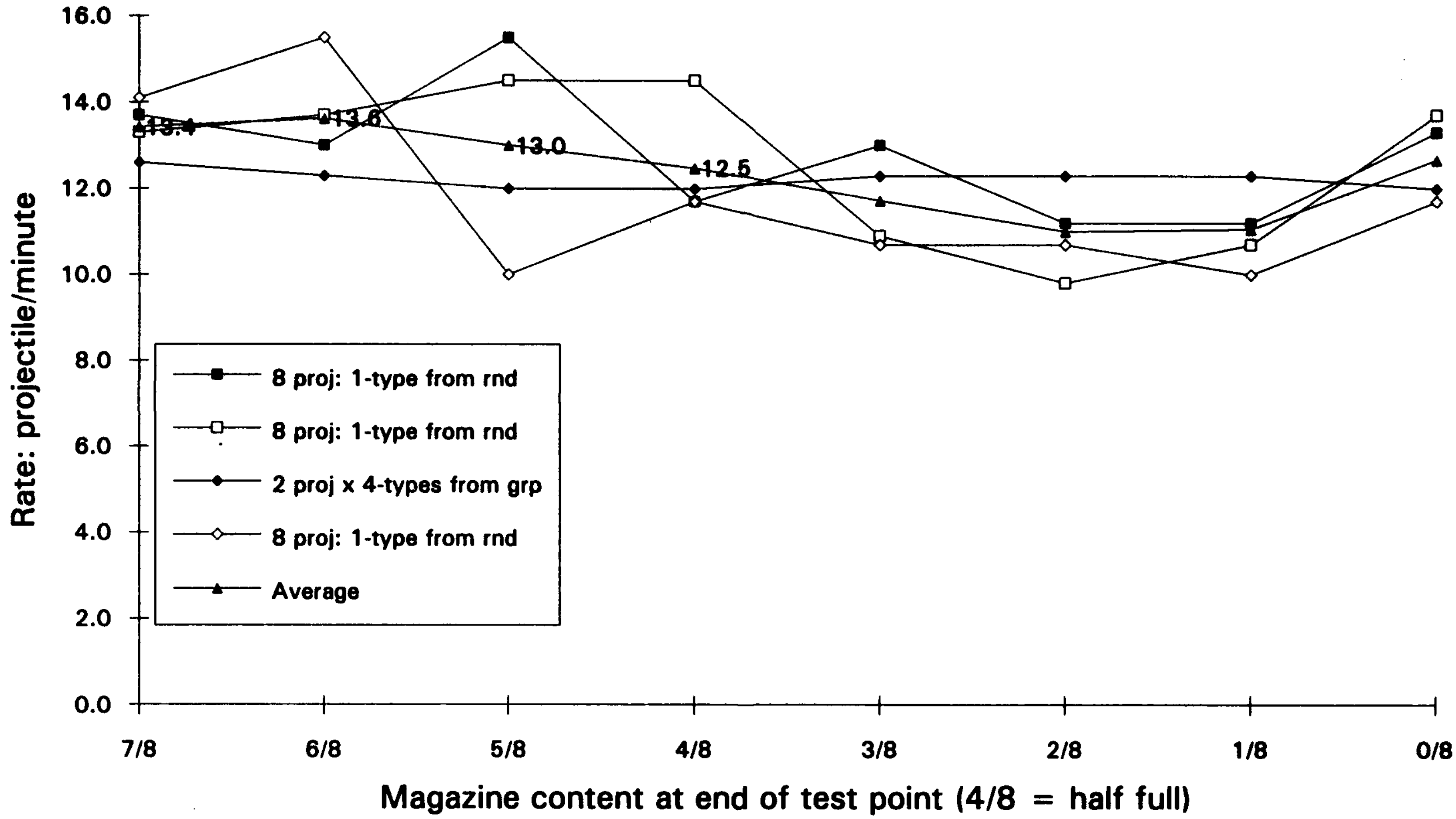


Figure 44. ARM-II/U download rate (conveyor start to projectile on tray)

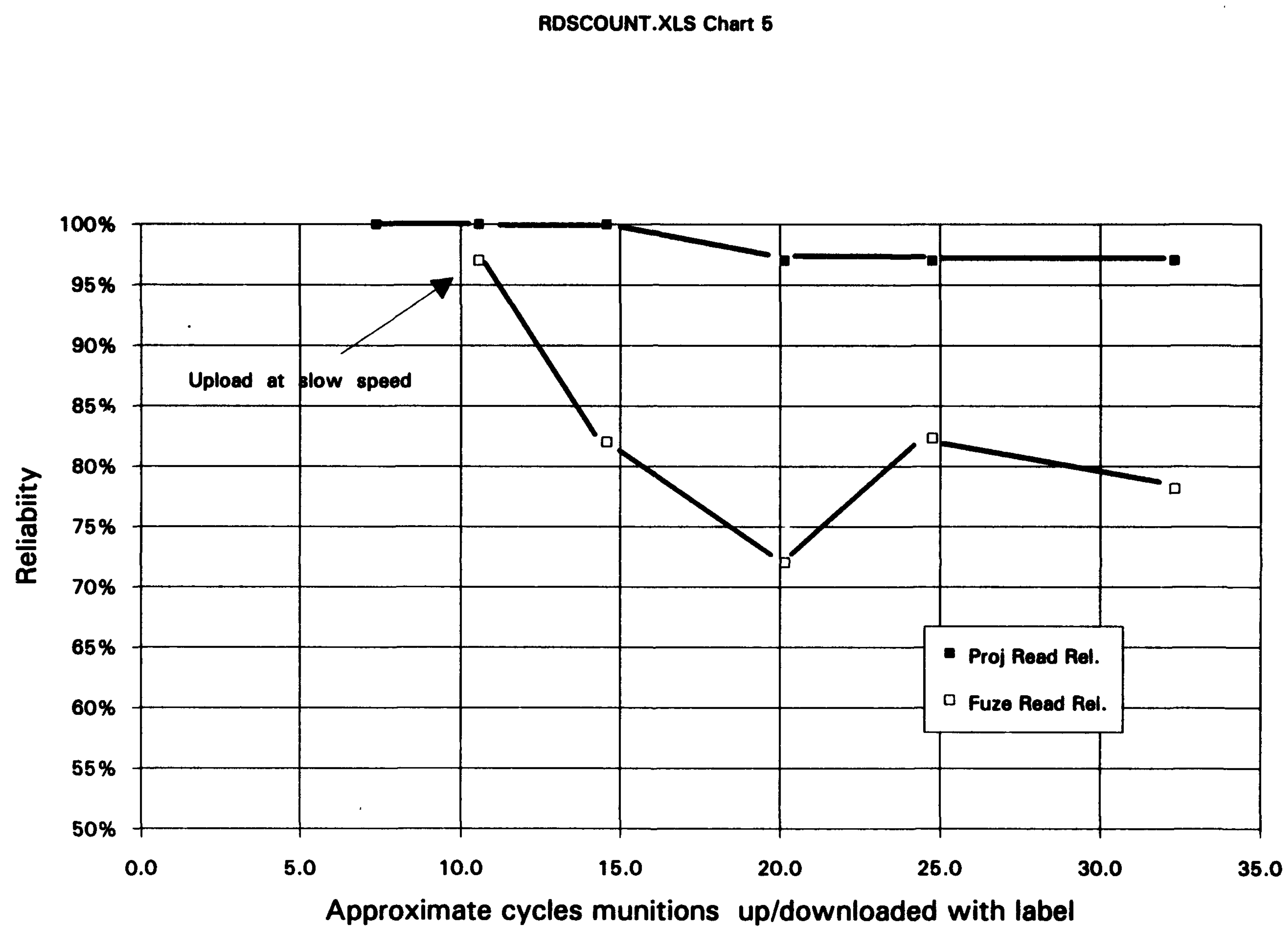


Figure 45. Projectile and fuze label read reliability

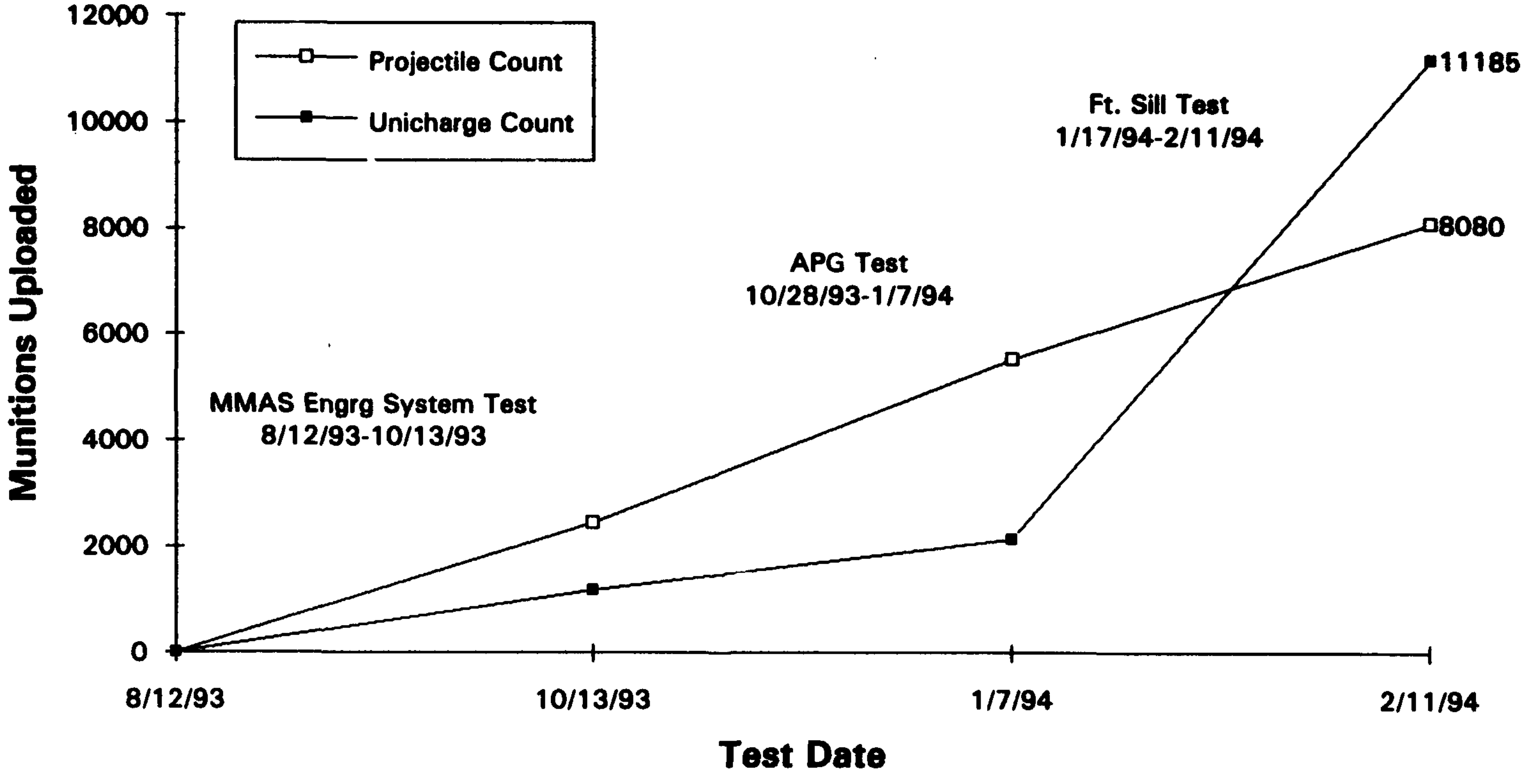


Figure 46. ARM-II/U testing - munitions uploaded

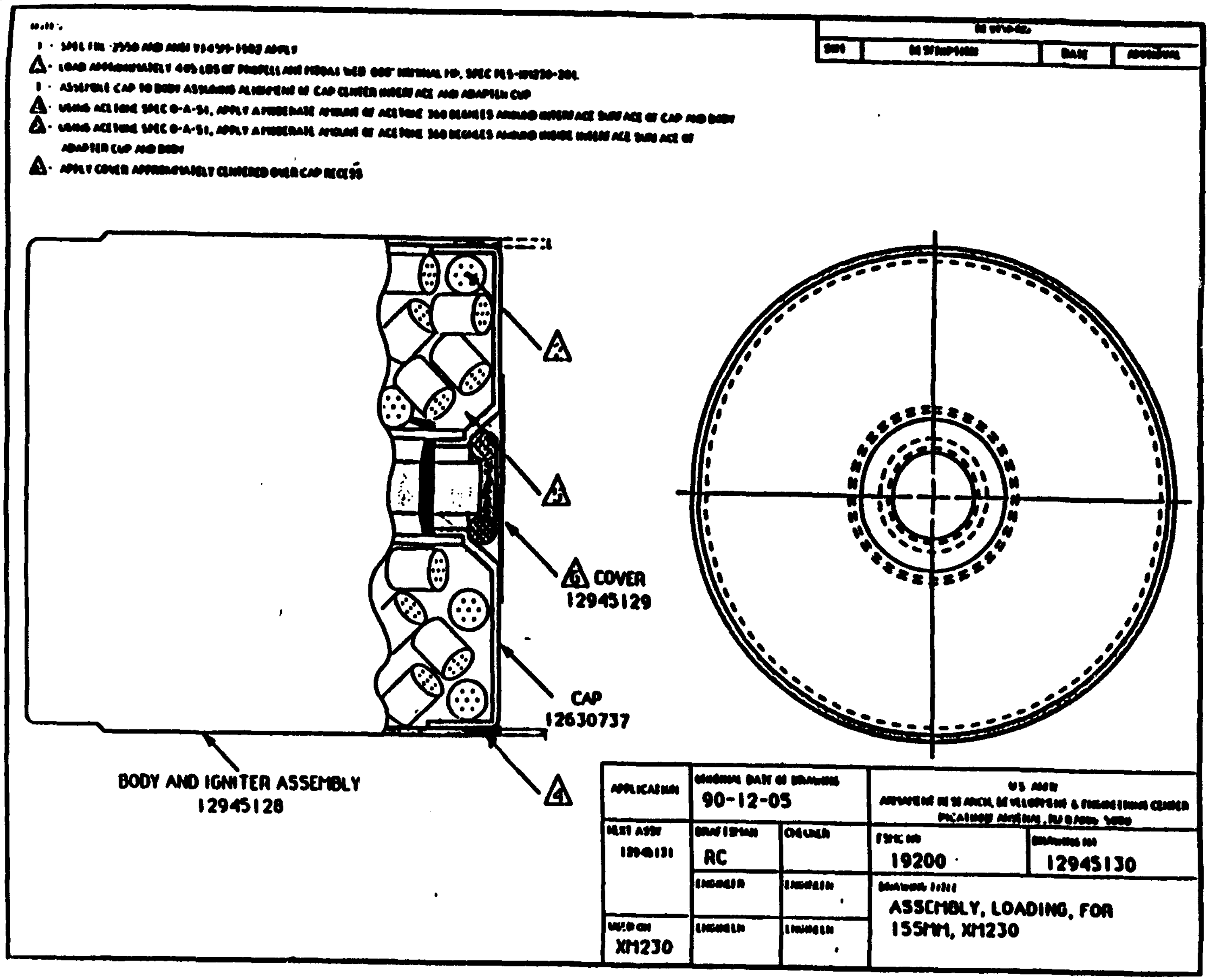


Figure 47. Unicharge configuration introduced at Ft. Sill

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