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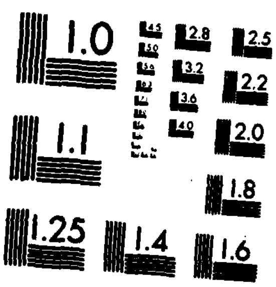

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Design Definition Study Report

Full Crew Interaction Simulator

Laboratory Model (FCIS-LM) Device X17B7

prepared for

Naval Training Equipment Center Orlando, Florida

Link

A DIVISION OF THE SINGER COMPANY

Report No: NAVTRAEQUIPCEN 77-C-0185-0001
LR-895

DESIGN DEFINITION STUDY REPORT

FULL CREW INTERACTION SIMULATOR-LABORATORY MODEL

(DEVICE X17B7)

VOLUME V - VEHICLE

Link Division, The SINGER COMPANY
Binghamton, New York 13902

FINAL
June 1978

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SECTION X

10. VEHICLE SYSTEMS STUDY AND CONCEPT FORMULATION

This section deals with the simulation aspects of the M60A3 vehicle and its various systems, including:

- Vehicle controls
- Miscellaneous engine related systems
- Hydraulic and Electrical systems
- Weapon and Fire Control systems

The section also covers the approaches to crew station simulation (configuration) as well as the simulation of various environmental effects such as aural cues. A number of these areas do not warrant a great deal of study effort with trade-off analysis since the design will be based on standard simulation techniques that will provide straight forward analogs of real-world systems.

10.1 Vehicle Simulation

10.1.1 Crew Station Simulation. To achieve as much realism as possible, the initial approach considered the use of an actual turret and cupola with a simulated driver's compartment attached. Studies indicated, however, that the weight of actual hardware would exceed motion system capabilities. Weight reduction by cutting out sections of the turret would still not sufficiently reduce weight. This required that alternatives be sought that would effectively provide crew members with the feeling of being in an actual vehicle even though it would have to be manufactured of a material to yeild a mass that could be easily and safely handled under motion.

In exploring the concept that placed the entire crew in one, enclosure, it was realized that all the mechanisms and controls required for turret traversing in the tank, could also be utilized in the simulator, along with the slip rings and other equipment interconnecting the hull and turret. This also meant that one motion system and one visual system would fulfill the necessary requirements as well as keeping the size of the facilities building down to a minimum.

Another approach was to separate the driver from the fighting crew and would require two separate and complete stations. This method lends itself more readily to the utilization of onboard observers as well as providing the capability of using each station as an individual crew trainer. This also creates the possibility of simplifying the visual system and making it more realistic for all crew members. This approach allows the eyepoints of the commander and driver to have a close relationship to their individual projector sources. It also allows the utilization of screens/domes of a much smaller radius than would be necessary if the entire crew were to have one visual system.

Since the motion system will provide the crew members the feel of a vehicle in motion, another approach is to either limit or eliminate turret rotating conditions. This would also eliminate the need for the various controls, drive mechanism, slip rings, and indicators associated with this feature. Simulation methods however, would have to be employed for some of the devices whereas others would be constructed for visual appearance only. This approach requires that the visual and motion systems provide the fighting crew members with the sensation that the turret is rotating while actually remaining in a non-rotating mode. In order to further simulate these conditions, it would appear that an additional visual cue,such as a portion of the hull normally seen by the crew inside the turret along with a rotating portion of the external hull as seen by the commander when operating "out of hatch", would add to the illusion.

One approach to cupola simulation would be to use it as an exact tank component. However, due to its excessive weight, an approach employing a lighter material (while maintaining appearance) seems to be more logical. Similarly , operational hatch covers could be used or manufactured specifically for the simulator (for weight reduction purposes).

10.1.1.1 <u>Instrument and Control Panels</u>. The only apparent, feasible approach to these devices is to physically locate them as in the actual tank for proper orientation by the applicable crew members. Appearance and function, by real or simulated methods, is a necessity that limits the number of possible approaches. For example; the speedometer and tachometer in the M60A3 are mechanically driven. The training device must provide simulation methods to produce the desired indicator displacements at any given time.

10.1.1.2 <u>Turret and Cupola Mechanics</u>. The requirement to provide continuous turret traverse introduces some serious problems in attempting to reliably transmit video signals through slip-rings. In addition, just the sheer quantity of signals required makes this approach a nearly impossible solution.

The use of special apparatus for providing communications between a moving and stationary terminal was considered. While devices of this nature have been demonstrated, their reliability in a complex system has not been established. The use of optical encoders for this type of transmission has not been implemented by Singer, since a continuously rotating crew station has not been a specific requirement in previous simulator systems. While this may be a feasible approach, no hardware interface exists.

A fixed-turret configuration is illustrated in Figure 10-1. The turret structure is supported by a rugged, welded frame which is the attachment interface with the motion platform. Concentric with the turret basket, is a cylindrical enclosure representing the interior hull of the tank. This hull is supported by rollers and bearings mounted to the motion platform. A hydraulic motor assembly mounted to the basket floor provides required hull rotation and the proper visual cueing of turret movement to the crew.

The turret, integrated with a motion system, as shown in Figure 10-2, represents a simplistic interface with the visual system, which in this case is a floor-mounted screen and projection system. The illusion of turret traverse is accomplished by rotation of the visual scene.

The turret system is shown mounted on a standard 3-degree-of-freedom motion platform. A motion onset cue or, in this case, a bump,is used to indicate movement. While this system appears to have merit, the exclusive use of picture rotation for turret traverse would not be sufficiently realistic. For that reason, turret motion, that is turret onset, etc, should be incorporated for the purpose of providing a short duration motion cue to identify turret movement and direction as well as turret stopping. This rotational (yaw) motion cannot be achieved utilizing a standard 3-degree-of-freedom motion system. Therefore, a modified system with limited turret rotation ($\pm 10°$) has been included (Figure 10-3).

Turret rotation, in this case, must be very smooth, since the nature of this motion is subtle and must be subliminable to prevent creating misleading cues.

While addressing the selection of motion systems, the use of a standard 3° system has been obviated by the inclusion of turret rotation, since no yaw motion can be provided by this system. The addition of turret rotation has produced a 4° system while complicating the integration of the crew station. In considering the optimum position of the visual projectors, the most favorable location is at the tank commander's eye position (out of the hatch). Locating the projector directly over this position, allowing clearance for the tank commander's head, presents a problem since the amount of heave capability in the motion system must be attenuated to preclude driving into the projectors. Prevention of this event cannot be easily or safely implemented by limiting the movement of the hydraulic cylinders. These considerations have been included in the concept shown in Figure 10-4 (a modified 3^{O} system) . For this implementation

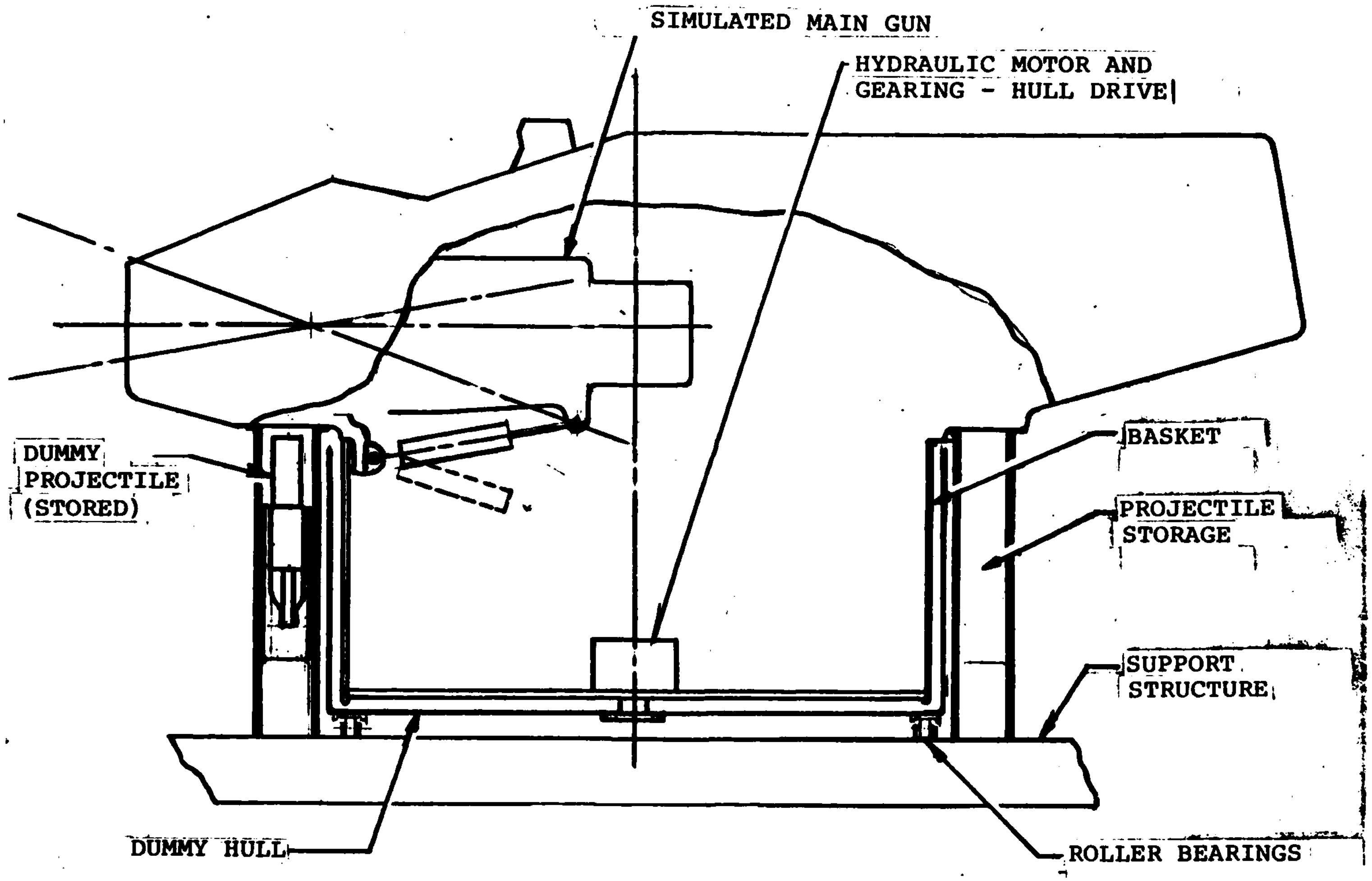


Figure 10-1 Fixed-Turret Configuration

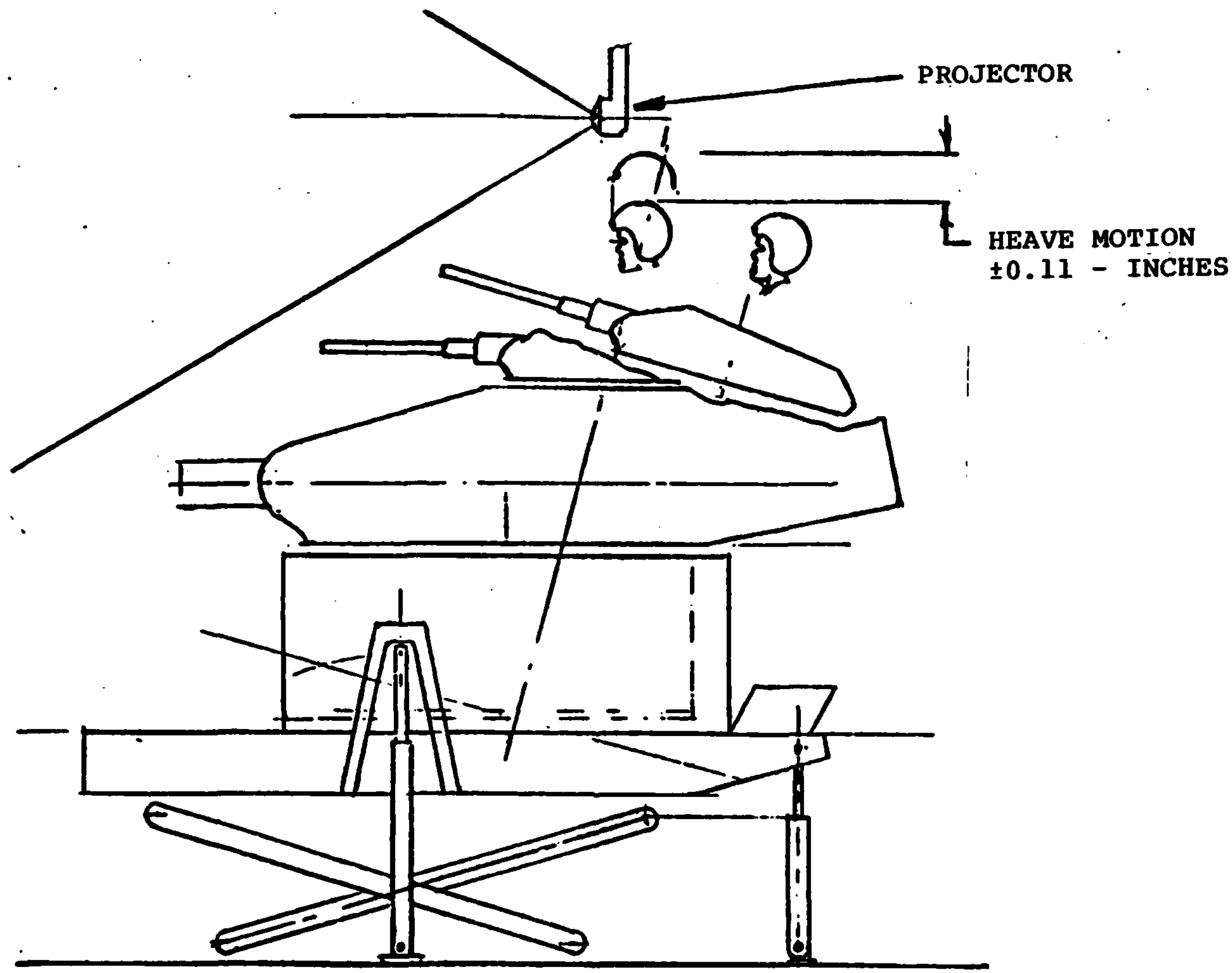


Figure 10-2 Standard 3-Degree-of-Freedom Configuration

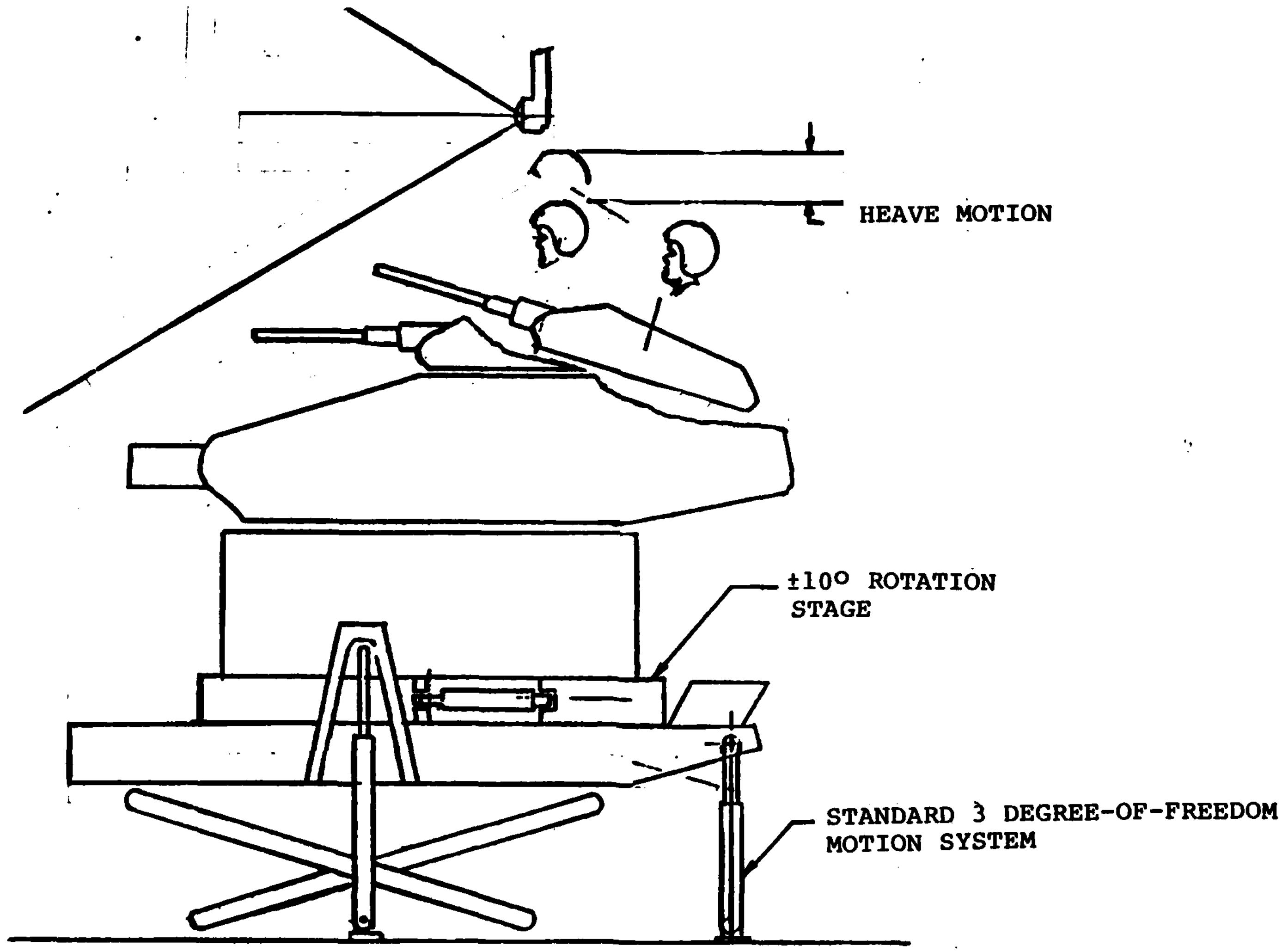


Figure 10-3 Rotary Motion Configuration

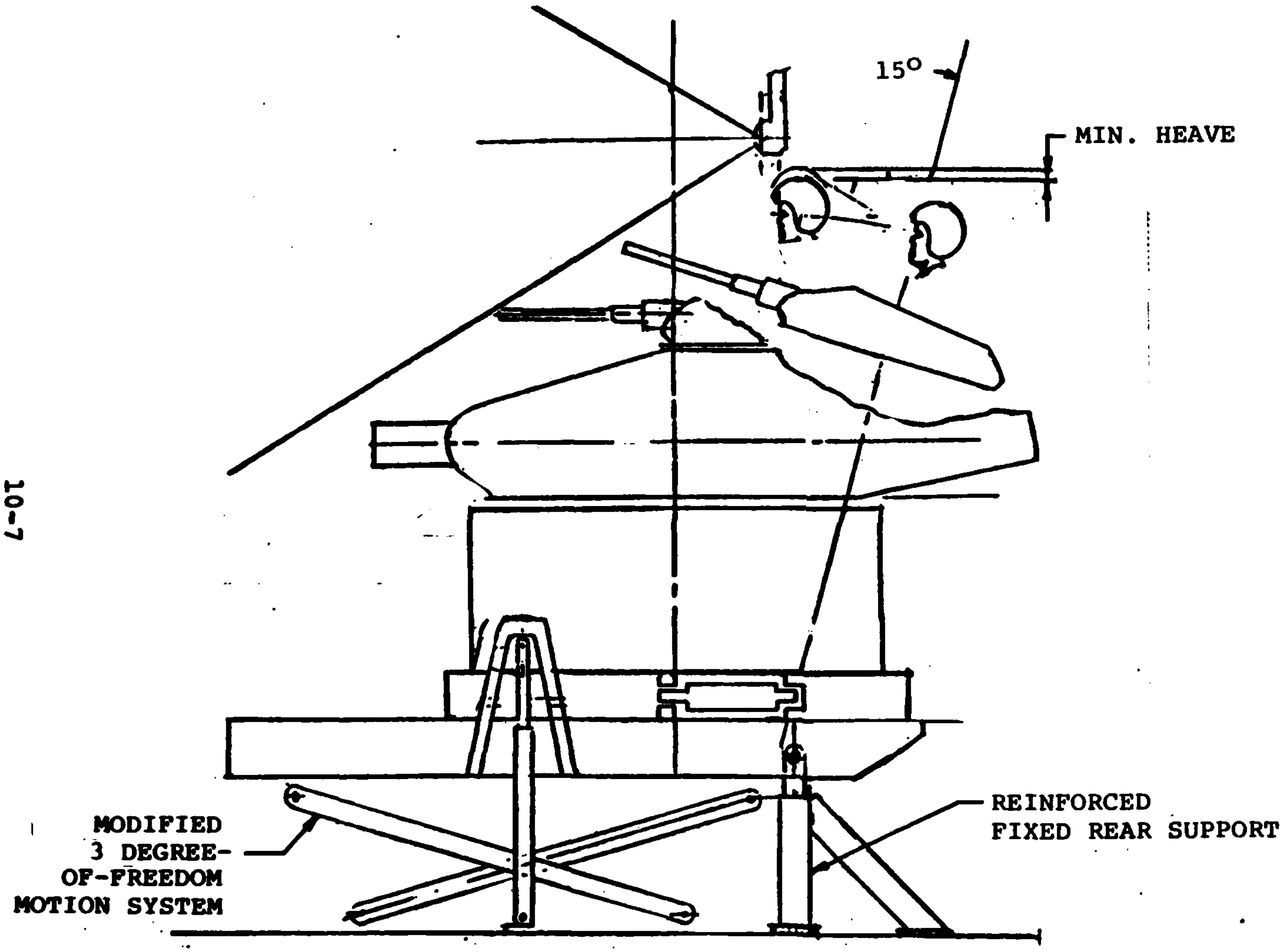


Figure 10-4 Limited Heave, Modified 3-Degree-of-Freedom Configuration

the rear cylinder has been fixed so that the maximum attainable heave is limited by the full stroke of both forward cylinders. By selecting a pivot position near the aft cylinder, the heave motion becomes more maintainable and is mechanically constrained within acceptable limits.

While this motion system is not standard, modifications can be implemented through straightforward redesign. Weight and inertia considerations of this system are within the capabilities of the standard 3-degree-of-freedom system system; and with the loading altered and combined with a stronger rear cylinder, these requirements can be readily met.

By limiting the heave motion, visual projectors can be located closer to the optimum eyepoint position, minimizing distortion. However, the distortion created by motion excursion, head clearance, and head excursions is still not acceptable when combined with an economically sized spherical screen. A screen with a larger radius to reduce distortion can certainly be constructed; but the cost of the screen plus increased facility cost make this approach prohibitive.

The next most obvious solution to minimize distortion inherent in this type of system is to locate the screen and projectors on the motion system. Now, motion excursions are eliminated and overhead clearance can be reduced. Of course, the payload of the motion system must be increased to accomodate the added weight and extensive support structure required to mount the screen.

With these considerations in mind, a re-evaluation, utilizing a 6-degree-of-freedom motion system is worthwhile, since both payload and structural support requirements can be satisfied. In addition, the turret derotation requirement can be met with existing hardware.

Cupola rotation will be limited to ±90° and will be manually powered using actual tank equipment. The ring gear and manual traverse gear box will be integrated with the simulated turret and cupola to provide realistic operation. The azimuth lock handle will be provided to permit locking the cupola at an azimuth zero position aligning it with the main gun. Travel gun. Travel limits will be installed to prevent the cupola from exceeding the 90° rotational limit.

While the simulated cupola will be significantly lighter than the actual equipment and therefore represent a lower inertia load, it is expected that the differences in operating force and feel will not adversely affect training. For this reason, there will be no additional friction or inertia loading added to this system.

10.1.1.3 Simulated Vehicle Controls (Driver Station). Many mechanically operated controls are located within the driver's compartment. These controls are associated with steering, braking, shifting, engine operation, fuel system operation, fire extinguishing, drain valve control, and turret sealing.

Since it is a requirement that all the above systems be partially or totally simulated, their related mechanical controls must be simulated. The following controls must be operational.

- Brake System
- Shifting Lever and Quadrant Mechanism
- Steering Control (T-Bar)
- Accelerator Pedal
- Fuel System Purge Pump Handle
- Fuel System Shutoff Handle
- Fire Extinguisher Controls and Mechanisms
- Hull Drain Valve Handles
- Turret Seal Hand Pump

10.1.1.3.1 Vehicle Controls. The following paragraphs discuss hardware simulation approaches to vehicle controls within the driver's compartment. Past experience in simulating hardware of this type, has dictated approaches that yield the highest simulation fidelity while considering cost, reliability, motionability, and complexity factors.

A tradeoff of cost of manufacturing versus purchasing of actual equipment is not considered at this time.

Brake System - Simulated hardware for the brake system can incorporate the actual hydraulic master cylinder gage and pedal equipment. Hydraulic outputs of the master cylinder can then drive a slave cylinder loading unit which will provide appropriate pedal pressure and master cylinder pressure response. The loading unit can also incorporate a pressure transducer which is returned electrically to the computer linkage for use by the brake and transmission computer program computations.

The parking brake linkage on the gearshift lever quadrant requires a special mechanism to simulate linkage at the transmission. This hardware will cause the gearshift lever, when in park and pedal pressure applied, to lock in place upen release of pedal pressure. The mechanism will be driven by simulation controlled logic.

Steering Control - The steering control (T-Bar) and linkage will be operational hardware. The steering linkage will be terminated in a spring loader beyond the driver's field of view. This loading unit simulates the "spring" feel created by the steering linkage of the actual tank. A component of the loading mechanism will be a position transducer, electrically coupled to the computer for use by transmission program computations. Since there are no significant differences between powered and unpowered modes, the need for hydraulic loading is negated.

Transmission Shift Lever - The gear shift lever, quadrant, and linkage will be used in the simulated tank. A friction-type loader and position potentiometer will be attached to the linkage to replace the feel created by the actual tank transmission connection. The position potentiometer is electrically connected to the simulation computer for sensing the simulated transmission program.

Accelerator Pedal - The accelerator pedal, pedal lock, return spring, and linkage of the actual tank can be used in the simulator. The linkage will be connected to a friction device to simulate the forces required to operate the pedal in the actual tank. A position potentiometer will also be a part of the friction mechanism and will be electrically connected to the simulation computer for sensing by the simulated engine program.

Fuel Shutoff Handle - The simulator fuel shutoff handle will be actual tank equipment. However, the push-pull cable that normally operates the fuel valve will operate a simulated mechanism representing the frictional forces of the valve assembly. This standard friction unit will also incorporate a switch for computer sensing by the fuel system program.

Fire Shutdown Handles - Fire shutdown handles, handleıdle mechanisms, and control heads for the CO_2 bottles used in the simulated system will be actual tank hardware. Bottles, plumbing, hoses, brackets, and cables of the actual system will also be used. However, the CO_2 bottles will not be charged.

External fire shutdown handles and related pull cables will not be simulated since there is no simulation requirement for the crew to operate the handles from outside the tank.

Hull Drain Valve Handles - The tank drain valve handles used in the simulator will be actual tank parts. The simulated form of the system will end where the linkage extends under the turret. A spring loader will be added to the engine compartment drain valve lever linkage to simulate forces at the handle caused by the actual drain valve spring. Switches will be added to the equipment for computer sensing of handle positions.

Turret Seal Hand Pump - Turret seal hand pump equipment from the tank system can be used in the simulator with the exception of the actual seal itself. An air bladder in a box will be sized to simulate the actual turret seal and in turn provide the correct response on the pressure gage and the required number of pump strokes for inflation.

Fuel System Purge Pump Handle - Two approaches can be considered to provide form, function, and feel of the pump handle. Both use actual pump equipment. One of the approaches however, will modify the valve body to accept a mechanical link.

The approaches are considered in terms of simulation fidelity, cost, complexity, servicability, and maintainability.

Approach I - Use actual equipment and add hydraulic components to simulate handle loading and provide computer inputs.

1. Additional components required: Pressure transducer, solenoid valve, pressure regulator, accummulator, restrictor, tubing, and coupling

2. Simulation fidelity - Excellent, because it duplicates the hydraulic feel of the actual system

3. Serviceability - Excellent

4. Maintenance - Different when required .

5. Cost - Four times that of a mechanical friction system.

6. Hardware complexity - Medium

7. Singer experience level - Low

Approach II - Use actual equipment, but modify the valve body to accept a mechanical link which is connected to a mechanical friction-type loader. The loader units will also incorporate sensors for computer inputs.

1. Additional components required: Electrically controlled friction unit, position transducer, torque tube and bearings, mounting brackets, modified valve, bell crank linkage

2. Simulation Fidelity - Good, because handle forces are duplicated and hydraulic 'feel' is not present

3. Serviceability - Excellent

4. Maintenance - Excellent

5. Cost - One-fourth the cost of approach I

6. Hardware complexity - Low

7. Singer experience level - High

The software approach for either of the above hardware approaches will remain essentially the same and cannot be considered a factor.

10.1.1.4 Miscellaneous Mechanical Systems. All controls and other mechanical devices utilized by the various crewmen must have the appearance and feel necessary to provide the realism required for the training function. This becomes the only possible approach to this area. These controls and devices include: Purge Pump, Emergency Fuel shutoff handle, Drain Control handles, Fixed Fire Extinguisher system, and primary controls (steering, brakes, shifting, and accelerator).

10.1.2 Crew Station Configuration. Tradeoff analyses of Visual, Motion, and Electronics Systems have shown distinct advantages of providing total FCIS capability on two separate motion systems - One for the driver and associated equipment and the other for the fighting crew and their equipment (Figure 10-5 and 10-6 respectively). Both figures show that the motion systems support the trainer enclosures, the onboard observer, and the visual system which includes screen and projector(s) as required.

It should be noted that the dual system approach offers not only FCIS, but may be minimally altered to provide COFT and individual system training as well.

10.1.2.1 General Construction Approaches Tradeoff Analyses. Two methods of constructing the crew enclosures were considered. One was to use molded fiberglass; the other, welded sheetmetal. The ensuing cost analysis indicated that welded sheetmetal would be less costly, sturdier, and more adaptable to safely support all necessary internal components.

Since actual turret rotation would provide many complications in the mechanical and visual systems, a simpler solution would be to fix the turret and simulate its rotation by utilization of the visual and motion systems combined with a rotatable portion of a simulated hull. Tables 10-1 and 10-2 provide tradeoff analysis for crew enclosures and cupola approaches.

10.1.2.2 Configuration Development. Link's many years of experience indicate that the utilization of two identical motion systems is the most logical approach, since it allows commonality of components, high reliability, and low maintainability.

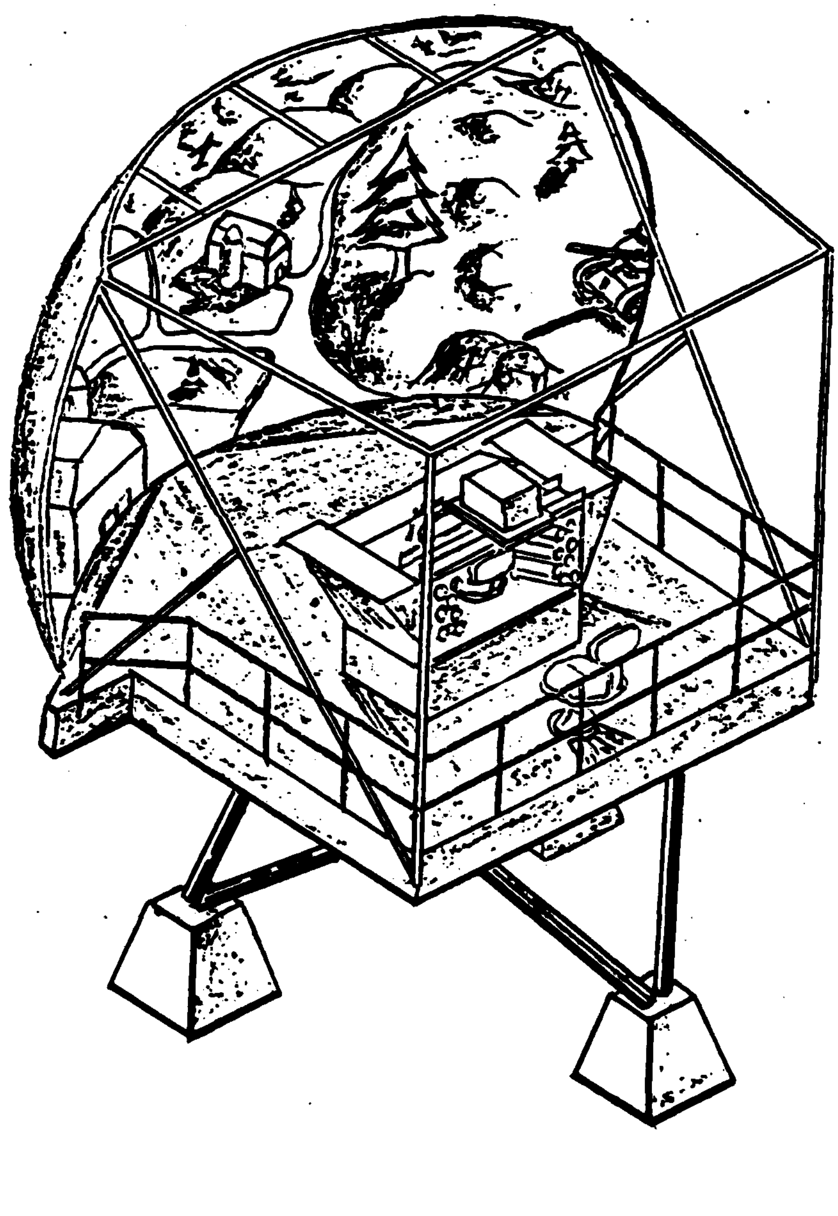


Figure 10-5 Motion System - Driver's Station

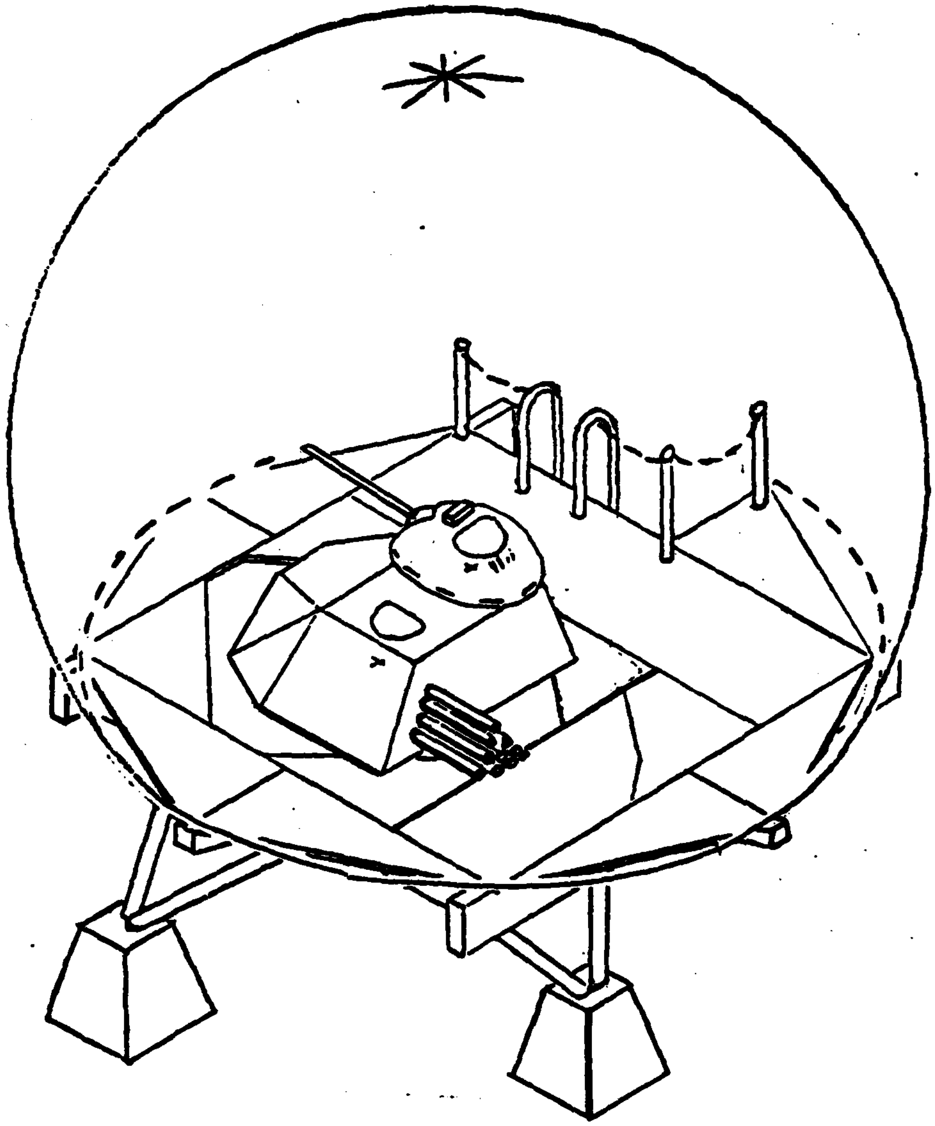


Figure 10-6 Motion System - Fighting Crew Station

TABLE 10-1 TRADEOFF ANALYSIS/SELECTION CHART - CREW ENCLOSURES (DRIVER AND FIGHTING CREW)

	TRADE-OFF PARAMETERS AND SELECTION CRITERIA	WEIGHTING FACTOR	MOLDED FIBERGLASS		WELDED SHEETMETAL							
			EF	FM	EF	FM	EF	FM	EF	FM	EF	FM
PARAMETERS	PERFORMANCE PARAMETERS											
	• STRENGTH	0.6	3	1.8	5	3.0						
	• OUTER APPEARANCE	0.1	5	0.5	1	0.1						
	• INTERIOR REALISM	0.8	3	2.4	5	4.0						
	•											
	•											
	PERFORMANCE SUMMATION			4.7		7.1						
CRITERIA	OVERALL PERFORMANCE			1.6		2.4						
	LOW PROCUREMENT COST	0.3	1	0.3	5	1.5						
	LOW OPERATING COST	0.8	5	4.0	5	4.0						
	SIMPLICITY	0.3	2	0.6	3	0.9						
	RELIABILITY	1.0	2	2.0	5	5.0						
	MAINTAINABILITY	1.0	3	3.0	5	5.0						
	SYSTEM COMPATABILITY	0.6	3	1.8	5	3.0						
	SYSTEM FLEXIBILITY	0.6	5	3.0	5	3.0						
	PRODUCIBILITY/AVAILABILITY	0.4	5	2.0	5	2.0						
	SAFETY ASPECTS	1.0	3	3.0	5	5.0						
	OVERALL SUMMATION		21.3		31.8							
	APPROACH REJECTION/SELECTION											

TABLE 10-2 TRADEOFF ANALYSIS/SELECTION CHART - CUPOLA

	TRADE-OFF PARAMETERS AND SELECTION CRITERIA	WEIGHTING FACTOR	MOLDED FIBERGLASS		WELDED SHEETMETAL							
			EF	FM	EF	FM	EF	FM	EF	FM	EF	FM
PARAMETERS	PERFORMANCE PARAMETERS											
	• STRENGTH	0.4	3	1.2	5	2.0						
	• OUTER APPEARANCE	0.4	5	2.0	3	1.2						
	• INTERIOR REALISM	0.7	5	3.5	2	1.4						
	•											
	•											
	PERFORMANCE SUMMATION			6.7		4.6						
CRITERIA	OVERALL PERFORMANCE			2.2		1.5						
	LOW PROCUREMENT COST	0.3	1	0.3	3	0.9						
	LOW OPERATING COST	0.8	5	4.0	5	4.0						
	SIMPLICITY	0.7	5	3.5	1	0.7						
	RELIABILITY	1.0	5	5.0	5	5.0						
	MAINTAINABILITY	1.0	5	5.0	5	5.0						
	SYSTEM COMPATIBILITY	0.6	2	1.2	5	3.0						
	SYSTEM FLEXIBILITY	0.6	5	3.0	5	3.0						
	PRODUCTIBILITY/AVAILABILITY	0.8	5	4.0	1	0.8						
	SAFETY ASPECTS	0.5	3	1.5	5	2.5						
	OVERALL SUMMATION			29.7		26.4						
	APPROACH REJECTION/SELECTION											

The selected approach (welded sheetmetal) also serves as a support structure and mounting surface for the many heavy internal components requiring secure attachment. The internal appearance of each enclosure will be even more realistic because even the mounting devices for the various components will be faithfully reproduced.

The driver's compartment can be fabricated with greater ease than the turret due to its basically flat surfaces. The compound curves and everchanging surfaces of the turret do not readily lend themselves to sheetmetal construction. Therefore certain liberties will be taken in fabricating the internal physical shape of the turret, without compromising its training value. The cupola, because of its overall shape, dictates the use of cast or molded plastic (or metal) along with metal plates to realistically duplicate appearance and function. Due to the type of construction under consideration, extremely high reliability and maintainability factors may be anticipated. No significant production problems are anticipated.

The facilities building would require a Simulator Room to house the two systems, a Computer/Instructor Station Room for electronics support, a Pump/Maintenance Room (s) for hydraulics, and a Receiving/Stock Storage area. Briefing rooms and administrative offices must also be considered a part of the training facility. (See Figure 10-7.)

10.1.2.3 Configuration Flexibility. Each crew enclosure, once designed for its original purpose (FCIS) can, with minor modifications, he converted to COFT or individual crew trainers (with or without motion and/or visual).

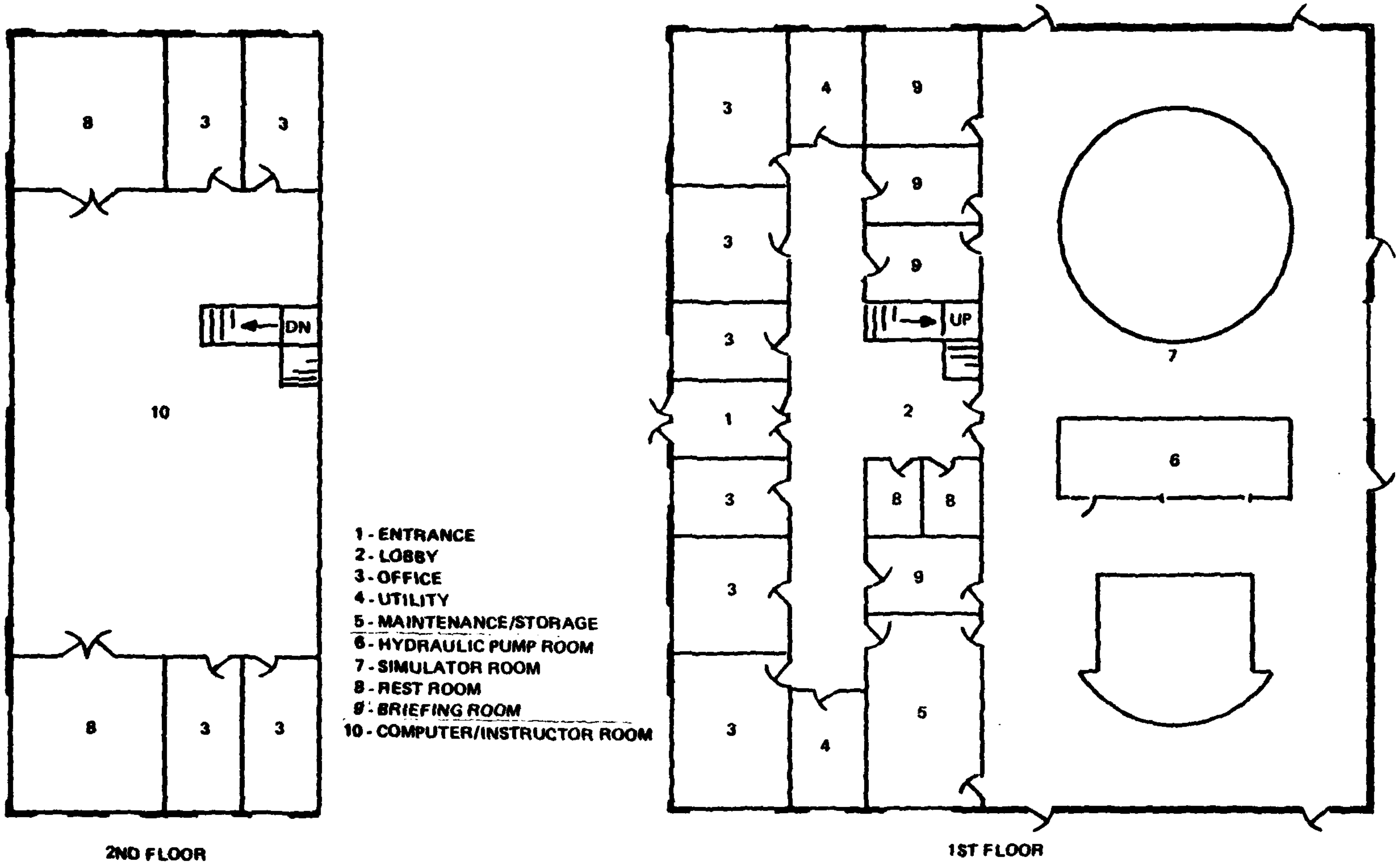


Figure 10-7 Suggested Simulator Facility Floor Plan

10.2 Vehicle Systems

10.2.1 Design Approaches.

10.2.1.1 Simulated Turret Hydraulic System. Turret hydraulic simulation should include all equipment and indicators related to creating a simulated hydraulic charge in the main hydraulic accumulator. The main accumulator, power pack, pressure gage assembly, and associated plumbing must be simulated.

A software program should compute accumulator pressure as a function of the simulated turret and gun elevation hydraulic demand, driving the hydraulic accumulator pressure gage through the computer linkage.

10.2.1.2 Simulated Turret and Gun Elevation Drives. Crew members require the capability to operate the elevation and traverse systems. Therefore, the controls, hardware, and other equipment used by the driver must be simulated. Simulated equipment should also operate in the manual mode. The super-elevation actuator and the stabilization equipment are required as a part of the simulated system.

Software programs will require control position inputs to the computer to determine drive rates for simulated elevation and turret drives. These programs should also include hydraulic and power logic, inputs from the stabilization system, and superelevation inputs from the ballistics computer. Other systems programs will require the position, such as instructor display, scoring, etc., of the gun and the turret azimuth.

10.2.1.3 Simulated Electrical System. The simulated electrical system should provide the driver with the applicable tank controls and indications. The simulated Master Control switch on the Master Control panel should provide simulated power to all tank systems, equipment, and lighting. Where tank systems are totally simulated, software power logic will be made available to the computer programs.

Simulated electrical system hardware (controls and indicators) should interface with the computer electrical system software. Software programs must compute battery condition based on engine and tank equipment operation. A capability should be provided to start the engine with a dead battery.

Circuit breakers not normally accessible to the crew or located under the turret need not be simulated. Dimming of the lighting system due to battery deterioration also need not be simulated.

10.2.1.4 Fixed Fire Extinguisher System . The fire system requires that the hardware at the driver's station be available for his use. This hardware should also provide sensing switches for display at the Instructor/Operator's CRT and for use by the fuel system computer programs, since activation of the fire extinguisher system shuts off fuel to the engine. An actual CO_2 charge in the system is not required.

10.2.1.5 Simulated Personnel Heater, Ventilation, and Gas Particulate Systems.

10.2.1.5.1 Simulated Personnel Heater. The personnel heater controls and equipment are located at the driver's station for his use. However, heated or fan-forced air is not required for sensing by the fuel,personnel heater,and electrical system programs. Personnel heater logic should be representative of actual tank system logic.

10.2.1.5.2 Ventilation System (Blower). The tank ventilation system control will be required simulation hardware. Actual exhaust blower hardware need not be simulated since the source of noxious fumes (main gun) does not fire actual shells. When the turret vent blower switch is actuated, an audible cue, representative of the blower assembly should be present.

10.2.1.5.3 Simulated Gas Particulate System. The simulated gas particulate system requires that system hardware be provided at all crew stations. The orifice connector at each crew station requires that clean air be available for crew NBC mask use. Also, the tank driver should have control of the operation of the system at the Driver's Master Control panel.

The Instructor or Operator Station should also have an indication of gas particulate system operation.

10.2.1.6 Hull-Turret Inflatable Seal. The simulated turret seal system requires that appropriate controls, indications, and hardware be available at the driver's station. The driver should have the capability to inflate and deflate the system with the appropriate pressure gage response.

A sensing switch should be provided for use by the instructor CRT program providing an indication of seal inflation.

10.2.1.7 Simulated Fuel System. The simulated fuel system should provide control and indications of tank fuel system operation. Therefore, related hardware should be available for the driver's use.

Fuel system software should compute fuel quantities as a function of engine and heater use and instructor fueling. The Instructor/Operator CRT should provide a means of fueling and defueling simulated fuel tanks. Fuel system logic must provide an accurate representation of actual tank fuel system power and control logic.

10.2.1.8 Simulated Bilge Pump. The hardware, control, and indication of system operation should be provided; however, actual power to the pump motor is not required. A sensing switch should be used to provide the simulated electrical system computer program with power ON information.

10.2.1.9 Simulated Sound System. Simulated tank sounds can be categorized by four areas of tank operation: engine starting and running, mobility or driving, weapons system operations, and miscellaneous internal turret and hull equipment operations. Additional sounds generated by the enemy must also be considered.

Typical diesel engine sounds are required and should include engine starting, engine air cooling fans, engine air intake and air cleaning fans, rushing air sounds due to the aforementioned fans, and electric fuel pumps.

Sound generators producing engine sounds should be located in a manner that will give the crew the same sense of direction as the actual sound.

Driving sounds such as track squeak, transmission and final drive moan, and automatic transmission whine, should be simulated. Transducer placement should provide the crew with the directional characteristics of the sounds being simulated.

Tank weapons sounds of the main gun and machine gun firing are required to be simulated. When firing the main gun (in the actual tank), a blast effect is sensed not only by the tank crew, but by any personnel in the near vicinity of the tank. This effect is essentially created by a rapid change in air pressure. The effects or sensation experienced by the crew is that of sudden air movement about the face. Duplication of this sensation could be hazardous to both personnel and equipment (even if it were necessary for training purposes). Rapid changes in air pressure would create stresses on the simulator enclosure and possibly the building housing the simulator.

Noise associated with firing the main gun can be reproduced at high volume levels to provide appropriate cues. Proper sizing of the speakers and amplifiers will enable the volume level to approach real-world levels if required. Such a heavy-duty system can move a large volume of air, thus providing some cuing in the form of pressure changes.

Although novice crews could show performance lags resulting from feared and confused reactions to these sudden, violent stimuli, more experienced crews (as those destined for FCIS training) are acclimated, and the only effects might be fatigue from blast effects, limited communication, and degradation of round sensing.

Decibel levels should be limited to comply with OSHA requirements. Transducer location should provide the crew with the appropriate direction of main-gun sounds.

The following turret equipment sounds are essential for good aural simulation.

- o Turret Drive Unit
- o Main Gun Elevation Actuator
- o Stabilization Gyros
- o Hydraulic Pump and Motor
- o Exhaust Fan
- o Personnel Heater

Sounds of distant enemy gunfire, as well as enemy close-range small arms fire, machine gun fire, and ATGM's are required. Also, sounds of small arms ricochets and projectile explosions on the tank's hull, are essential to the combat environment. Finally, freight train sounds of enemy projectiles passing by is a desirable sound.

Sound transducers should be positioned to give the most realistic directional cues to the crew members.

Overall sound levels must be controllable by the Instructor or Operator from the IOS console.

10.2.2 Simulated Systems Development.

10.2.2.1 Simulated Hydraulic Power. (Figure 10-8) The hydraulic power supply for turret hydraulic equipment will be simulated. Software and hardware will be utilized to give the same hydraulic control and responses as experienced in the actual tank system.

Software programs will be designed to compute hydraulic pump logic, hydraulic pump pressure, accumulator pressure as a function of pump pressure and demand, and produce an indicator drive computation to control the simulated hydraulic pressure.

Simulated hardware for the system will resemble that of the actual M60A3 in form, functions, and feel. The simulated hardware will include the power pack and reservoir, pressure gage and accumulator, and related plumbing and cabling.

Performance characteristics of the simulated system will meet or exceed that of the actual tank and are as follows:

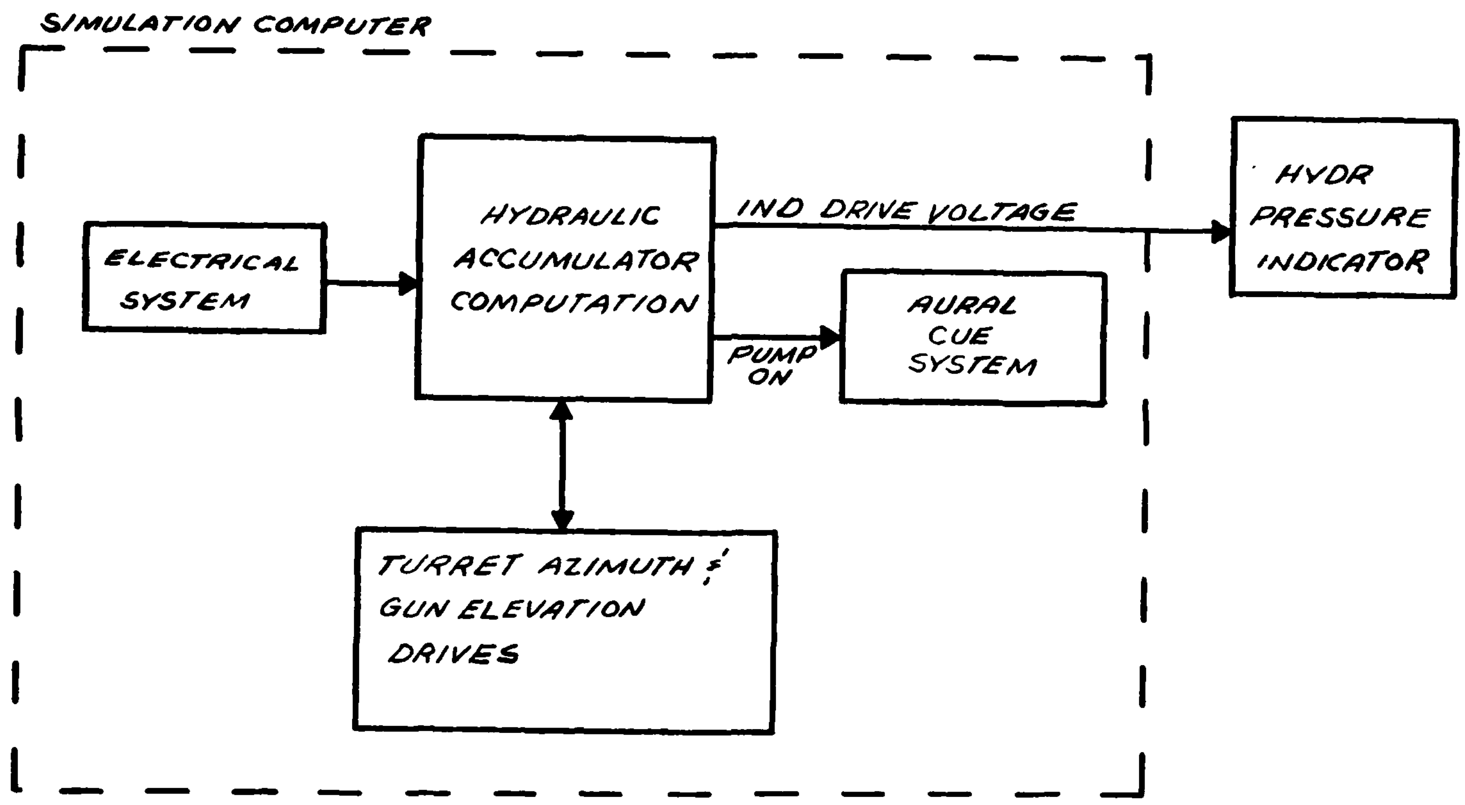


Figure 10-8 Simulated Hydraulic System Block Diagram

System Pressure Rate Tolerance	- +25%
System Pressure Tolerance	- ±5% to 500 psi ±25 psi from 500 psi to 1225 psi
System Pressure Range	- 0 to 1225 psi ± 25 psi.
Regulated Pressure to Using Systems	- 900 psi ± 25 psi

10.2.2.2 Turret and Gun Elevation Drives. (Figure 10-9). Both hardware and software will be used to simulate the gun elevation and turret drives.

Turret Drive - Turret drive software will compute a simulated turret position with respect to the front of the tank. The position will be computed as a function of the gunner or commander's control handle input and simulated hydraulic accumulator pressure. The simulated turret may also be manually positioned using the hand-drive mechanism. In the simulated stabilization mode, a variable rate parameter, modeled to reflect stabilization criteria, will drive the turret to maintain a constant turret-to-target angle. Turret position will not be computed if the turret lock mechanism is engaged.

Since the turret itself will be fixed to the motion base of the simulator, a rotatable hull will be combined with the dynamic visual display to simulate the illusion of turret motion. The above turret drive software will also counter drive the rotatable hull.

The azimuth indicator will be simulated using a motor drive for positioning. A derivative of the above turret drive software will be used to drive the azimuth indicator.

Gun Elevation Drive - The gun elevation control handle position (gunner or commander's) will be fed to software programs that compute gun elevation angle. This computation also includes simulated hydraulic system capability, elevation, system rates, and system logic. The gunner's manual elevation handle position will be a part of the position computation along with deck clearance logic.

From the computed elevation parameter, the simulated gun elevation drive is computed, which in turn, drives the gun and related ballistics equipment to the commanded position.

Traverse and gun elevation power logic will be computed as a function of the power switch position on the gun control panel, simulated electrical power available, and hydraulic power available. Simulated magnetic brake and elevation shutoff valve conditions will be programmed as a result of the gunner or commander's palm switch positions. These parameters are to be used in the aforementioned turret and elevation drives.

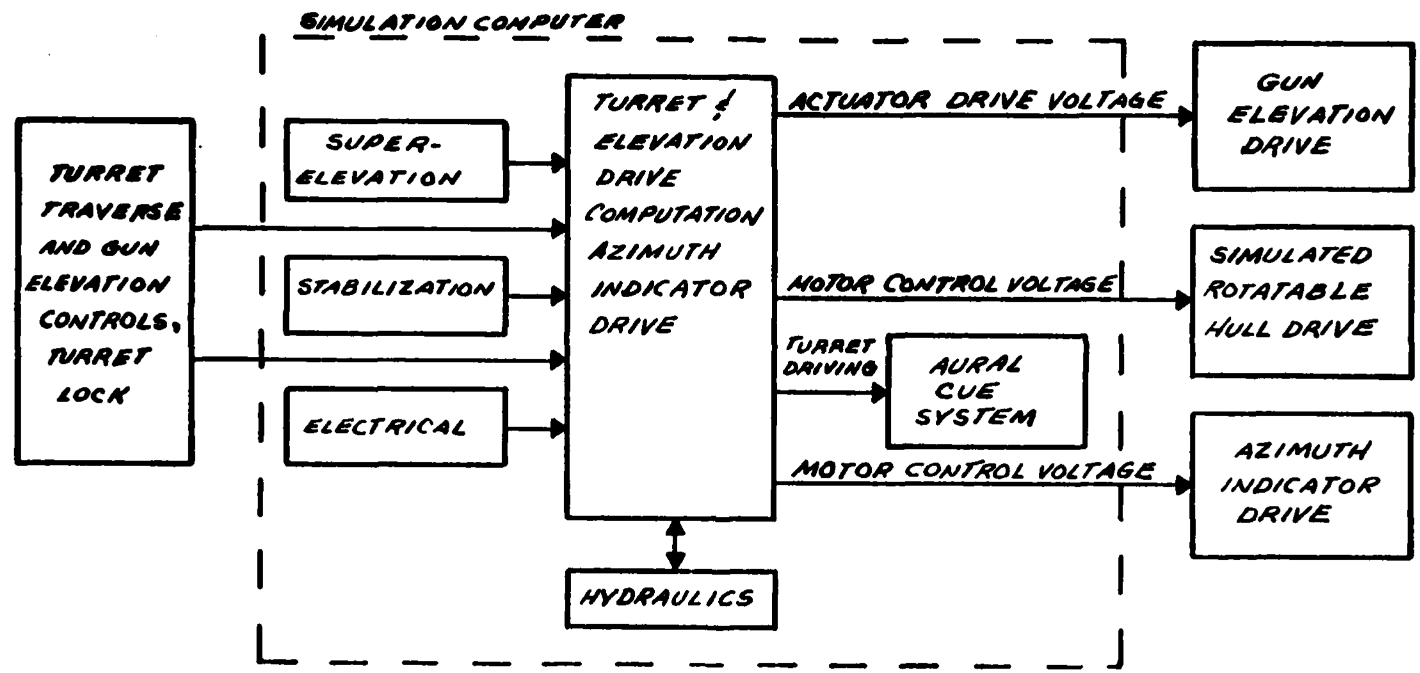


Figure 10-9 Simulated Turret and Gun Elevation Drives Block Diagram

Turret and Gun Elevation Hardware - Table 10-3 lists equipment used on the M60A3 tank and how this equipment is used (or not used) in the FCIS. All hardware will be installed at appropriate locations as prescribed by M60A3 data. If a piece of hardware is not required for simulation purposes, and is not readily identifiable by the crew in terms of form or feel, it need not be part of the simulated hardware system.

TABLE 10-3 GUN ELEVATION AND TURRET DRIVE HARDWARE DISPOSITION

	SIMULATOR EQUIPMENT				
	FUNCTIONAL	ACTUAL	MODIFIED	SIMULATED	NOT REQUIRED
Commander's control handle	X	X			
Stab Anti-backlash cyl					X
Turret traverse mechanism	X			X	
Commander's stab shutoff	X	X			
Traverse stab valve					X
Hand traverse	X	X	X		
Stab control selector box	X	X	X		
Superelevation Actuator	X	X			
Power solenoid	X	X			
Override solenoid	X	X			
Deck clearance valve					X
Hydraulics riser accumulator	X	X	X		
Stab-shutoff valve					X
Stab filter					X
Pressure gauge	X			X	
Elevation safety shutoff	X			X	
Pressure req. valve	X			X	
Selector valve					X
Relief valve, accumulator	X			X	
Rate tachometer	X	X	X		
Azimuth Indicator		X	X		
Control rods	X	X			
Hydraulic tubing	X			X	
Turret lock	X	X	X		
Gunner's control handle	X	X			
Hand elevation pump	X	X	X		
Main Accumulator	X	X	X		
Stab rate sensor	X	X			
Elevating Cylinder	X			X	
Stab Elevation valve	X			X	
Relief Valve, elevation	X			X	
Locking valve, elevation	X			X	
Stab controller unit	X	X	X		

Functional-Is the equipment operational or does it appear operational. Actual - Use actual tank equipment. Modified - Actual tank equipment modified to accept simulation equipment interface Simulated - Hardware specifically designed for FCIS.

Performance of simulated turret and elevation drives is presented in Table 10-4.

TABLE 10-4 SIMULATED TURRET AND ELEVATION DRIVES PERFORMANCE CHARACTERISTICS

Maximum elevating & turret acceleration rates *(simulated system)	
Azimuth	300 miles/sec^2 (computed)
Elevation	600 miles/sec^2 (computed)
Slew Rate*	
Azimuth	0.50 to 400 miles/sec (computed)
Elevation	0.50 to 71 miles/sec (computed)
Elevation manual	10 miles/crank revolution

*The rates are controllable and can be reduced to satisfy crew training safety requirements.

Gun Elevating	
Depression	10° for 180° of rotation centered on front vehicle centerline. 0° for 180° of rotation centered on rear centerline.
Elevation	20° for 360° of turret rotation
Turret Traversing System	
Power traverse	360° in 15 sec
Manual Traverse	17# average force applied tangentrally at crank to level turret
Manual Traverse	10 mils per crank revolution full 360°
Simulated Rotatable Hull Mechanism	
Rate	0.50 to 400 miles/sec
Position*	$360^\circ \pm 5.0^\circ$

*Accuracy of system is not required since the hull is used as a visual cue within the turret only.

10.2.2.3 Electrical System (Figure 10-10). The M60A3 tank electrical system controls, indicators, and lighting will be simulated. Circuit breaker hardware not directly accessible to the crew in the actual tank will not be included in the hardware simulation.

Software - Electrical system software will compute power and control logic, battery condition due to equipment loads and alternator charge rate, and also provide a drive computation for the battery/generator indicator. A power available discrete, dependent upon battery condition and logic, will be provided to the simulated tank systems for computation of power and control.

Hardware - Simulator electrical system hardware consists only of the Master Control switch and indicator, the Battery/Generator Indicator, lighting control switch assembly, Blackout (BO) Selector drive switch, high/low beam floor switch and indicator, dome lights and controls, and utility power outlets.

Three driving light switch conditions will be visually simulated. These are normal driving lights, high and low beam, and blackout drive (BO). Infrared (IR) driving lights, parking, and tail lights need not be simulated. Panel lights on both the driver's gage and indicator panel and the Master Control panel will be controlled by the panel DIM/BRIGHT control.

Utility outlets, located through the crew stations, and the slave power receptacle will not be powered. However, a jump-starting capability will be provided by an instructor/operator function when the simulated battery has gone dead.

Circuit breakers that are not easily accessible by the crew or that have an automatic reset feature will not be simulated. Software may be provided to simulate the CB's but it will be totally controlled by the instructor.

Simulated Electrical System Characteristics

Simulated Battery Capacity	100 amp/hr
Simulated Battery Voltage	28 vdc
Simulated Alternator Voltage	25 to 30 vdc
Simulated Alternator Capacity	650 amps at 2400 rpm

10.2.2.4 Fire Extinguisher System (Fixed) (Figure 10-11). The fire extinguishing system will be simulated. The controls and indications at the driver's station will simulate that of the actual M60A3 tank.

Software - The fire extinguishing software will consist of fuel system logic and timer necessary to shut down the simulated tank engine.

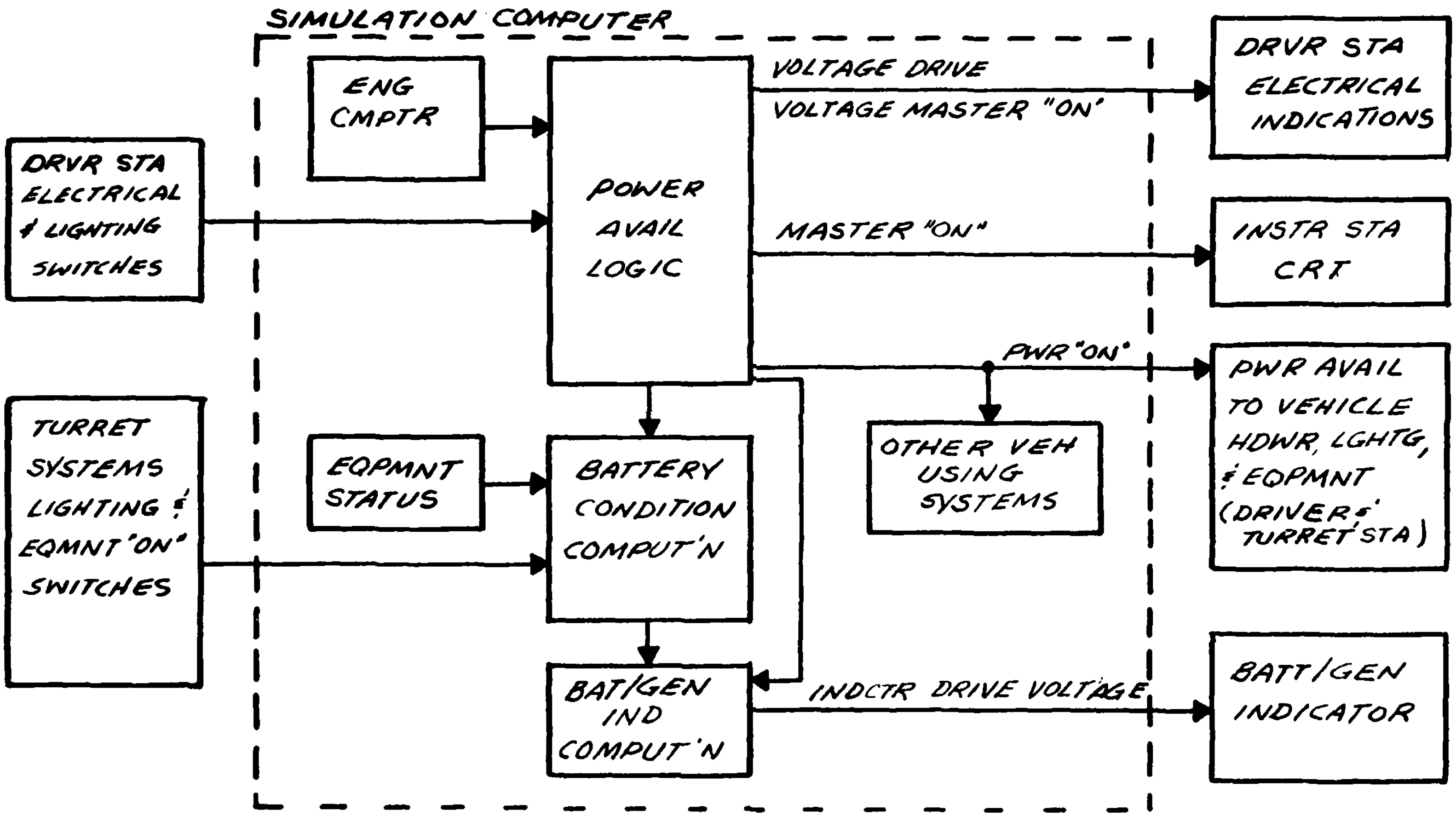


Figure 10-10 Simulated Electrical System Block Diagram

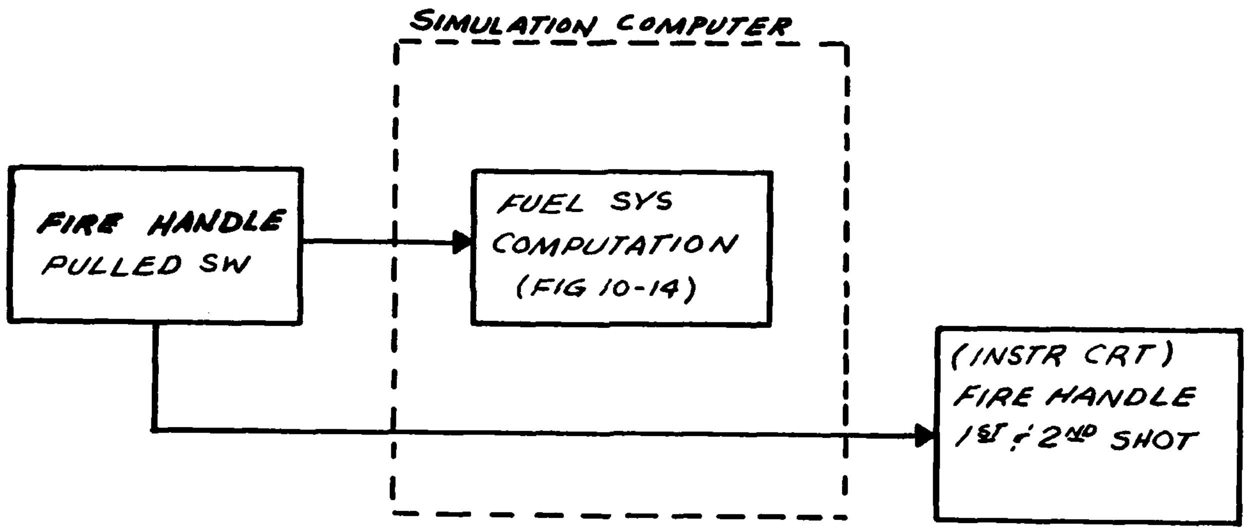


Figure 10-11 Simulated Fixed Fire Extinguisher System Block Diagram

Hardware - Fire extinguisher system hardware at the driver's station will consist of control handles, cabling, handle pull mechanisms, bottle control valves, and bottle assemblies. External fire control handles need not be simulated nor will the CO_2 bottles be charged. The CO_2 plumbing will be terminated within the driver's compartment at a nonobtrusive location. The hardware will be safety wired as in the actual tank system.

10.2.2.5 Personnel Heater, Gas Particulate, and Ventilation System.

10.2.2.5.1 Personnel Heater (Figure 10-12). The Personnel Heater system will be simulated by providing the controls and component hardware at the simulated driver's station. The location and physical characteristics of the equipment will duplicate that of the actual M60A3 tank.

Software - System software will include power and control logic and fuel use rate logic. The logic will also control the Personnel Heater ON indicator light.

10.2.2.5.2 Ventilation System (Blower). The control for the ventilation system blower will be simulated. Power logic will be computed and whenever the control switch is operated, the aural cue system will produce the appropriate sound. No actual blower assembly hardware will be supplied.

10.2.2.5.3 Gas Particulate System (Figure 10-13). Gas Particulate System simulation will include all the system hardware, excluding only the filters and turret slip-joint hardware. The simulated system will accommodate the individual crew face mask hookups as in the actual tank.

Software - Software - System software will include power and control logic and operate the Gas Particulate ON Indicator Light on the Master Control panel.

Hardware (Driver's station) - Driver's station hardware for the gas particulate system will include all controls and associated plumbing. All plumbing exceeding the confines of the simulated driver's compartment will be terminated and capped. The air heater assembly and orifice connector will still be available for the driver's use as it is within the immediate area of his simulated station. Although the air heater control and indicator are provided, they will not be operational due to the higher ambient air temperatures available in the simulator complex.

Hardware (Crew Stations) - Hardware for the turret crew station of the simulator will consist of the orifice connector assemblies, M3 air heater units, and associated plumbing. The heater units will not be operational due to the normally higher ambient air temperature available in the simulator complex.

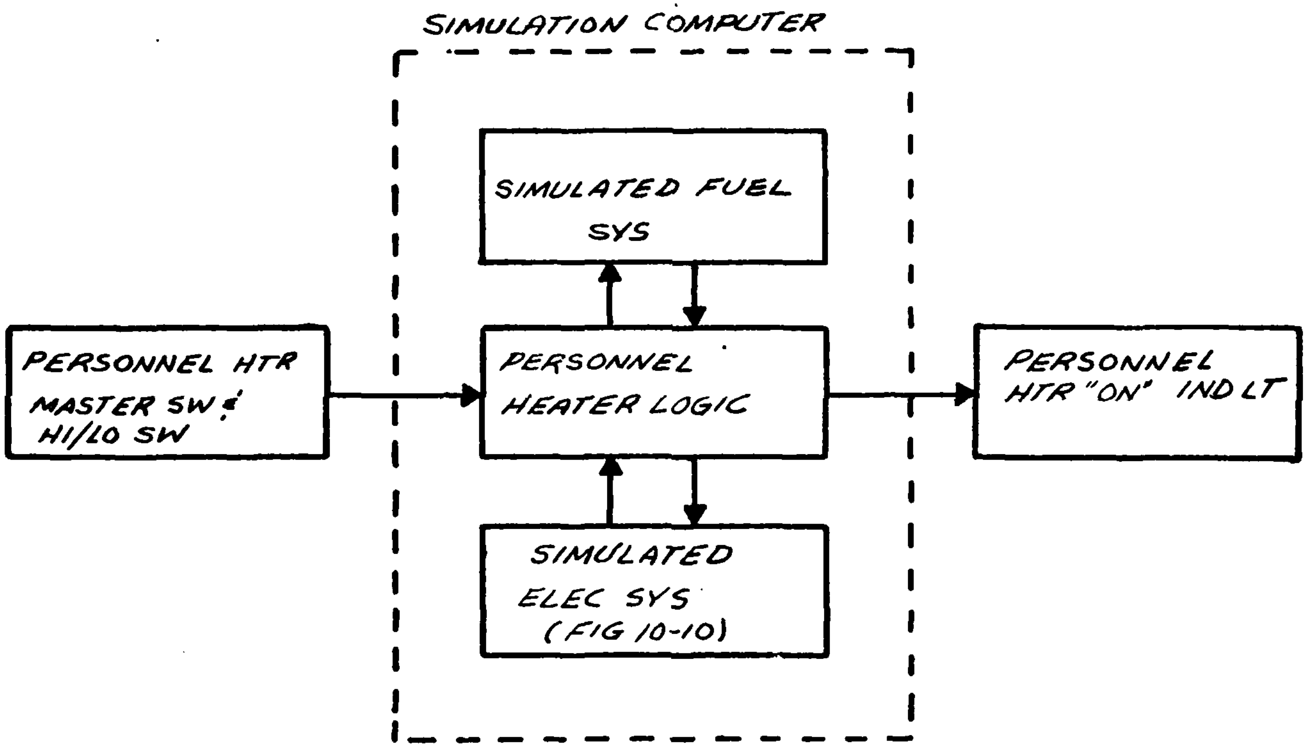


Figure 10-12 Simulated Personnel Heater Block Diagram

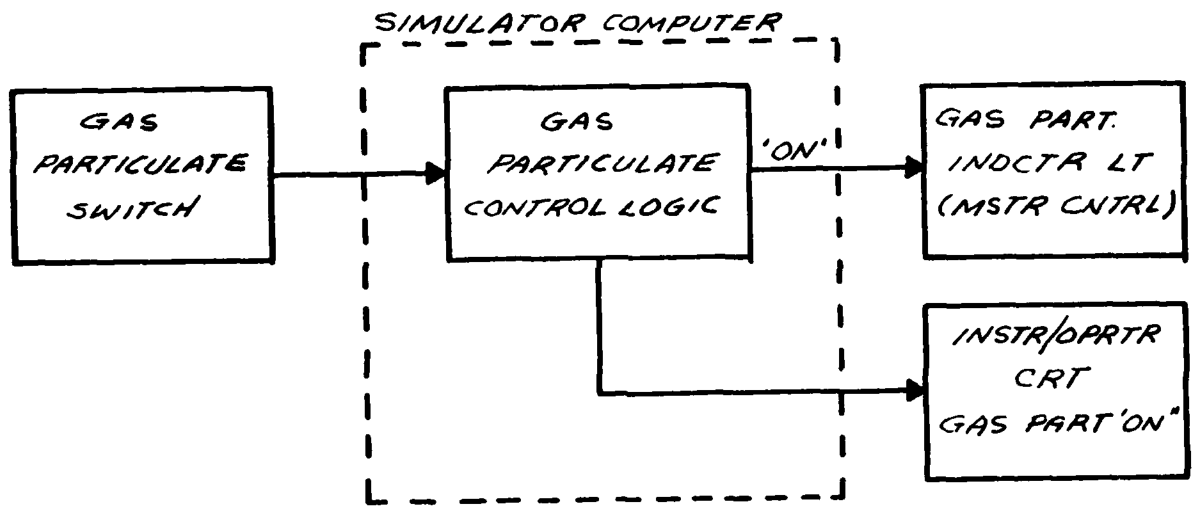


Figure 10-13 Simulated Gas Particulate System Block Diagram

10.2.2.6 Fuel System (Figure 10-14). The fuel system will be simulated with all controls and indicators at the driver's station operational.

Software Simulation - The simulated fuel system will include fuel system power and control logic and fuel system quantities as a function of instructor input and simulated engine and personnel heater demand. System performance will be the same as in the actual system and provide the driver with the same indications as would the actual M60A3 tank.

Simulation software will also provide fuel available logic to the engine, simulated purge pump, capability for engine starting, manifold heating, engine fuel suction capability, and fire handle shutdown logic.

A software subroutine will integrate purge pump handle position, which in turn, will provide pump hardware with changes to pump handle forces representative of pumping air vs. pumping fuel.

The simulated fuel quantity gage will be driven by indicator drive software that also includes gage power and control logic.

Hardware Simulation - All fuel switches, handles, and indicators located at the driver's station will be simulated in form, function, and feel. Intertank isolation valve hardware will not be provided since the location of the actual hardware is external to the turret and internal to the engine compartment. Software will be provided to simulate the isolation valve which will be instructor-controlled.

Simulated Fuel System Characteristics

Left tank quantity	192 gal.
Right tank quantity	197 gal.
Electric Fuel Pump rate	220 gph
Fuel System delivery rate	50 gph
Fuel System delivery rate due to suction (estimated)	20 gph

10.2.2.7 Bilge Pump (Figure 10-15)

Software Simulation - Bilge pump software will consist only of the ON switch input to the simulated electrical systems load program. No other system characteristics need be simulated.

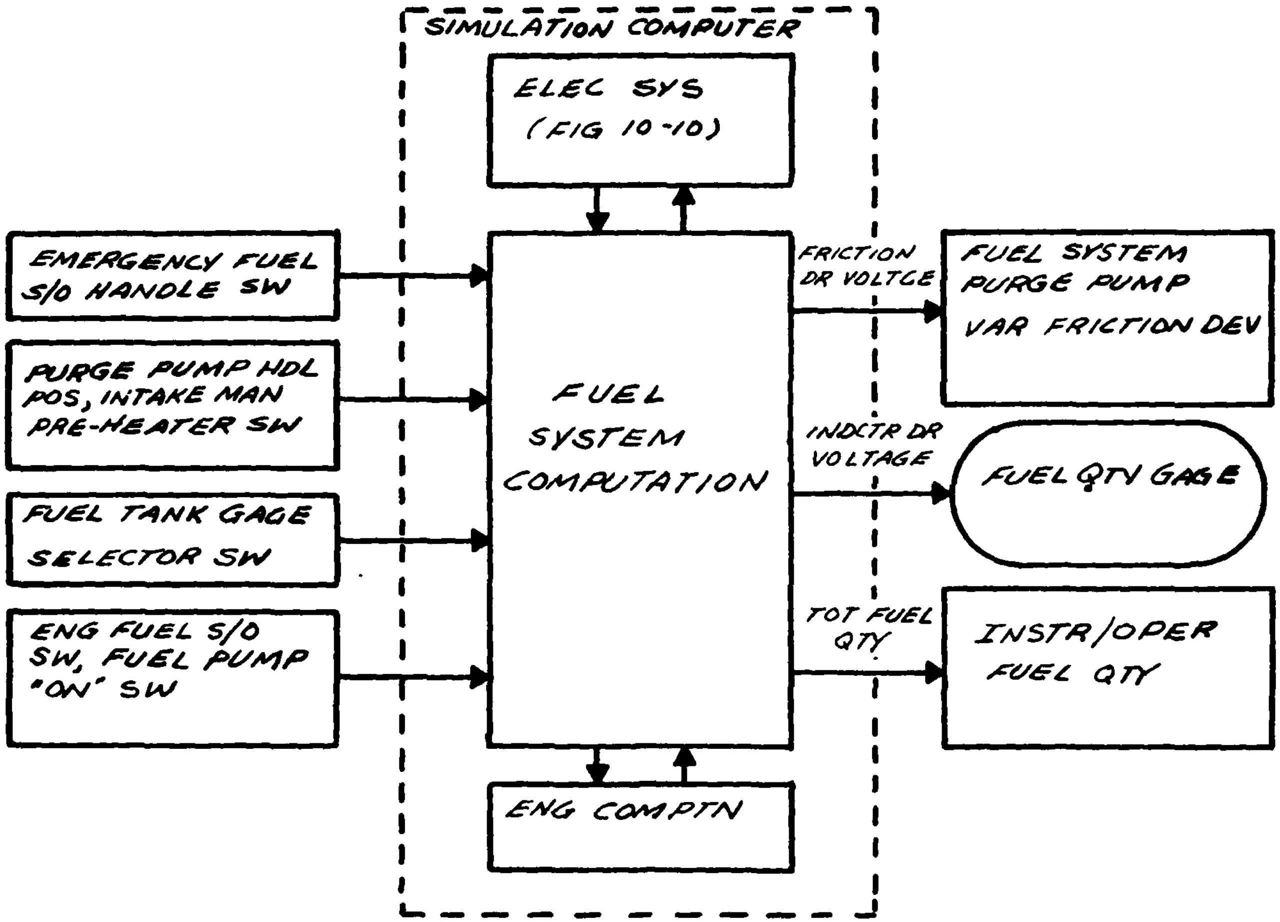


Figure 10-14 Simulated Fuel System Block Diagram

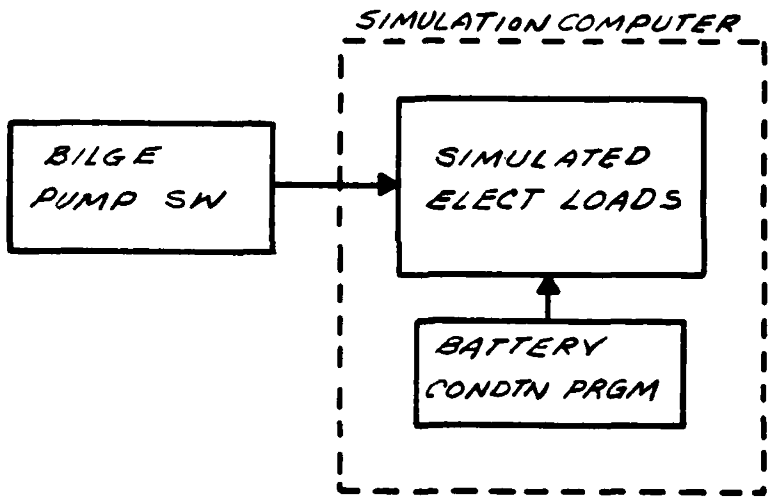


Figure 10-15 Simulated Bilge Pump Block Diagram

Hardware Simulation - Hardware, as observed at the driver's compartment of the operational M60A3 tank will be installed in the simulator. The hardware need not be operational since the simulator will not be in contact with actual water.

10.2.2.8 Turret Seal (Figure 10-16). The turret seal system will be simulated to the extent of providing operational hardware in the driver's compartment. The actual inflatable turret seal need not be used.

Software - Turret seal system software, other than providing a switch input, representing the inflated pressure of the system to the instructor CRT, is not required.

Hardware - The controls and indicator for the system will be installed at he driver's station along with associated components. The actual inflatable turret seal will be replaced with a bladder in a box to give the desired air volume and pressure representative of the actual system. The "box" will also contain a pressure operated switch for computer use in generating the instructor station CRT page.

10.2.2.9 Sound Simulation. The aural cue system will simulate the sounds of turret equipment, driving gear, and driver's station equipment. The sounds will also include own tank as well as enemy gunfire. The sounds will be provided by transducers located to provide directionality to the sounds being simulated. Figure 10-17 gives an overview of Link's solution to the sound system problem.

Software Simulation - Software will consist of computer programs designed to drive hardware circuitry that will synthesize sounds representing the tank and its equipment. These programs will also control the intensity of each unique sound through associated hardware. The overall sound level at each station will be software-controlled through the instructor's CRT console input.

Sounds of enemy gunfire and hull ricochets will be controlled by sound system software. Where the sounds are associated with visual cues, the timing and direction will also be synchronized by the sound software.

Machine gun and main gun sounds generated during firing exercises will be controlled and synchronized with the functional systems by aural system computer programs. If the tank equipment includes grenade launchers, the simulated sound system will drive sound hardware to provide appropriate cues.

The following list of sounds will be produced by the sound system hardware and controlled by computer programs.

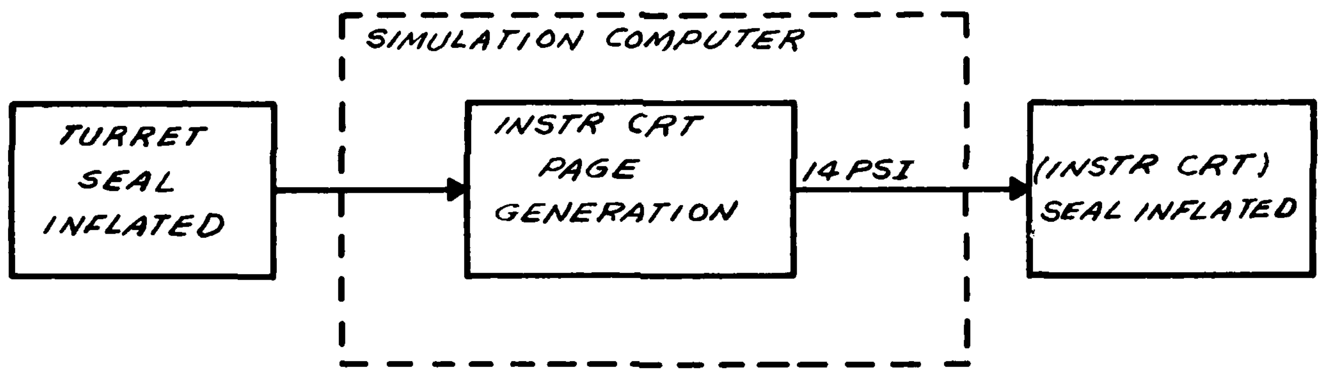


Figure 10-16 Simulated Turret Seal Block Diagram

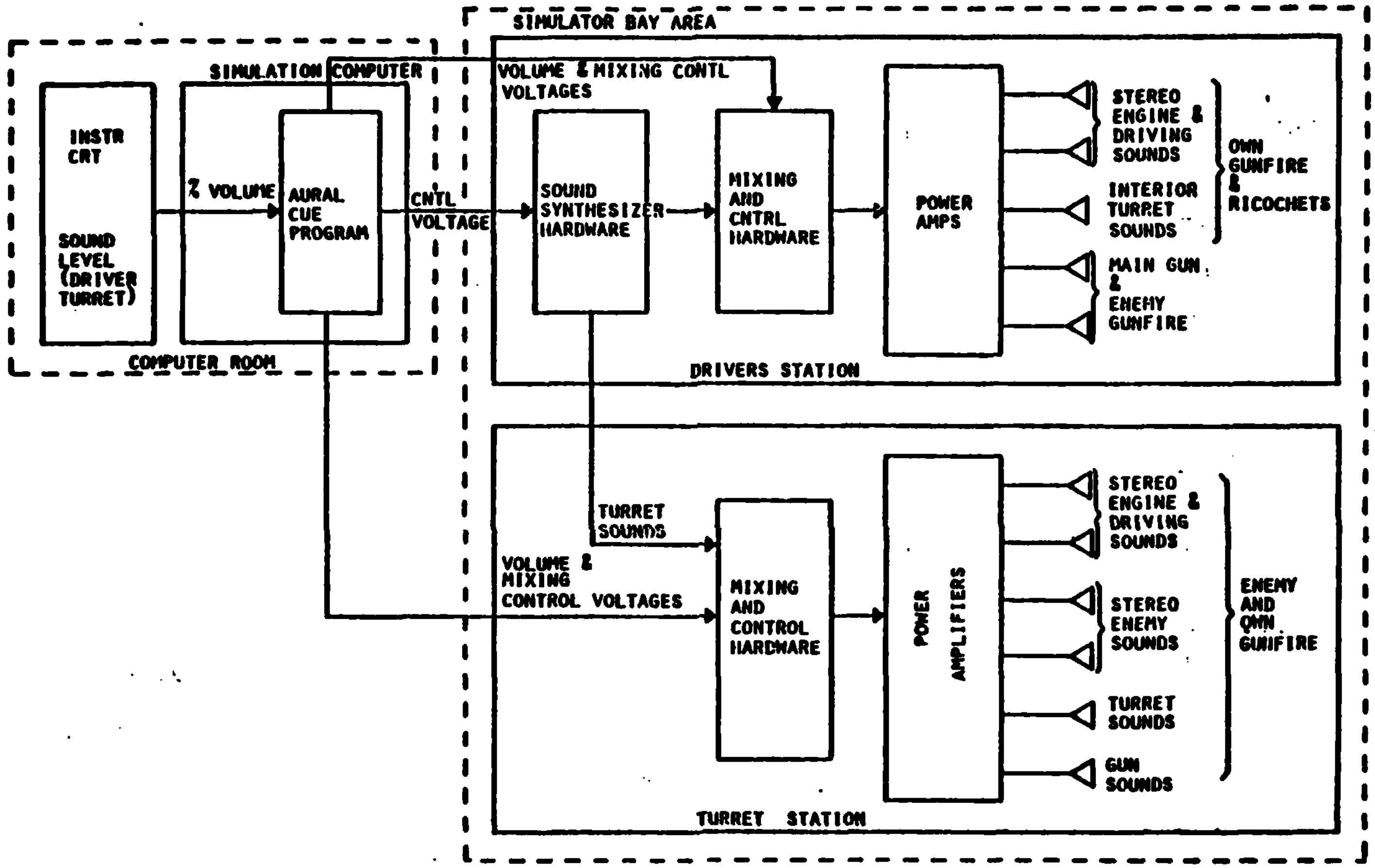


Figure 10-17 Aural Cue - System Diagram

Engine

Basic Diesel
Engine Starter
Electric Fuel Pump
Engine Intake Air Cleaner
Exhaust Turbochargers
Engine Cooling Fans

Driving Sounds

Transmission Whine
Transmission Groan
Track Squeek
Track Rumble

Turret Equipment

Turret Ventilation Blower
Hydraulic Pump
Stabilization Gyros
Turret Azimuth Drive
Super Elev Drive

Own Gun Sounds

Main Gun
7.62 Machinegun
0.50 Caliber Machinegun
Grenade Launcher

Enemy Sounds - (Distant)

Gun Fire
Explosions

Near Miss Sounds

Freight Train Sound (Large Projectiles)
Random Gunfire
Anti-Tank Guided Missile (ATGM)

Hit By Enemy Gunfire

Random Small Arms Ricochets
Explosion (Large Projectiles)

Hardware - Hardware required to produce the aforementioned sounds will consist of computer controlled oscillators, filters, white noise generators, attenuators, mixers, and amplifiers. The amplifiers will be connected to transducers located at both the Driver's Station and Turret stations. The transducers will be positioned to locate the exterior sounds of the tank close to the source that would have produced the sound in the actual tank. Using stereo transducers for both driving and enemy produced sounds also provides directional sound capabilities.

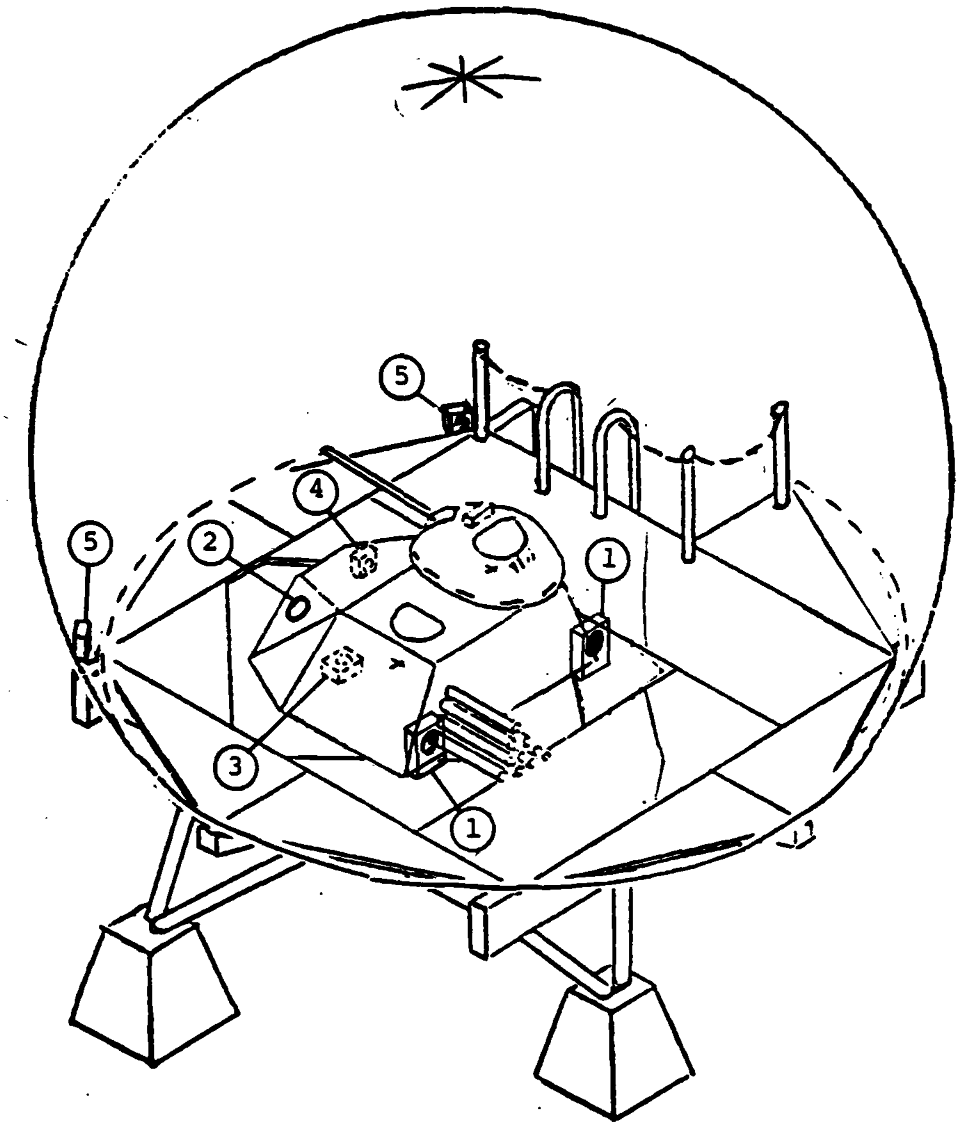
Internal sounds of the tank or sounds heard from the interior are directional in nature, but due to the echo effects caused by materials used in the interior, they become non-directional. Therefore, the sound transducer placement for interior sounds becomes much less critical. Figures 10-18 and 10-19 give approximate locations for the sound transducers.

The sound synthesizing hardware will be located at the driver's station and provided through cabling to the turret station mixing, control, and power amplifier hardware. This will give greater flexibility in segregating and controlling sounds that are more unique to each training station.

10.2.2.9.1 Crew Station and Simulator Room Environment (Aural Cue Only). Since the M60A3 crew is subject to sound intensities of 60 to approximately 160db, the tank simulator could approach the same levels if safety and equipment limitations are not imposed. Working within this environment can be hazardous to the health of the personnel. According to MIL-STD-1472 and the Occupational Safety and Health Administration (OSHA STD 1910.95). Figure 10-20 describes the overall aural intensity problem, giving actual tank sounds versus limitations specified by the aforementioned standards. Lettered references appearing in the following paragraphs are documented in Table 10-5.

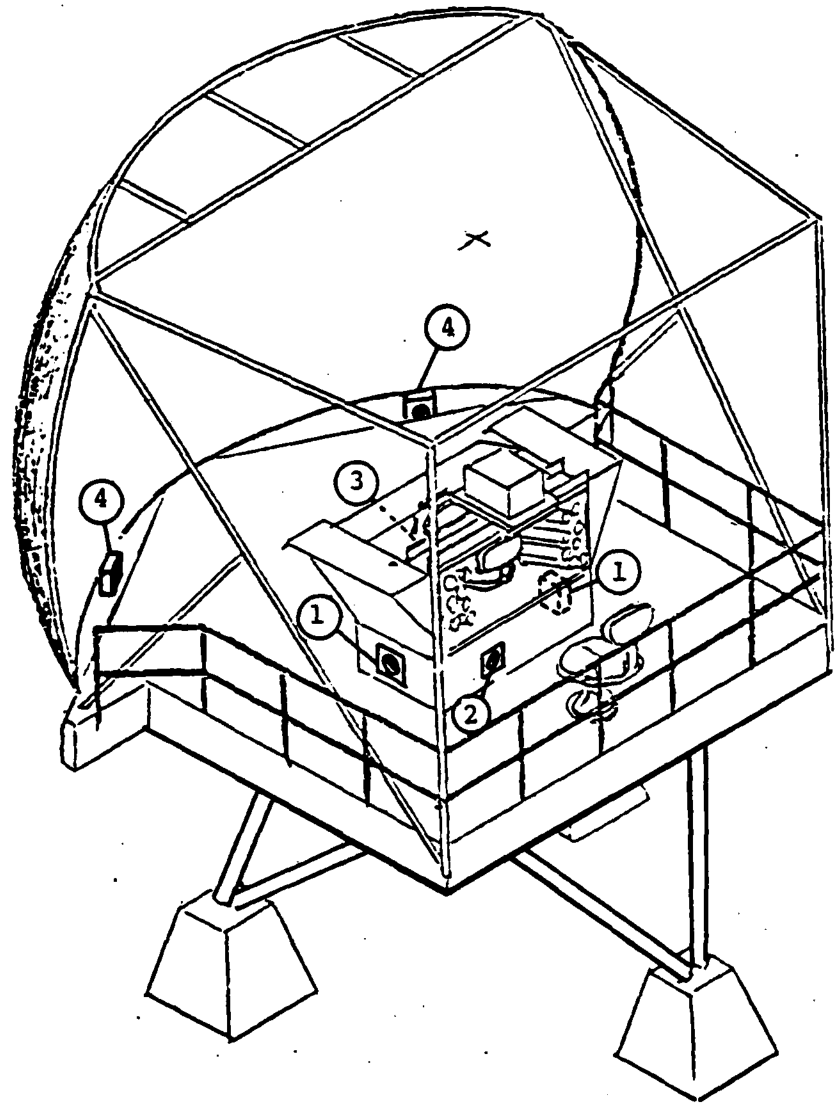
There appears to be a marked difference in the levels between machinegun and the 105mm main gun sounds (Figure 10-20). This may be so because the operator's ear is much closed to the muzzle of the main gun. Also, the main gun generates a longer transient sound which gives the effect of a "big sound".

An overall look at Figure 10-20 gives the impression that the 135db level is the design safety limit for the simulator; however, exposure to machine gun fire at this level causes a rapid accumulation or equivalent exposure time. This reduces the equivalent exposure to time at the 85db level. According to Figure 10-21, the Nomogram produces an Equivalent Exposure Time (EET) of 10,000 minutes for a 0.1 minute machine gun burst where the maximum allowable is 480 minutes for a 24-hour period. If the aural system limit is set to 115db maximum, machine gun bursts of 0.1 minute give an EET of 110 minutes. This allows: (480 ÷ 110) X6=26 sec of machine gun usage in an 8-hour day. Thus, for unprotected ears, 115db is a good, safe maximum limit for aural systems operating level. Assuming that the sound system is set to give 115db sound levels for the machine gun, then, according to Figure 10-20, the main gun produces a proportional 90db + sound with the same EET. However, AFR 161-35, Attachment 1, deems this low-level impulse type noise negligible and additive only as a real time component.



1. STEREO DRIVING SOUNDS FOR HEADS-UP LISTENING (INCLUDES ENGINE SOUNDS)
2. GUN FLASH UNIT
3. TURRET & WEAPON SOUNDS (FRIEND & FOE)
4. MAIN GUN & MACHINEGUN SOUNDS
5. ENEMY WEAPONS SOUNDS (STEREO)

Figure 10-18 Speaker Locations - Fighting Station



1. STEREO DRIVING AND OWN WEAPON SOUNDS
2. TURRET SOUNDS, ENGINE BACKGROUND
3. LOCATE GUN FLASH UNIT
4. MAIN GUN & ENEMY GUNFIRE (IN STEREO)

Figure 10-19 Speaker Locations - Driver's Station

TABLE 10-5 SOUND SYSTEM REFERENCE DATA

REFERENCE	SOURCE	SUBJECT COVERED
A-	MIL-STD-1474 (MF)	POSTING ,NOISE HAZARD AREA
B-	AFR 161-35, AEROSPACE MEDICINE, HAZARDOUS NOISE EXPOSURE	MACHINE GUN db LEVEL
C-	AFR 161-35, AEROSPACE MEDICINE, HAZARDOUS NOISE EXPOSURE	EAR PROTECTORS
D-	AFR 161-35, AEROSPACE MEDICINE, HAZARDOUS NOISE EXPOSURE	140 db EAR PROTECTORS
E-	AFR 161-35, AEROSPACE MEDICINE, HAZARDOUS NOISE EXPOSURE	115 dB EAR PROTECTORS
F-	AFSC DESIGN HANDBOOK HUMAN FACTORS ENGINEERING, SERIES 1-0, DH 1-3	NOMOGRAM
G-	AFSC DESIGN HANDBOOK HUMAN FACTORS ENGINEERING, SERIES 1-0 DH 1-3	RECOMMENDED AND MANDA-TORY EAR PROTECTORS
H-	AFSC DESIGN HANDBOOK HUMAN FACTORS ENGINEERING, SERIES 1-0 DH 1-3	NON-AUDITORY PAIN THRESHOLD
I-	OSHA STD 1910.95	
J-	OCCUPATIONAL NOISE EXPOSURE MIL STD 1474 PAGE 25 FIGURE 3	140dB EAR PROTECTION FOR IMPULSE NOISE
K-	MIL-STD-1474 (MF)	DATA RECORDING
L-	MIL-STD-1474 (MF)	MANUALS
M-	MIL-STD-1474 (MF)	NOISE LIMITS 100 dB

REFERENCE DESIGNATIONS APPEAR IN FIGURE 10-20

COMPOSITE DIAGRAM OF
TANK SOUND LEVELS
VS AURAL SYSTEM SOUND LEVELS,
EAR PROTECTION LEVELS,
AND EXPOSURE GUIDE LINES

NOTE: SOUNDS ARE CONSIDERED BROAD BAND FREQUENCY NOISE

1 FROM REF D,J
2 FROM REF H
3 FROM REF B
4 FROM REF E
5 FROM REF G
6 FROM REF A
7 FROM REF C

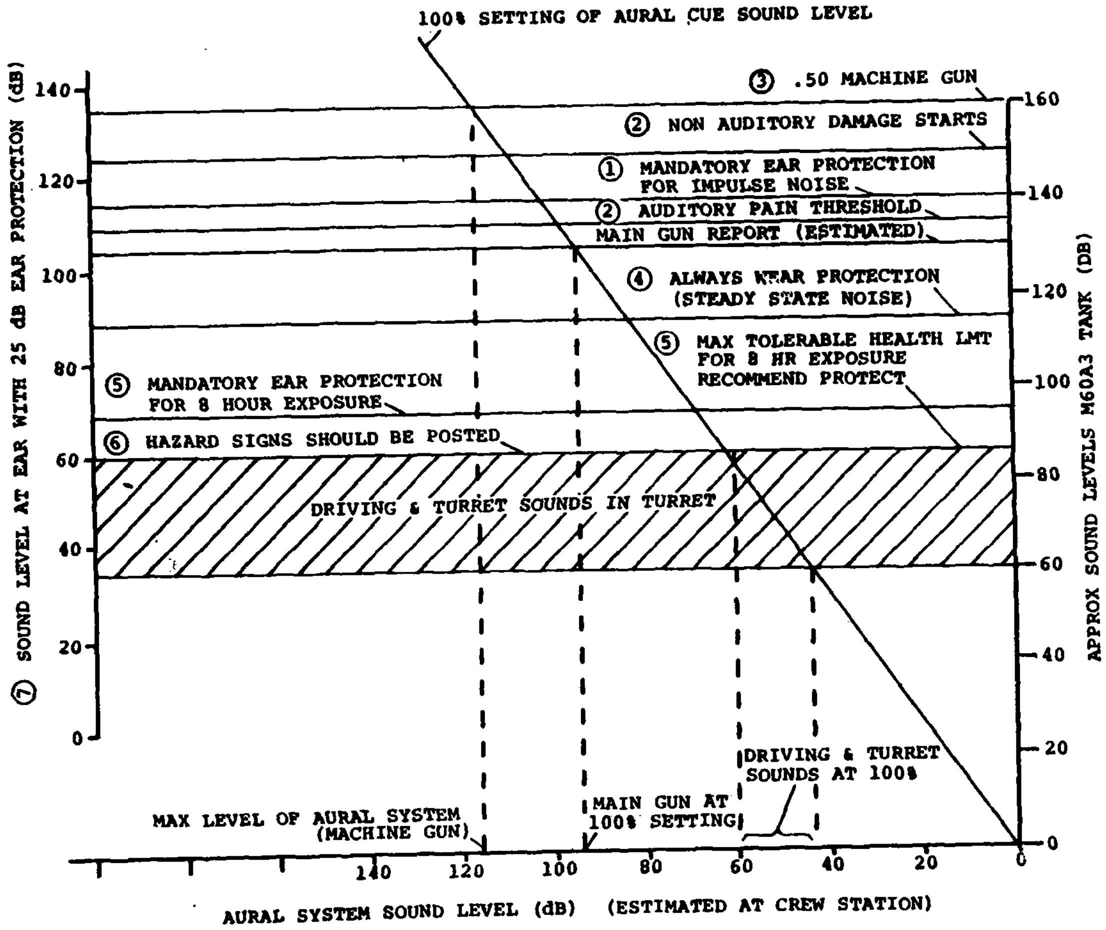


Figure 10-20 Tank vs. Aural System Sound Levels

NOMOGRAM FOR COMPUTING EET AND LAET

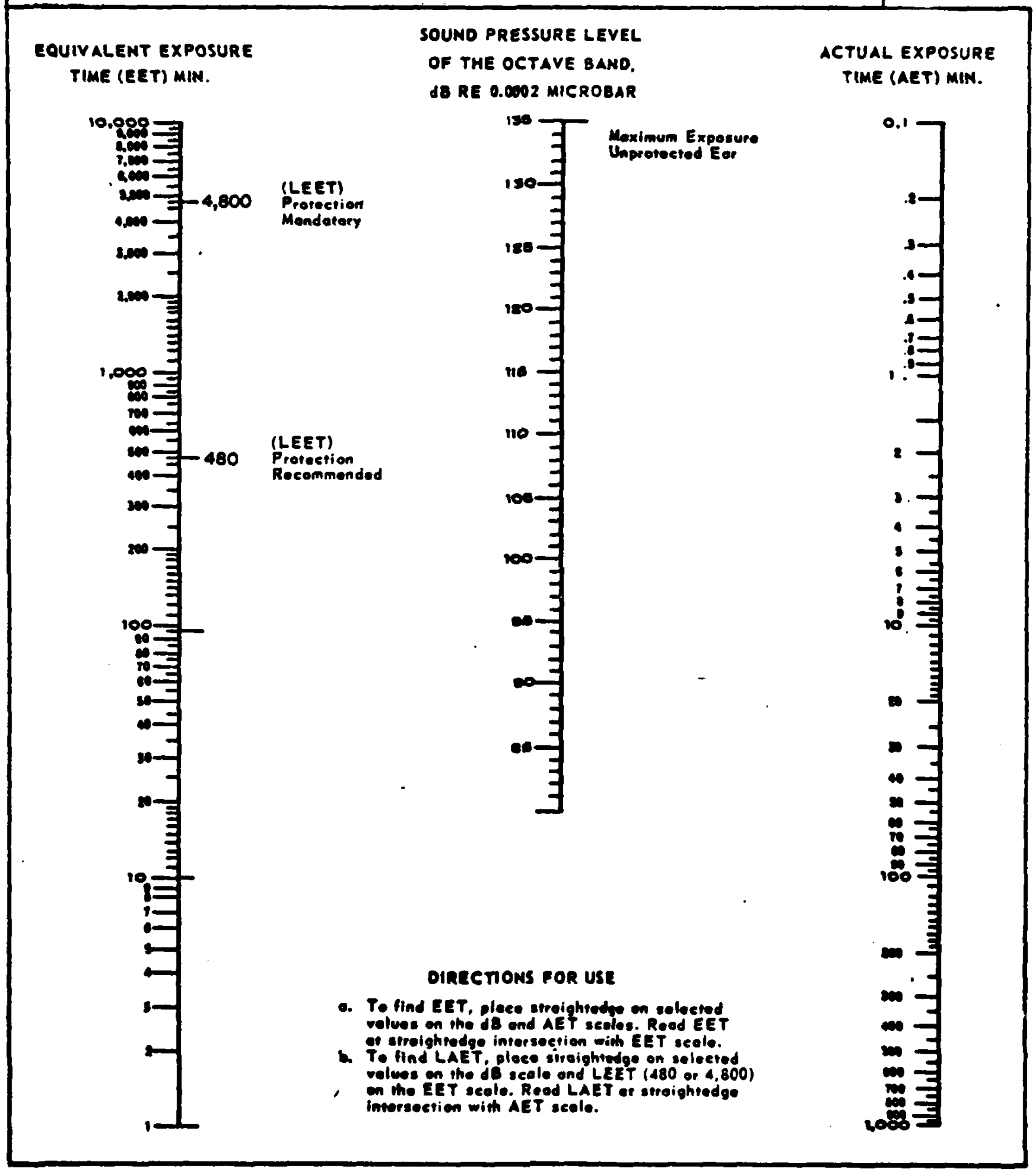


Figure 10-21 EET/LAET Nomogram

The preceding statements assumed that the level of sounds produced would be at the ears of the crew members when at their respective stations. Simulator instructors/operators will also be exposed to these same levels. However, maintenance personnel in the area, experience a lower level, due to their distance from the transducers and, in turn, receive a lower exposure time to the high-level sounds.

Ear protection is a requirement at the 115db intensity level and above. It is also recommended for continuous exposures of 85db noise for 8-hour periods according to references in Figure 10-20. It is a requirement for tank crews to wear helmets for physical protection as well as communication through the built-in intercom. This helmet will provide up to 25db of attenuation which will reduce the maximum noise level to 90 db. There will be a need for the instructor and operators to communicate with the training crews, which should be done through the intercom system. The communication receiver can be a headset of the type that would attenuate external sounds, reducing the overall exposure to high-level noise. If everyone within the simulator area is wearing or using helmets with intercoms, the steady-state noise limit can then be 100db (Ref. M, Table 10-5).

Warning signs should be posted at the entrance to the simulator room and within the room itself, indicating the presence of a hazardous enviornment. The signs should state that ear protection is required when the simulator is in operation. Ear protection equipment should be issued to maintenance personnel who normally work in the area while the simulator is in operation.

Test procedures and technical manuals provided as simulator documentation will contain discussions of the hazards of dangerous sound levels present (Reference L, Table 10-5).

During the course of simulator evaluation at final installation, measuring equipment will be used to check the quality and quantity of sound and evaluate this with the training scenario to gain average exposure numbers. From these numbers, a final decision can be made as to whether mandatory ear protection is required for maintenance personnel (Reference K, Table 10-5).

In summary, the maximum setting of the sound system can provide 115db of machine gun noise to the unprotected crewman's ears allowing 26 seconds of exposure in an 8-hour day. Ear protection will possibly reduce the sound to 90db, increasing the allowable machine gun usage to approach 125 minutes in an 8-hour day (a more realistic number). Since sound system volume is variable by the instructor/operator, the setting can be reduced to any desirable level. A discrete setting could be used that would allow a 90db (or less) sound level for crew operation without ear protection or during maintenance periods.

Main Gun Blast Environment - The main gun (105mm) creates a pressure transient, that in a simulator environment, can be dangerous to both personnel and equipment. The simulator must meet safety requirements as specified in MIL-STD-1472. Therefore, the main gun will sound like the actual gun but at reduced levels and with no large air pressure transient. The sound levels will be in line with those discussed in crew station aural environment.

10.3 Weapons Systems Simulation

10.3.1 Weapons Simulation Approaches. Realistic simulation of main gun operation, including loading and firing, is essential, and is a major objective of the FCIS study. Special effects such as simulated ammo, ejected shell casings, recoil, aural cueing, and other related sensations must be considered essential to the training task. In the case of lighter weapons, recoil and shell ejection are not critical considerations when creating battlefield conditions.

10.3.1.1 Main Gun. Simulation of main gun operation can be best described by identifying its required subsystems:

- o Recoil Motion System
- o Breech Mechanism Assembly
- o Gun and Mount Assembly
- o Replenisher
- o Hydraulic System
- o Simulated Ammunition
- o Projectile Transport
- o Projectile Storage
- o Ammunition Identification

The aforementioned items represent simulation tasks that must be resolved to achieve the final system configuration.

The first requirement in attempting to simulate the main gun is faithfull, physical reproduction of functional elements. Therefore, items such as the breech mechanism, replenisher, machine gun interface, ballistics interface, and protective guards must present a high level of fidelity. Accomplishment of this task may require the use of actual hardware, modification of actual hardware, or the creation of new hardware.

10.3.1.1.1 Recoil Motion System. The reproduction of recoil motion must be accomplished with the utmost consideration for crew safety, as the recoil function is an activity which can cause serious bodily injury. The rate of recoil must be controllable and adjustable so that the recoil profile can be altered, if required for safety reasons. With this in mind, several approaches to simulated recoil have been investigated:

(a) Modified Recoil-cylinder

(b) Pneumatic recoil drive

(c) Hydraulic cylinder

In the operational main gun, a concentric, hydrostatic cylinder is coupled to the gun tube through a movable piston or shock absorber. In the recoil direction, this cylinder has been designed to permit a controlled flow of oil to pass around the piston thereby limiting the rate of recoil. Counter-recoil is accomplished by extension of a recoil spring from a compressed position.

Approach (a) involves redesigning the piston assembly and adding a servovalve and plumbing (as shown in Figure 10-22) thereby creating a double-acting piston assembly. This piston can then be driven through the servovalve with rates of recoil and counter recoil controlled as required.

A similar method (approach (b)), utilizing a pneumatic servo system to drive the modified piston has also been considered. This configuration was considered in conjunction with an "air blast" ejection concept described elsewhere.

Approach (c) which employs a small hydraulic cylinder, servo valve, etc. is shown in Figure 10-23. The piston rod of this cylinder is mounted to the gun tube with recoil motion provided by controlled operation of the valve.

Breech Mechanism Assembly - This assembly consists of the breech mechanism, breech block, and breech ring. Since loading and ejection of empty shells is a simulation requirement, duplication or use of operational equipment is essential to realistic training and is reflected in the following approaches:

(a) Modified Breech Assembly - The previously described parts would be purchased from Chrysler and modified for integration with the gun assembly. Modifications will include: reducing weight, redesign of breechblock spring, and interfacing with other gun system components.

(b) Redesigned Lightweight Breech Assembly - This assembly would be a combination of new parts and actual gun hardware. Although some exterior differences would be apparent, there would be no adverse effect on crew training.

Gun and Mount Assembly - The gun assembly (ref. Figure 10-23) can be considered to be two separate systems. A fixed, trunion-supported member (gun mount) and a moving (recoil) portion

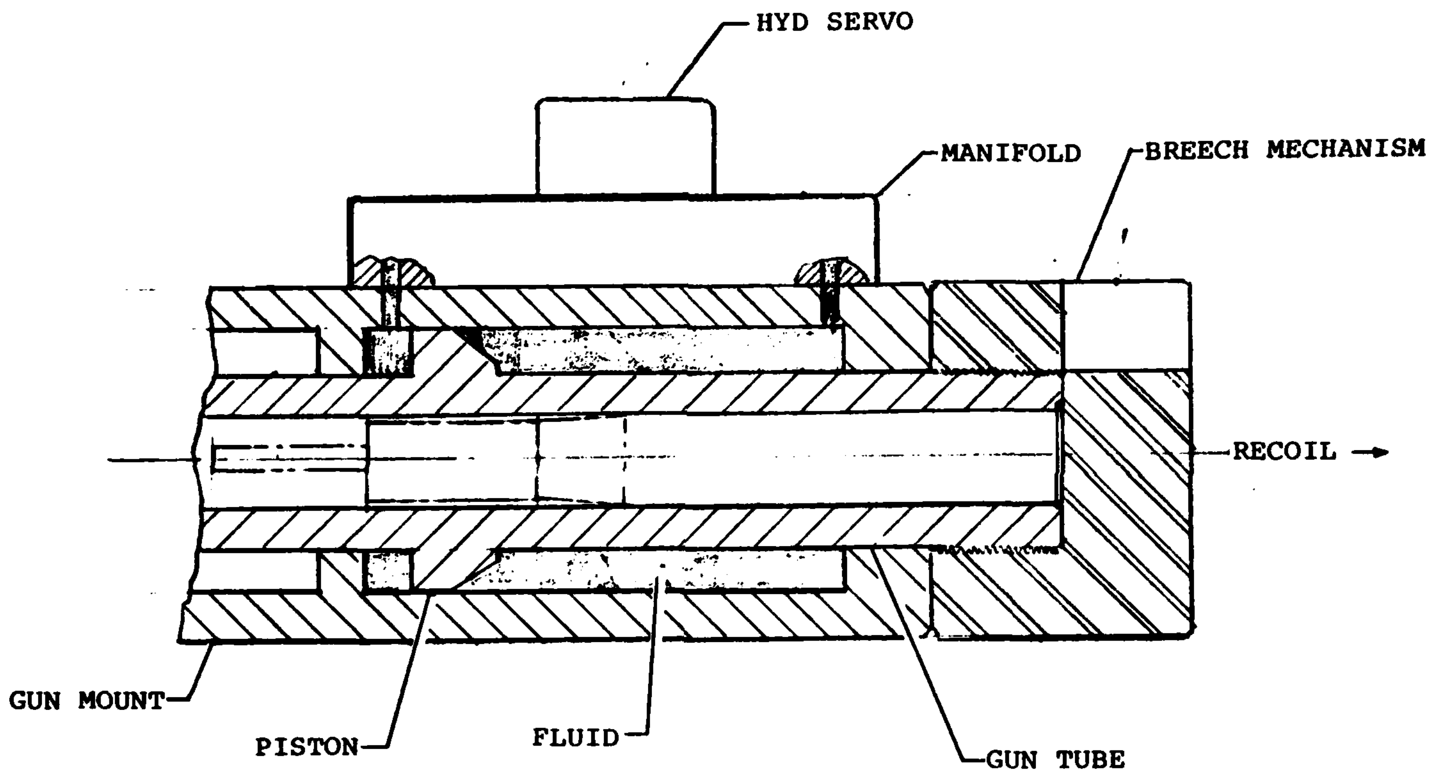


Figure 10-22 Modified Recoil Approach for Recoil Motion System

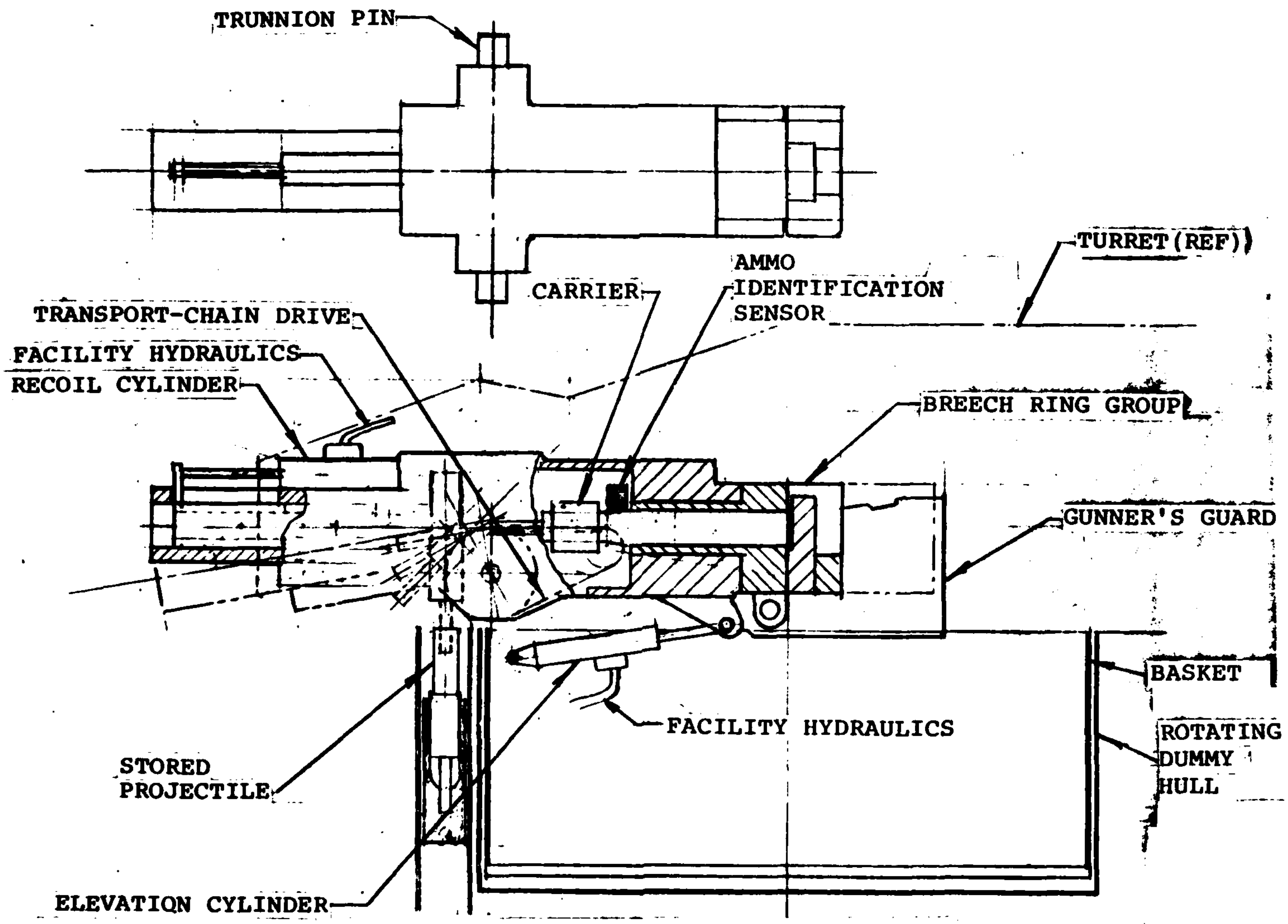


Figure 10-23 Simulated Main Gun

carrying the breech mechanism and gun tube. This configuration interfaces with all gun subsystems, the turret installation, ballistics, loader's station, and gunner's station. The configuration of these items is a result of this interface and the physical shape of the gun.

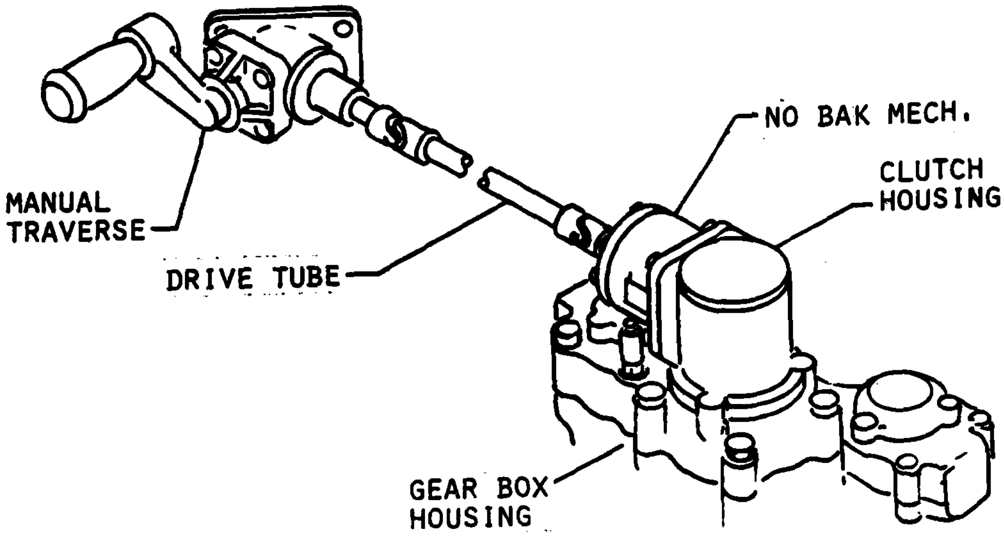
Hydraulic System - The tank hydraulic system provides a means of control and operation of turret traverse and gun elevation. The simulated turret station will not be traversed. Instead, it will rely on platform yaw displacement, visual cues, and simulated hull derotation to create turret movement. However, all turret hydraulics will be represented by either simulated or operational hardware. Both power and manual modes of operation will be faithfully reproduced.

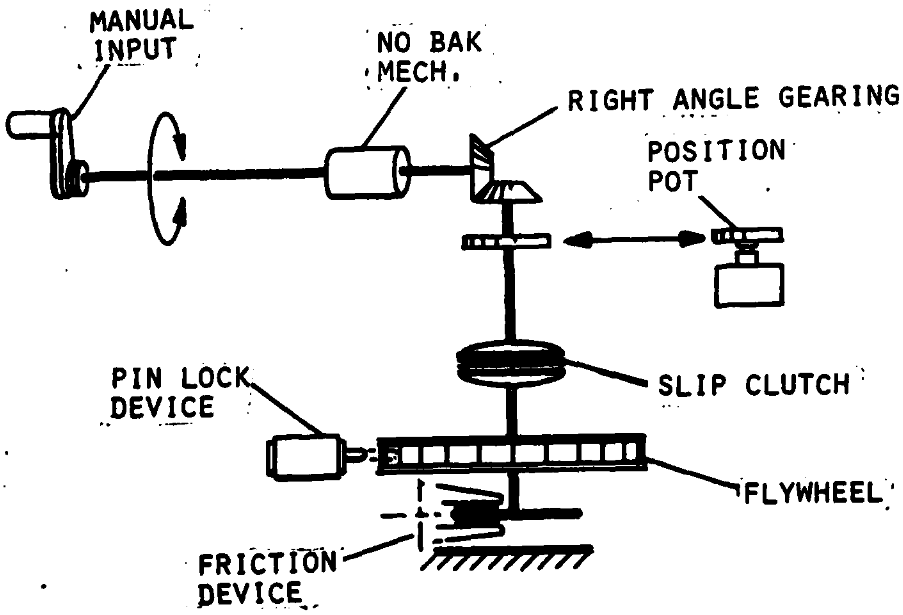
All hand controls, gages, and switch boxes utilized will be actual tank hardware (modified as required).

In the power traverse mode, function and feel requirements can be achieved by operation of the actual equipment. However, the manual requirements will have to be implemented by the addition of control loading systems as required.

Simulation of the manual crank cannot be achieved simply by the addition of a friction device to duplicate the operating force, since the reflected inertia of the turret can be sensed at the crank handle. When the handle rotation is halted, the no-bak mechanism prevents overshoot or backdriving. This activity can be duplicated (as shown in Figure 10-24) by initializing the no-bak mechanism, or equivalent, and simulated friction and inertia forces. As indicated, the flywheel inertia load will duplicate the turret reflected load with the friction load added by the friction device. To simulate a jammed or locked turret, a solenoid-operated pin device will lock the inertia shaft. The force to rotate the crank must now exceed the slip clutch torque, just as the actual tank system would react. This mechanism will be concealed within the dummy power pack housing.

Manual elevation of the main gun requires cranking a pump which moves hydraulic fluid through a shuttle valve, thus moving a spool which ports fluid to either side of the elevation cylinder. The power mode will employ an elevation cylinder similar to the actual equipment and will be controlled through the use of actual gunner and tank commander controls. A new elevation cylinder design appears necessary since it may be impractical to implement existing equipment with the simulated main gun. As shown in Figure 10-23 (Ref), the system will utilize facility hydraulic pressure rather than the tank stand-alone system. By using the actual manual crank and control system to elevate the gun in both modes, an exact training procedure is achieved.





SCHEMATIC

Figure 10-24 Manual Crank Assembly

Ballistics - The XM21 ballistics system will be modified for simulation purposes as described in section 10.3.1.5 All interfaces such as the ballistics drive, gunner's periscope, laser rangefinder, stabilization system, rate tachometer, crosswind sensor, etc. will be duplicated. In some cases such as crosswind sensor, rate tachometer, and output unit, the function of the device will be accounted for in the simulation hardware and only dummy enclosures will be utilized. For all optical devices, actual equipment, modified for simulation will be utilized.

The azimuth indicator will be provided with a servo drive system that causes the indicator to move properly when turret rotation occurs. This servo will provide position and rate functions proportional to the control inputs.

10.3.1.2 Simulated Ammunition. The need to simulate the effort required to load the main gun requires dummy ammo with the proper shape and weight distribution of actual 105mm shells. Five basic ammo styles (Heat, NEP, APERS,APDS,and WP) will be simulated.

In addition to these requirements, shells must be designed so that the projectile portion separates from the casing when the simulated gun has been fired. The casing is ejected as in the normal counter recoil sequence while the projectile is moved to a storage position and held until the training mission is completed. These items must be designed to be reassembled without special tools or skills, to eliminate or minimize mechanical malfunction potential, and to be rugged enough to withstand repeated usage.

The design criteria for this requirement are subdivided as listed below:

- Weight and CG duplication
- Standardization of Projectile Shape
- Separation Mechanics
- Materials and Life Cycle Requirements

The weight and CG of the various ammunition types can be closely approximated by adding or subtracting weights as required, and shifting the location along the principal axis of the round. The projectile shape and CG must be retained to a level sufficient to make the rounds appear and physically handle like the real items (Figure 10-25). Variations even beyond the subtle level can be incorporated if the requirements for identification and basic feel are not.compromised. Some standardization of these features is needed to simplify stowage and transport.

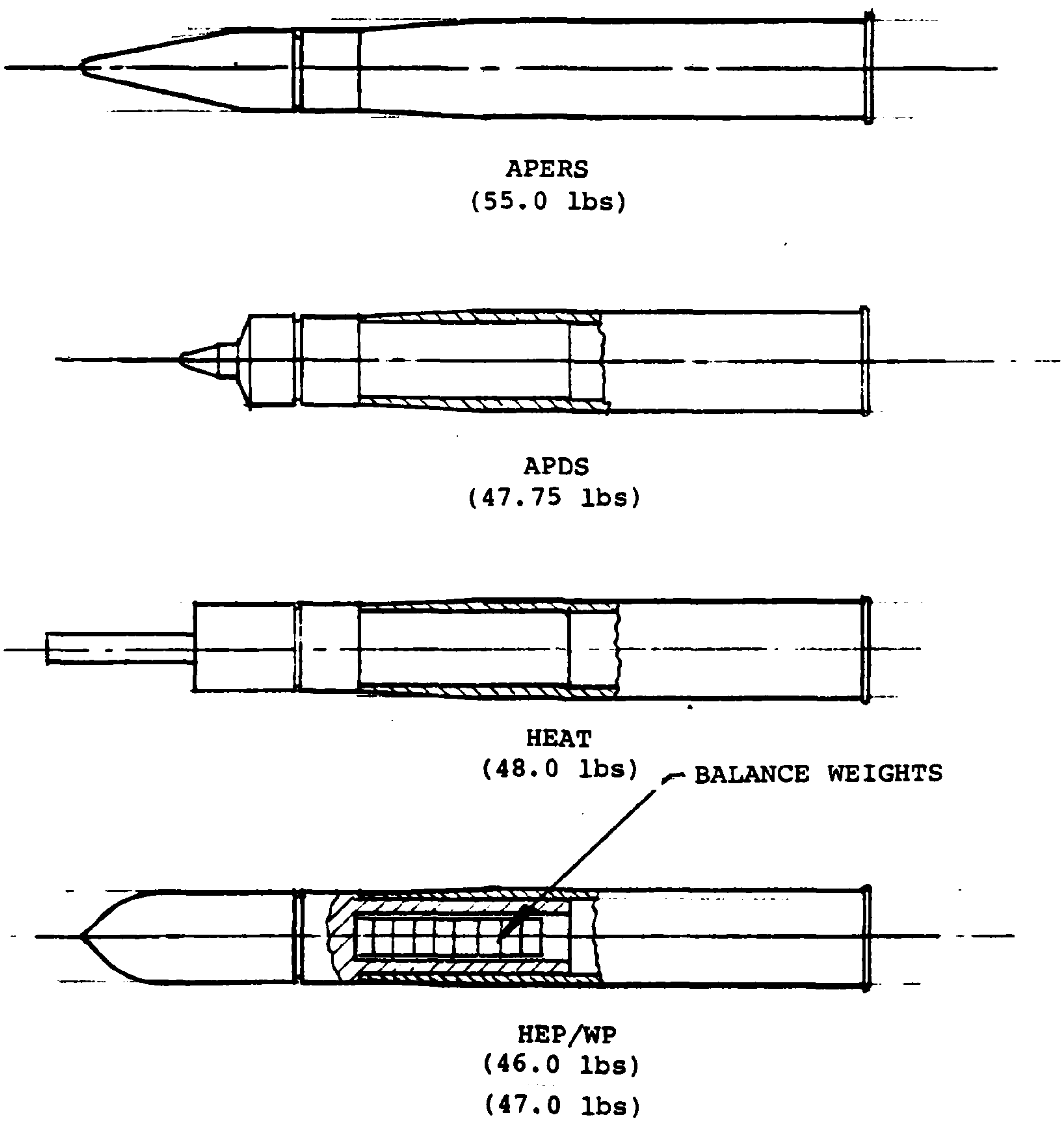


Figure 10-25 Simulated Ammunition - Weight and CG

The projectile separation mechanism must be designed to operate in a positive manner when required and to be locked in an equally positive manner when the rounds are being handled. In effect, the operation of the gun should not be compromised by faulty operation of the projectile separation mechanism. That the projectile shall not slip from the shell casing accidently due to a faulty design is of equal importance.

Selection of material for the projectile should reflect the need for extended service life without damage due to normal and even abusive handling.

In Figure 10-26, several separation mechanisms and the requirements for projectile standardization are depicted. These mechanisms reflect the style of transport system being proposed. Three separation devices are described herein.

Friction Locking - Utilizes an "0"-ring or rings to provide a suitable locking force to contain the projectile. Separation is accomplished by an "air blast" or transport mechanism.

Pneumatic Actuator - Air pressure operates a positive detent arrangement which permits separation.

Mechanical Actuator - A positive detent arrangement that is electromechanically operated when the loader's FIRE switch is activated.

Projectile Transport - The separation of the projectile from its casing is accomplished by actuation of the separation mechanism and withdrawal of the projectile via a transport mechanism. This activity is a combination of both transport motion and gun recoil. Removal should be accomplished in a positive manner to assure that the projectile is always delivered to the storage area and accounted for. To assure this is accomplished, a series of detectors can be employed for verification.

Once the projectile has been moved to the storage area, it must be positioned so that it can be received and stored properly. Proposals include:

- o A Cam-Guided Hydraulic Actuator
- o A Cam Guided Chain Drive
- o Pneumatic Transport

As seen in Figure 10-27 and 10-28, all of the methods are similar and differ only in the form of the drive member. The cam guide arrangement assures that each projectile enters the storage area in the proper attitude and can be released to

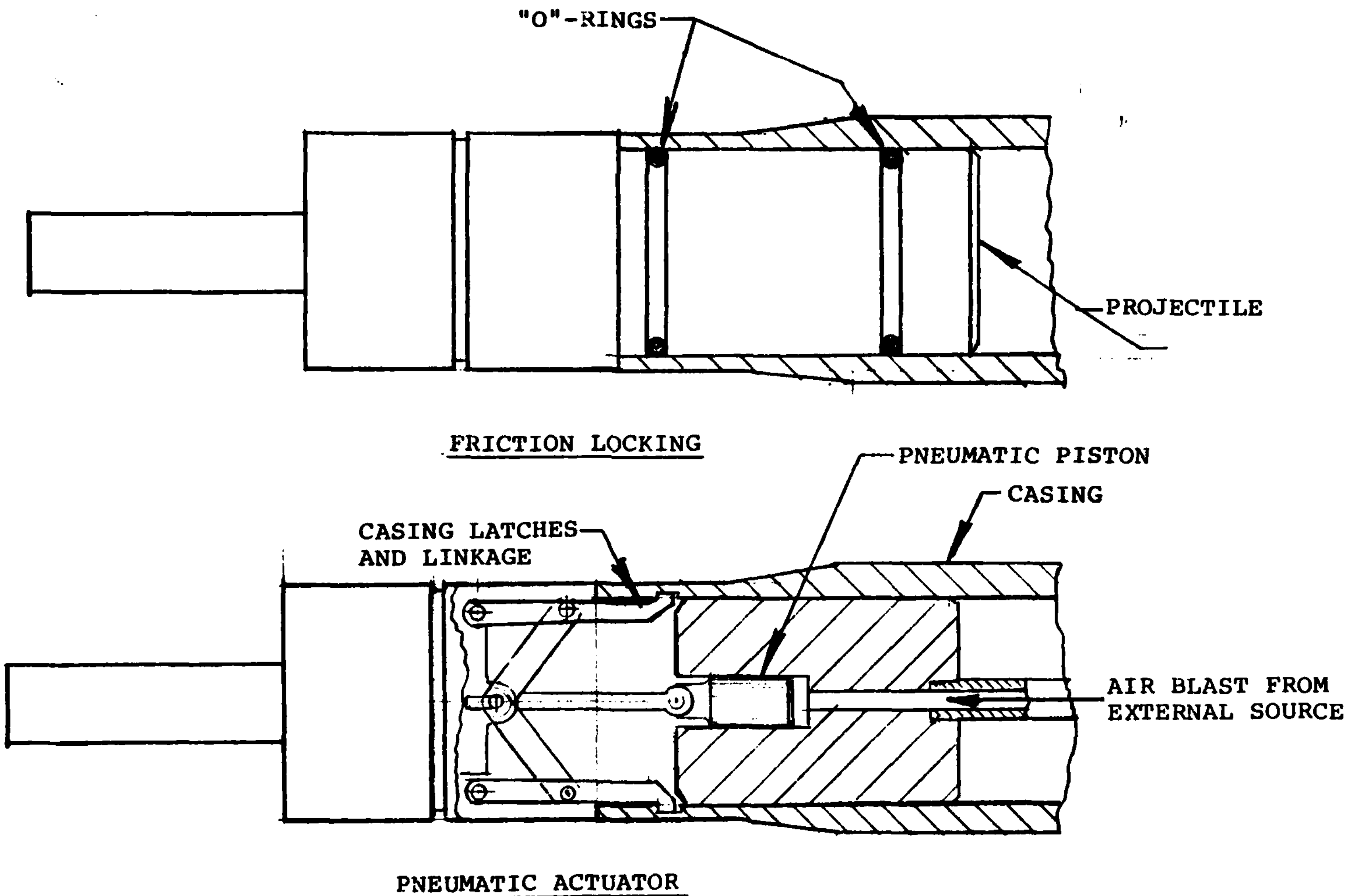


Figure 10-26 Projectile/Casing Separation Mechanisms

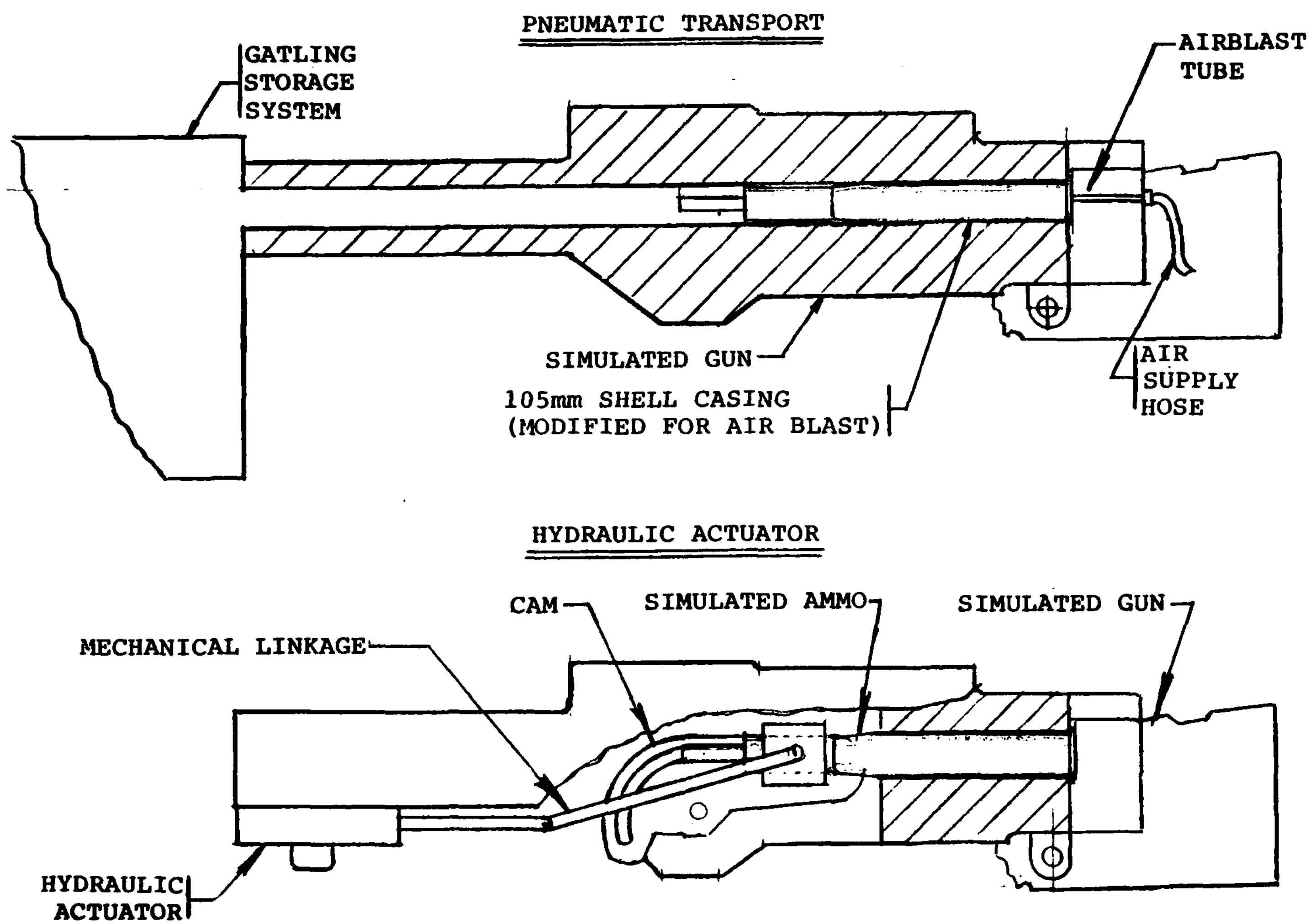


Figure 10-27 Projectile Transport Mechanisms - Pneumatic and Hydraulic

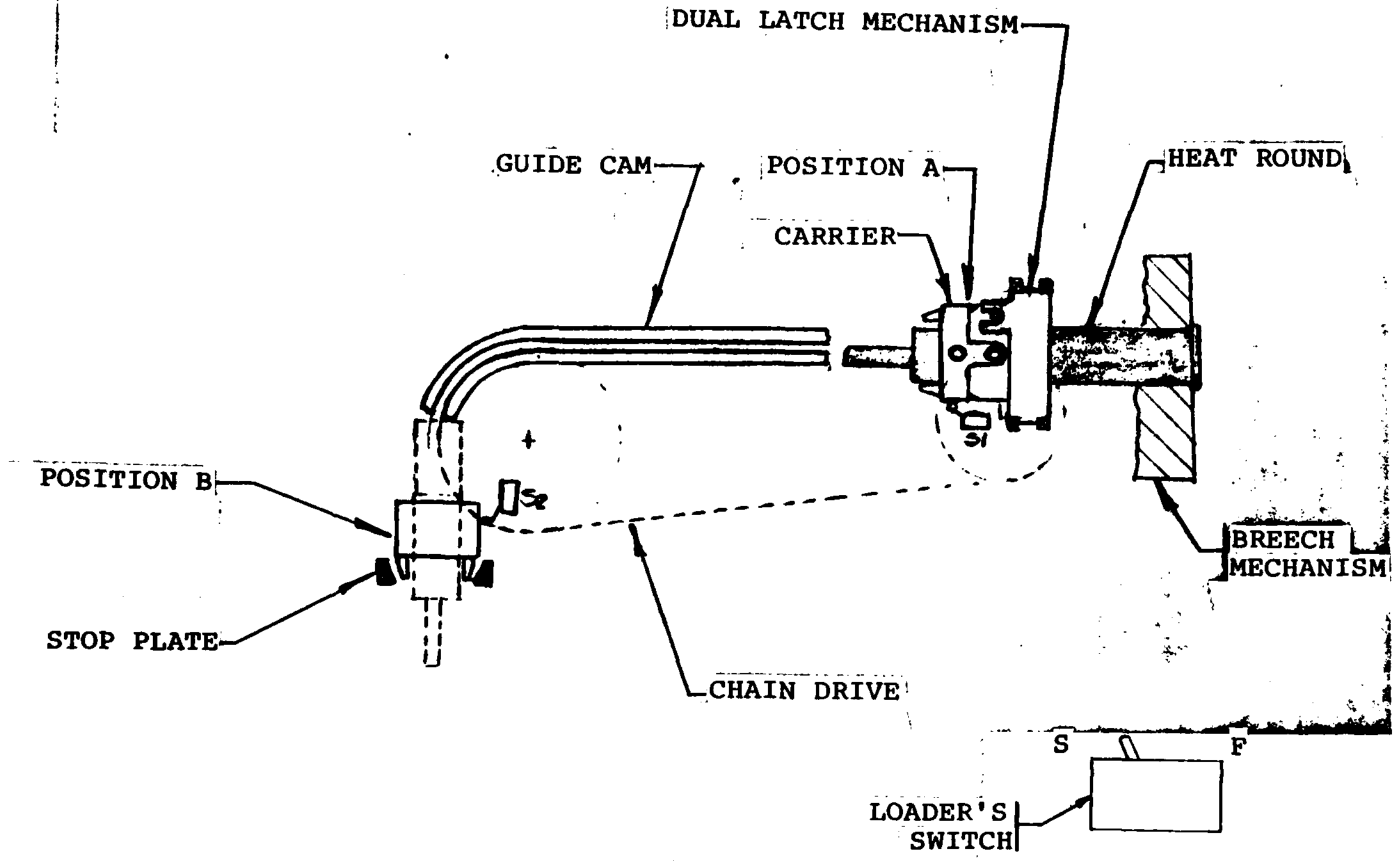


Figure 10-28 Projectile Transport Mechanisms - Cam - Guided Chain Drive

drop into the storage drum. The pneumatic transport is a departure from these two methods. The projectile is separated from the casing by an air blast through the shell casing. The projectile is then moved to a storage system.

Projectile Storage - The projectile expended during a training sequence must be stored in a safe and secure manner. Provisions for firing and storing 30 rounds will be incorporated. Again, the need for positive motion and accountability must be maintained. The following storage devices shown in Figure 10-29 and 10-30 are considered.

- o Gatling Drum
- o Radial Enclosure
- o Forward Enclosure

The gatling drum, shown in Figure 10-29 (Ref) can store 15 projectiles in a 29-inch diameter storage drum. The concentric drum driver permits a high-density storage system for the total space utilized. Expanding the capacity to 30 rounds reduces the efficiency of this system.

As depicted in Figure 10-30, the radial storage system will contain a maximum of 30 rounds. After the projectile reaches the storage system, it is immediately indexed to a new position to permit storage of the next projectile.

The forward enclosure features a high density scheme for storage of 30 projectiles, with positive indexing as previously described.

Replenisher - Movement of the replenisher tape, as a function of the recoil system oil level, will be simulated. The tape will be driven by an electromechanical device that is commanded by the operational status of the gun. Ambient temperature, number of rounds fired, accumlative time of firing,and other pertinent data,are all utilized in providing this output. Two schemes for implementing the replenisher system are Remote Drive and Integral Drive.

The Remote Drive System (Figure 10-31) utilizes a linear drive to rotate the tape drum. Position of the tape is determined by the ON/OFF condition of the position switches located inside the replenisher case. The replenisher has been modified by adding switches, return spring etc. The cap end, however, has been retained to allow simulated bleeding and filling activities as required.

The Integral Drive design (Ref Figure 10-31) utilizes a linear actuator and motor/gear system attached to the replenisher case. The switching design proposed for the Remote Drive can be employed with this concept.

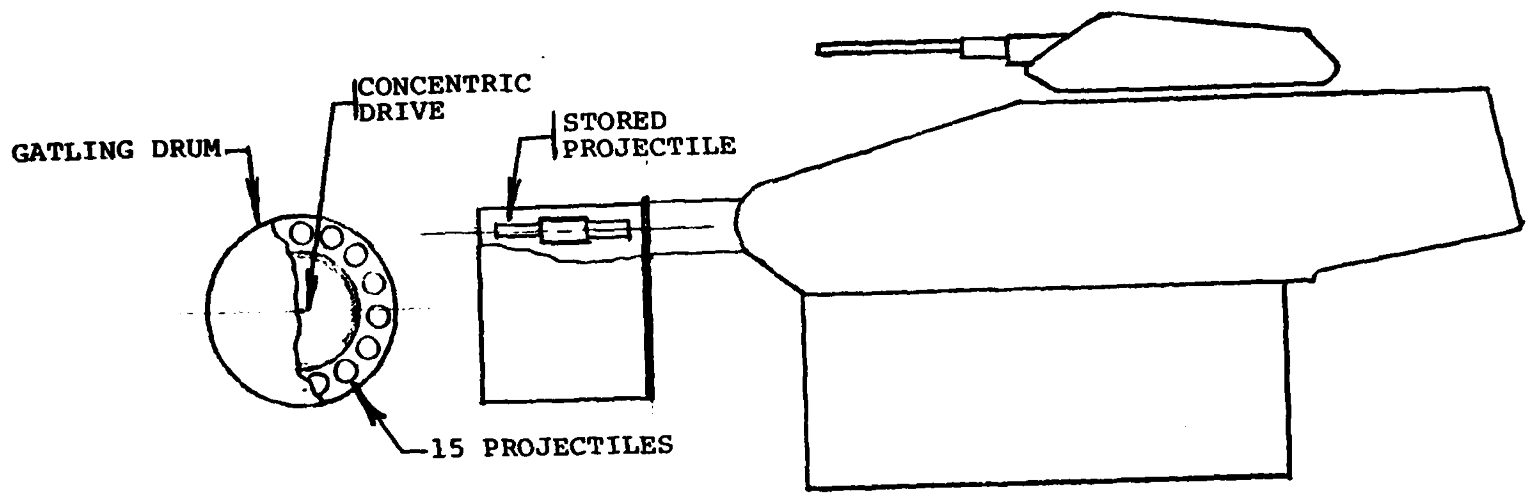


Figure 10-29 Projectile Storage - Gatling Drum System

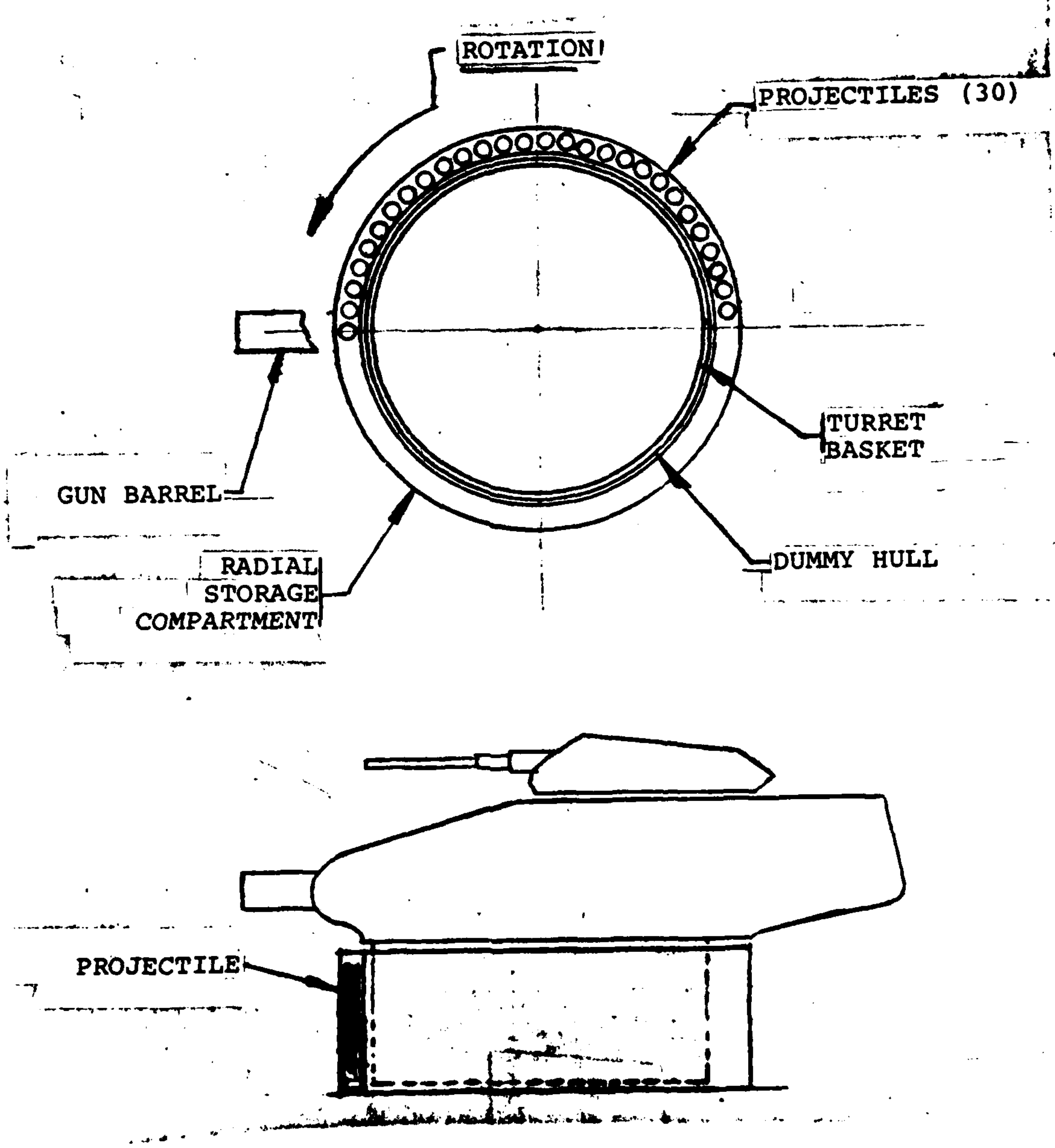


Figure 10-30 Projectile Storage - Radial System

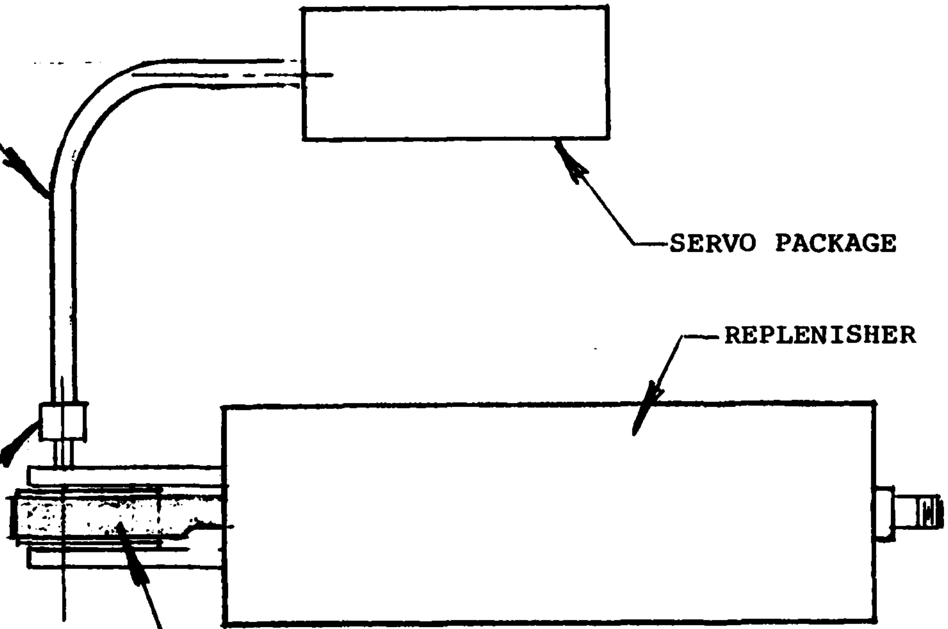


Figure 10-31 Remote Drive System

Ammunition Identification - The type of ammunition actually loaded into the gun must be identified to verify the loader has responded properly to the loading command. To accomplish this, some sort of device must be located within the main gun to identify the loaded round, or else another scheme for doing this must be considered.

Several types of coding methods can be considered. In one case a series of bands painted around the projectile or casing can be used. A second method utilized small grooves,again located in a similar fashion. As seen in Figure 10-32 readout devices will be either a photo scanner to detect dark and light patterns (painted lines) or a series of switches which "read" the number of small grooves.

10.3.1.3 Machineguns .

10.3.1.3.1 7.62mm Coaxial Machinegun. Provision for mounting this weapon in a similar location and manner will be accomplished by the main gun design. The use of an actual weapon must be considered for both physical and functional requirements. Since loading, troubleshooting, boresighting, and correcting malfunctions are all tasks to be considered, the use of the actual weapon is recommended.

Loading the weapon can be accomplished by using dummy ammunition belts and modifying the weapon by adding a sensor to detect the presence of a round in the chamber. Since both manual and electrical firing will be simulated, modifications must be accomplished by incorporating switches to detect the following:

- Safety Position
- Manual Trigger Position
- Changer Position
- Loading Cover Position

Electrical signals from these various switches will be conducted through a new cable and connector configuration similar to the actual tank wiring system.

Machinegun firing is initiated by operation of the control switch. Suitable aural cues are furnished, but no recoil motion will be provided. Misfiring can be accomplished by halting audio cues and energizing a solenoid operated switch located at the gun. In this manner, the trouble can be rectified by the loader by restoring the switch manually. This scheme is depicted in Figure 10-33.

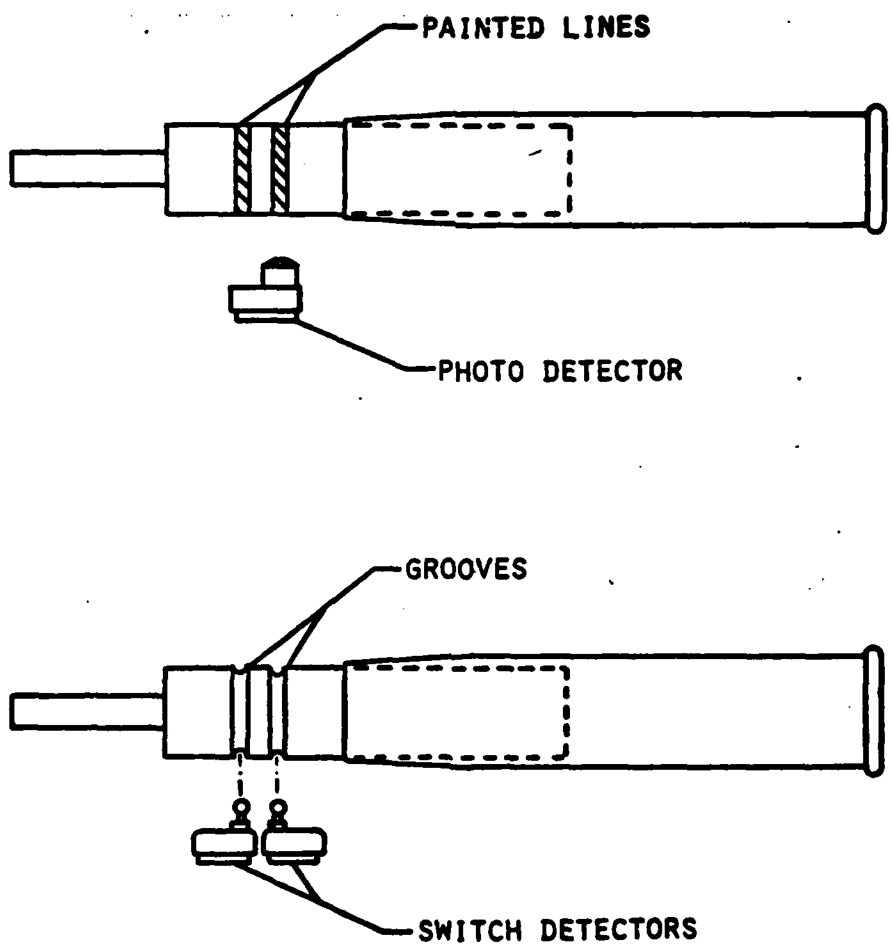


Figure 10-32 Simulated Ammunition Coding Methods

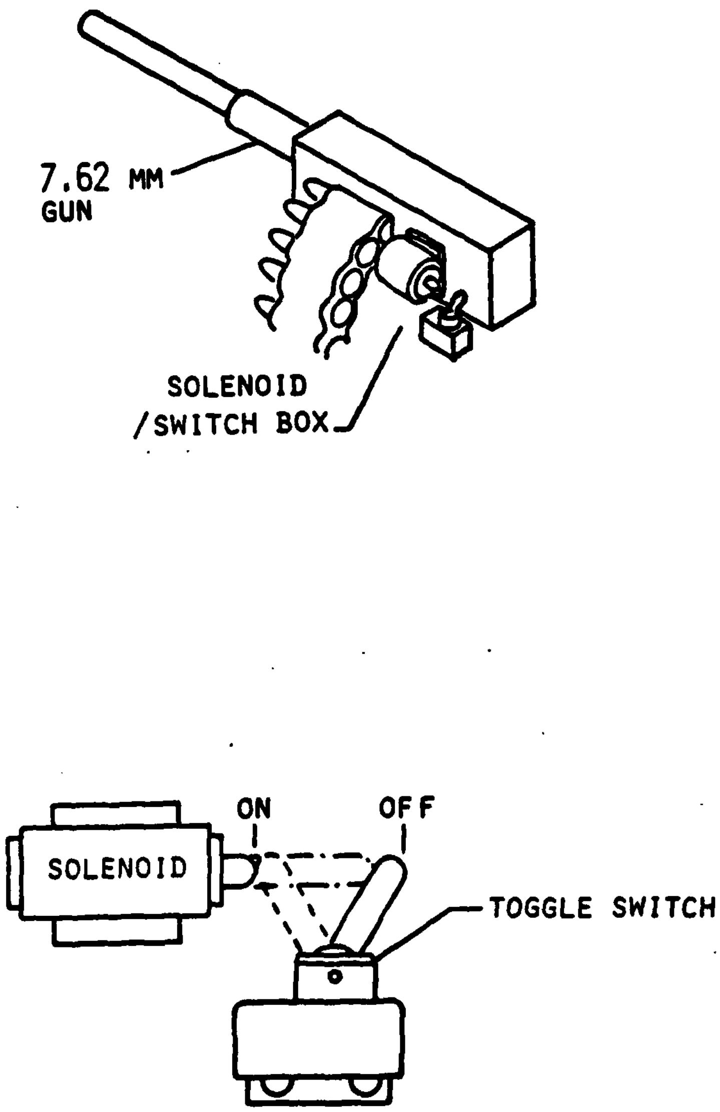


Figure 10-33 7.62 mm Misfire Mechanism

10.3.1.3.2 .50 Cal. Machine Gun. The requirements for this weapon are very similar to the 7.62mm gun and use of the actual weapon is justified. The simulation of this weapon will be essentially the same as that of the 7.62mm gun.

10.3.1.4 Grenade Launcher. This device will be fired by operating the proper firing switch. Audio cues will be furnished to signify this event. Visual indications of resulting smoke screens will be provided.

10.3.1.5 Ballistics Computer. The Ballistics Computer (XM21) is designed to assist the M60A3 crew in its performance as an efficient tactical unit. The effectiveness of this assistance is dependent on proper crew interaction with the computer. To facilitate a meaningful evaluation of this interaction in a simulated system, and more generally to evaluate crew offensive operation performance, it is necessary to provide accurate ballistic computer computations.

Any one of the following computational mediums could be utilized to provide an accurate simulator implementation of the required Ballistics Computer equations:

a) An Unmodified XM21 Ballistic Computer

b) A Modified XM21 Ballistic Computer

c) A Link Built Dedicated Processor

d) Software (Implementation in Mainframe Computer)

Each of the latter three is capable of equalling the accuracy and providing the same simulation fidelity as an unmodified XM21. In lieu of performance tradeoffs, system compatibility and cost become the dominant factors in the determination of which represented approach is optimum for a particular simulator configuration. The following paragraphs discuss various aspects of each approach. Emphasis is placed on interface of the particular approach to associated simulation elements. In effect, several systems are described. In each, approaches that would be most compatible are indicated.

Use of an unmodified XM21 requires that inputs be compatible with the unit's internal circuitry. Additionally, particular simulator inputs may require duplication of processing in order to format signals to appear as seen operationally by the XM21. A prime example is the wind sensor interface. In a simulation environment, wind is generally instructor-controlled via the computer. To interface with the XM21, wind speed and direction selected by the instructor must be processed to appear as sense inputs from the wind sensor allowing the XM21 to recompute speed and direction. Interface to XM21 outputs must also be compatible with its electronics. Considering the preceding restrictions, it may be seen that use of an unmodified unit is desirable if there is a significant amount of interface to other unmodified or compatible subsystems. Conversely, if few unmodified subsystems are used, an unmodified XM21 is less desirable, especially if special hardware buffers must be designed to interface the XM21 to other simulator subsystems.

Incorporation of an unmodified XM21 provides a distinct advantage in that should the unit fail, it can be replaced with another which would be readily available at the installation site. Furthermore, the failed unit would be repairable by on-site maintenance personnel.

In a system where ballistic computations require little interface to unmodified subsystems, yet one in which there is a significant amount of interface to hardware subsystems, it becomes advantageous to use either a modified XM21 or a dedicated processor.

There are three catagories of modification applicable to the XM21; bypassing unnecessary electronics, modifying existing circuitry, and designing in new circuitry. An example of the first category would be to eliminate computational redundancy such as that demonstrated for the determination of sensed wind speed and direction. In this case, the mainframe computer could provide inputs to the appropriate ballistics equations rather than to the wind sensor circuitry. Modifications of existing circuitry (category 2) might include gain changes or the use of bypassed circuitry to increase interface capabilities. Designing in (category 3) new circuitry would be primarily associated with making the unit interface compatible with other subsystems. Such add-in electronics would be contained on a printed circuit board designed to either replace an existing board or to be inserted into an existing spare slot. In general, most modifications of this type would require associated hardwire interfacing.

A disadvantage of a modified XM21 is that it cannot be interchanged readily with operational units available on-site.

The tradeoff associated with employing a modified XM21 or designing a dedicated processor, basically depends on the extent of modification that would be required for a particular system application. There is obviously a point at which modification is no longer feasible (space, power supply restrictions, etc) and/or cost-effective. An important consideration in this tradeoff is an awareness that the total design of a dedicated processor may be optimized for application in a particualr simulator system configuration. This optimization relates not only to interface circuitry, but also to equation formatting and processing. Functional computations, normally processed by associated subsystems (i.e., stabilization system) may be partially contained in the dedicated processor to reduce total system complexity.

A dedicated processor may be implemented using analog or digital integrated circuitry (the analog approach would include some digital interface electronics). Microprocessor technology may also be incorporated. Consequently, if a dedicated processor is most appropriate for the M60A3 trainer, an additional tradeoff analysis would be required to determine the preferred processing implementation. Numerous interrelated cost factors would be included in the analysis; design and development costs, recurring hardware costs, maintenance requirements, complexity (as related to the training required for maintenance) and changeability (cost of modification to reflect future changes in the XM21). In general, an analog system (similar to the XM21) would have the lowest design and recurring costs but would have the highest maintenance cost. A digital system would require significantly less maintenance but would cost slightly more to design and would have a higher recurring cost due primarily to printed circuit card requirements dictated by the greater number of integrated circuits involved. A microprocessor would have a significantly high development cost due to the expense of programming the system with recurring costs at a level compatible with an analog system. Microprocessor maintenance requirements would be minimal, however. Due to systems complexity, maintenance personnel would require a higher degree of technical proficiency than normal to maintain an analog or digital system. In terms of future XM21 changes, a microprocessor would be inherently more flexible. whereas the analog and digital systems would be somewhat restricted. However, at the expense of increased hardware, either of the latter systems could be designed to receive potentially changeable parameters from the computer.

Software simulation of ballistics equations becomes the most attractive approach if numerous associated subsystems are to be simulated within the mainframe computer. This approach is advantageous in that there is no ballistic computer hardware to design, develop, and maintain. However, consideration must be given to the fact that software simulation may require that additional hardware be designed to facilitate interfacing with the mainframe computer (which might not be necessary in some other approach). As indirect hardware requirements increase (i.e., more hardware simulated subsystems), software simulation becomes less advantageous. It should be noted, however, that some associated hardware subsystems must interface with the mainframe computer regardless of the ballistics computational approach selected. For example: parameters representing switch positions on the gunner's control unit and the ammunition selection units, must be interfaced via the mainframe computer to facilitate mission record/playback and to be available for display at the instructor's station.

In addition to ballistics computational electronics, the XM21 contains circuitry dedicated to self-test. Whereas the training value of the ballistic results is dependent on the equations used to obtain those results, the training value of the COMPUTER FAIL indication is not specifically related to the cause of that indication.

More specifically, the commander and gunner should not be concerned with why the unit failed, but rather with their ability to respond to insure that the unit failure has minimal tactical impact. Consequently, the ballistic computer failure is to be an instructor-controlled malfunction and a self-test capability is not required in the alternate ballistic implementations. However, should a modified or unmodified XM21 be utilized, the computer fail output may be monitored and logically 'OR'ed with the instructor-controlled malfunction in order that simulated or actual failures would be indicated. An alternate method that is frequently used in simulation devices, is to automatically trip the unit's power when an actual failure is sensed. It should be noted, that regardless of which method is selected, a simulated malfunction must provide the proper direct failure indication (fail lamp) and must fail or degrade the unit's outputs appropriately. Furthermore, normal, non-failed indications must be implemented (i.e., for system ok and lamp test).

10.3.2 Tradeoff Analysis of System Development. Many factors were considered in the selection of the main gun configuration. Major subsystems were studied and tradeoff analyses were made. The gun configuration was developed from a detailed study of the turret, fire controls, gun configuration, and turret basket, and their relationship to the simulated turret compartment.

Since main gun simulation requires that a projectile be separated from its casing, removed from the gun and safely stored in the simulator, an investigation was required to develop an approach that would not compromise main gun design. With this constraint, the gun must still interact with its respective gun laying devices, coaxial machine gun, turret basket, etc., without sacrificing fidelity of operation.

Each subsystem is discussed in this section with detailed tradeoff analyses tables (when applicable) following each affected subsystem. Selections are integrated into the main gun configuration shown in Figure 10-23 (Ref.).

10.3.2.1 Main Gun Selected Approaches. The simulated gun will be designed to have the same physical characteristics, duplicate the loading process, utilize dummy ammunition with real ammunition characteristics, provide recoil action, eject spent brass, and provide aural/visual/motion cues consistent with real gun operation.

Main gun subsystems are listed below with an evaluation of design criteria following.

- Recoil Motion
- Breech Mechanism
- Gun and Mount Assembly
- Replenisher
- Hydraulic System
- Safety
- Simulated Ammo
- Projectile Transport
- Projectile Storage
- Ammunition Identification

10.3.2.1.1 Recoil Motion (Table 10-6). The use of a servo-controlled hydraulic cylinder mounted externally to the gun tube appears to offer the best recoil drive. The cylinder is offset, allowing the gun tube to be utilized for boresighting.

TABLE 10-6 TRADEOFF ANALYSIS/SELECTION CHART - SYSTEM: MAIN GUN, SUBSYSTEM: RECOIL MOTION

	TRADE-OFF PARAMETERS AND SELECTION CRITERIA	WEIGHTING FACTOR	MODIFIED RECOIL CYLINDER		PNEUMATIC RECOIL DRIVE		HYDRAULIC CYLINDER					
PARAMETERS	PERFORMANCE PARAMETERS		EP	FM	EP	FM	EP	FM	EP	FM	EP	FM
	• ENERGY ABSORPTION	.3	5	1.5	3	.9	4	1.2				
	• RATE	.4	3	1.2	3	1.2	5	2.0				
	• STIFFNESS	.8	5	4.0	1	.8	5	4.0				
	•											
	•											
	PERFORMANCE SUMMATION			6.7		2.9		7.2				
CRITERIA	OVERALL PERFORMANCE			2.2		1.0		2.4				
	LOW PROCUREMENT COST	.2	1	.2	1	.2	4	.8				
	LOW OPERATING COST	.5	3	1.5	3	1.5	4	2.0				
	SIMPLICITY	.5	1	.5	1	.5	3	1.5				
	RELIABILITY	.9	3	2.7	3	2.7	5	4.5				
	MAINTAINABILITY	.9	3	2.7	3	2.7	4	3.6				
	SYSTEM COMPATIBILITY	.5	5	2.5	3	1.5	4	2.0				
	SYSTEM FLEXIBILITY	.5	3	1.5	2	1.0	5	2.5				
	PRODUCIBILITY/AVAILABILITY	.9	3	2.7	1	.9	4	3.6				
	SAFETY ASPECTS	.9	3	2.7	3	2.7	5	4.5				
	OVERALL SUMMATION		17.0		13.7		25.0					
	APPROACH REJECTION/SELECTION						X					

The servo system allows easy adjustment of the recoil rate. This type of hydraulic system has been employed in many other Singer systems and presents no particular design problems.

10.3.2.1.2 Breech Mechanism. A redesigned breech mechanism, utilizing in part, operational components, is a more versatile solution than a modified actual breech assembly, since the interface of the breech and transport mechanism requires extensive flexibility. Modification of the operational breech mechanism limits the amount of freedom needed to integrate the transport with the gun and breech mechanism. Tradeoff analysis/selection is presented in Table 10-7.

10.3.2.1.3 Gun and Mount Assembly. This configuration, shown in Figure 10-23(Ref.), was determined by interfacing all gun subsystems, and by integrating the main gun with other tank equipment. The outside shape of the gun will be a close replica of the actual equipment but will exhibit some differences in shape due to modifications required to transport and store projectiles. These discrepancies, however, will not affect training effectiveness.

10.3.2.1.4 Replenisher. The replenisher tape will be driven by an electrical servo system and be controlled by either computer or instructor override. An integral design will be utilized since the servo system can be packaged unnoticed on the far side of the replenisher (Figure 10-34). For this design, a simple motor and potentiometer arrangement can be employed. Four discreet tape positions will correspond to respective potentiometer voltages. Motor speed will be fixed and position accuracy need not be tightly controlled.

10.3.2.1.5 Hydraulic System. As previously discussed, all turret hydraulics will be physically represented. In some cases such as the traverse drive, certain equipment will be nonfunctional, but a nonfunctioning replica of the exterior of the item will be properly located to maintain the physical integrity of the tank interior. Also, all required hand controls, dials, ranges, etc., will be modified actual equipment.

Hydraulic actuators will be powered from the facility system, since it is common to util. ∙ ≥ this energy to drive auxiliary equipment. Individual hydraulic systems include:

- o Gun Elevation (powered and manual)
- o Hull Rotation
- o Recoil System

TABLE 10-7 TRADEOFF ANALYSIS/SELECTION CHART - SYSTEM: MAIN GUN, SUBSYSTEM: BREECH MECHANISM

	TRADE-OFF PARAMETERS AND SELECTION CRITERIA	WEIGHTING FACTOR	MODIFIED BREECH		REDESIGNED LIGHT-WEIGHT							
PARAMETERS	PERFORMANCE PARAMETERS		EF	FM	EF	FM	EF	FM	EF	FM	EF	FM
	• WEIGHT (LOW)	.4	2	.8	5	2.0						
	• ADAPTABILITY	.4	3	1.2	5	2.0						
	• OPERATION	.7	5	3.5	3	2.1						
	•											
	•											
	PERFORMANCE SUMMATION			5.5		6.1						
CRITERIA	OVERALL PERFORMANCE			1.8		3.0						
	LOW PROCUREMENT COST	.2	1	.2	4	.8						
	LOW OPERATING COST	.5	3	1.5	3	1.5						
	SIMPLICITY	.2	1	.2	4	.8						
	RELIABILITY	.9	5	4.5	4	3.6						
	MAINTAINABILITY	.5	5	2.5	4	2.0						
	SYSTEM COMPATIBILITY	.9	2	1.8	5	4.5						
	SYSTEM FLEXIBILITY	.9	2	1.8	5	4.5						
	PRODUCIBILITY/AVAILABILITY	.9	1	.9	4	3.6						
	SAFETY ASPECTS	.9	5	4.5	4	3.6						
	OVERALL SUMMATION			17.9		24.9						
	APPROACH REJECTION/SELECTION					X						

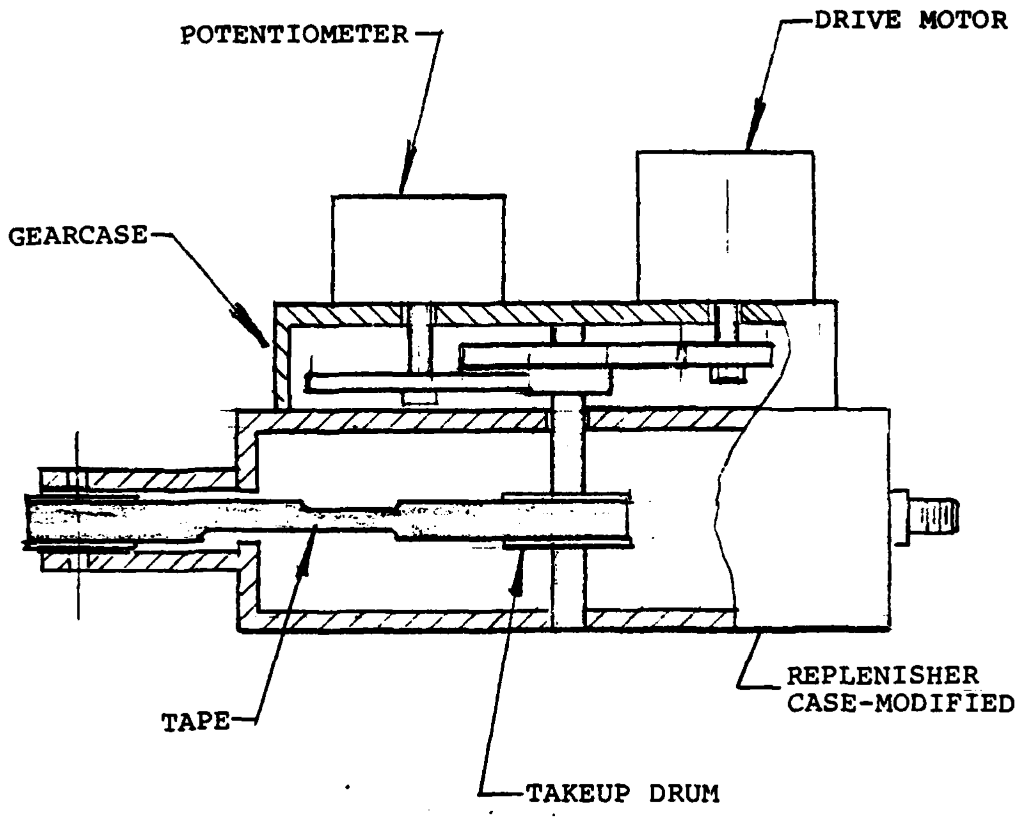


Figure 10-34 Replenisher - Integral Design

The gun elevation system, in both powered and manual mode, will be functional. The rate of travel and excursion will be equal to that of the actual tank. Manual elevation will employ the same pump system used on the tank and will require the equivalent amount of exertion.

The rotatable hull (Ref Figure 10-1) will be supported by roller bearings and guided by a center driveshaft. A hydrostatic drive motor, coupled with a planetary gear box will provide power to drive the hull. Hull position and rate of travel will be computer-controlled.

The recoil system will consist of the cylinder, servo valve, and control devices. The rate of recoil and counter-recoil will be adjustable, permitting the recoil rate to not only be changed but even shut down if required.

10.3.2.1.6 Safety. In recoil and elevation, and particularly in the stabilized mode, movement of the gun can be hazardous to tank personnel. To maintain realistic conditions and yet reduce danger due to dynamic reactions, safety measures will be instituted. To minimize injury due to impact between the gun and trainee, wherever possible, rubber padding will be added to moving parts of the gun. In addition special pressure sensitive floor mats will be installed behind the gun in the danger zone. These mats will detect the presence of a heavy object (Personnel) in that position and disable the recoil system.

In addition, a safety device will be introduced into the hydraulic circuit which controls the simulated recoil motion. This device, utilized in other Link equipment, will also be activated by weight on the pressure-sensitive floor mat. In operation, it will cause fluid in the hydraulic cylinder to be diverted from the high-pressure side to the low-pressure side reducing the force of recoil. Although this system takes 50 milliseconds to react, it will be effective and reduce the effects of impact if triggered at the start of recoil. It should also be noted that the moving mass (250 lbs max.) of the simulated main gun will be many times smaller than the actual gun, further reducing the possibility of injury.

10.3.2.2 Simulated Ammunition. The shape, weight, and projectile CG have been described in Section 10 and are illustrated in Figure 10-35 and 10-36. The principal standardizations of the projectiles follow.

- o Outside diameters will be identical for all types
- o Carrier Latching Groove

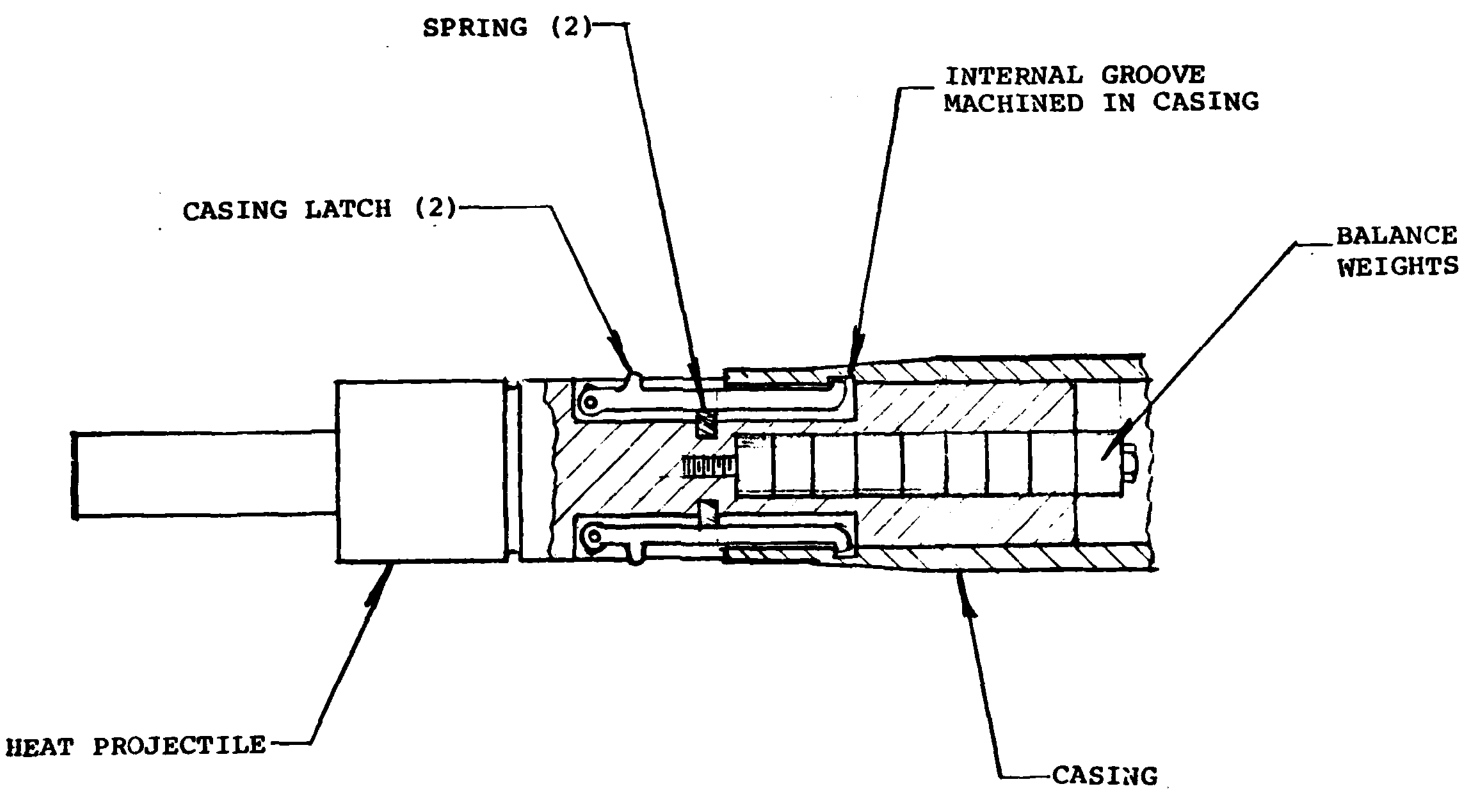


Figure 10-35 Projectile Standardization

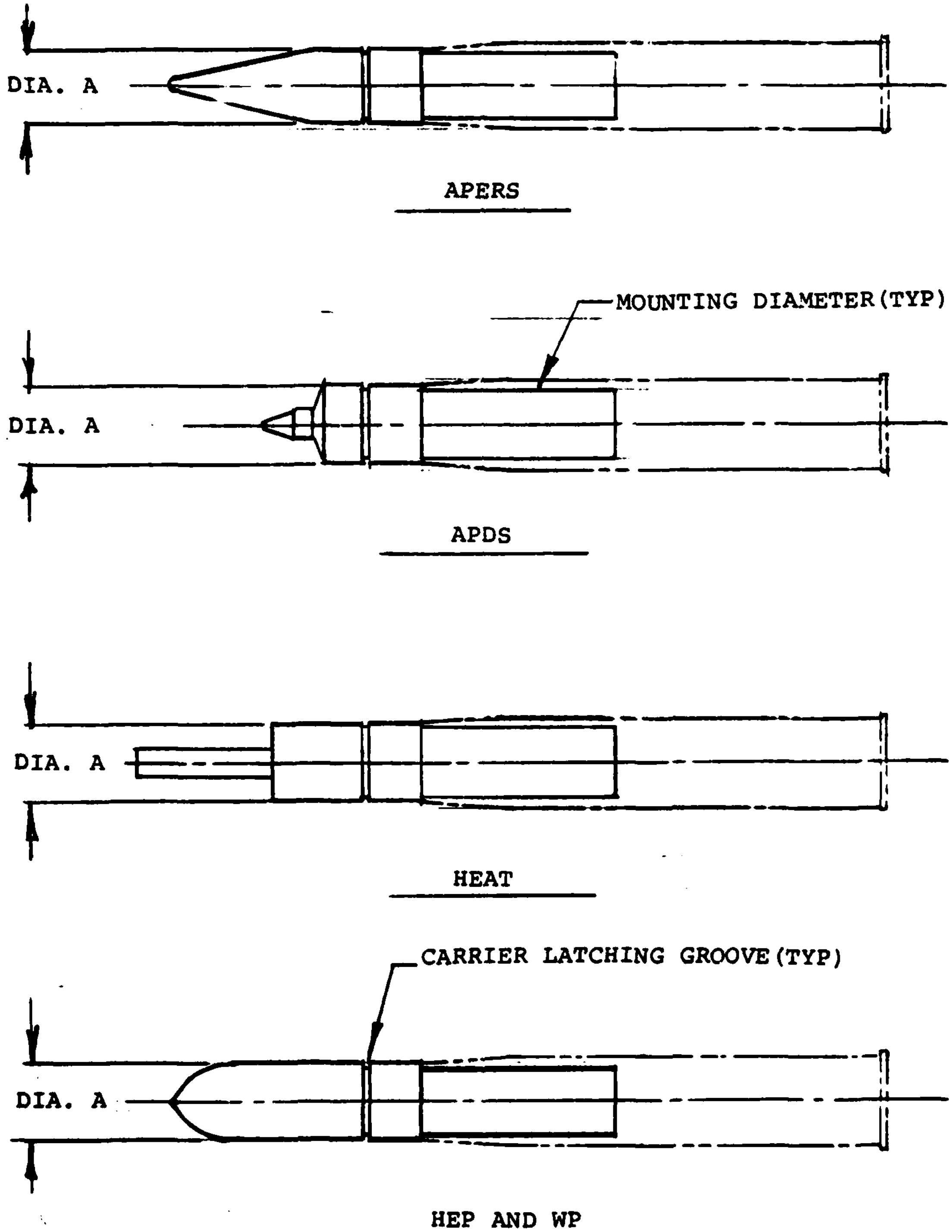


Figure 10-36 Standard 105mm Projectiles

o Casing latches (Figure 10-35 Ref.) will be incorporated

o CG and weight adjustment features (Figure 10-35 Ref.) will be common.

The use of mechanical detents (latches) to lock the projectile and casing offers positive connection of these members and simple reassembly. The latching groove is needed to operate the transport mechanism.

Construction of the simulated ammunition will be as shown in Figure 10-36 (Ref.). Construction of the projectile will consist of an outer plastic portion bonded to a metal core. The plastic will be a high impact material which will withstand abusive handling while sustaining little damage. This construction will extend the useful life of the projectiles.

The shell casings will be actual casings modified by machining an internal groove as shown in Figure 10-35(Ref.). The reuseability of these items should be quite extensive since the rugged nature of this item will not be altered.

Tradeoff analysis/selection is presented in Table 10-8.

10.3.2.2.1 Projectile Transport Mechanism. The transport system consists of a carrier mechanism, guide cam., stop plate, latching mechanism, drive mechanism,and switches. A chain drive mechanism has been selected since it offers more flexibility and can be adapted better to the interfacing devices. A schematic representation of this system is shown in Figure 10-37. The sequence of operations of this system will be as follows:

1) 105mm round selected and loaded into breech mechanism, carrier at position "A".

2) Dual purpose cam unlatches the carrier from the projectile, while projectile and casing are still latched together (Figure 10-38)

3) Loader's switch moved to FIRE position.

4) Dual latch mechanism (Ref. Figure 10-37) rotates 60°, returning cam and latching the projectile to the carrier and unlatching the projectile from the casing (Figure 10-39)

5) Main gun fired, recoil motion and projectile transport begin simultaneously

6) Projectile is advanced to position "B" via carrier, chain drive, and guide cam arrangement.

7) At position "B" carrier is stopped and the manual unlatching levers are operated when the stop plate is contacted.

TABLE 10-8 TRADEOFF ANALYSIS/SELECTION CHART - SYSTEM: MAIN GUN, SUBSYSTEM: SIMULATED AMMUNITION

	TRADE-OFF PARAMETERS AND SELECTION CRITERIA	WEIGHTING FACTOR	PNEUMATIC ACTUATOR		FRICTION LOCK		MECHANICAL ACTUATOR					
			EF	FM	EF	FM	EF	FM	EF	FM	EF	FM
PARAMETERS	**PERFORMANCE PARAMETERS**											
	• POSITIVENESS	.7	4	2.8	3	2.1	5	3.5				
	• INTEGRITY	.4	5	2.0	3	1.2	5	2.0				
	•											
	•											
	•											
	PERFORMANCE SUMMATION			4.8		3.3		5.5				
CRITERIA	OVERALL PERFORMANCE			1.6		1.1		1.8				
	LOW PROCUREMENT COST	.5	3	1.5	5	2.5	3	1.5				
	LOW OPERATING COST	.8	4	3.2	5	4.0	4	3.2				
	SIMPLICITY	.5	3	1.5	5	2.5	3	1.5				
	RELIABILITY	.8	2	1.6	2	1.6	5	4.0				
	MAINTAINABILITY	.9	5	4.5	2	1.8	5	4.5				
	SYSTEM COMPATIBILITY	.5	1	.5	3	1.5	5	2.5				
	SYSTEM FLEXIBILITY	.3	2	.6	5	1.5	5	1.5				
	PRODUCIBILITY/AVAILABILITY	.7	3	2.1	3	2.1	3	2.1				
	SAFETY ASPECTS	.5	5	2.5	1	.5	5	2.5				
	OVERALL SUMMATION		18.9		18.0		23.3					
	APPROACH REJECTION/SELECTION						X					

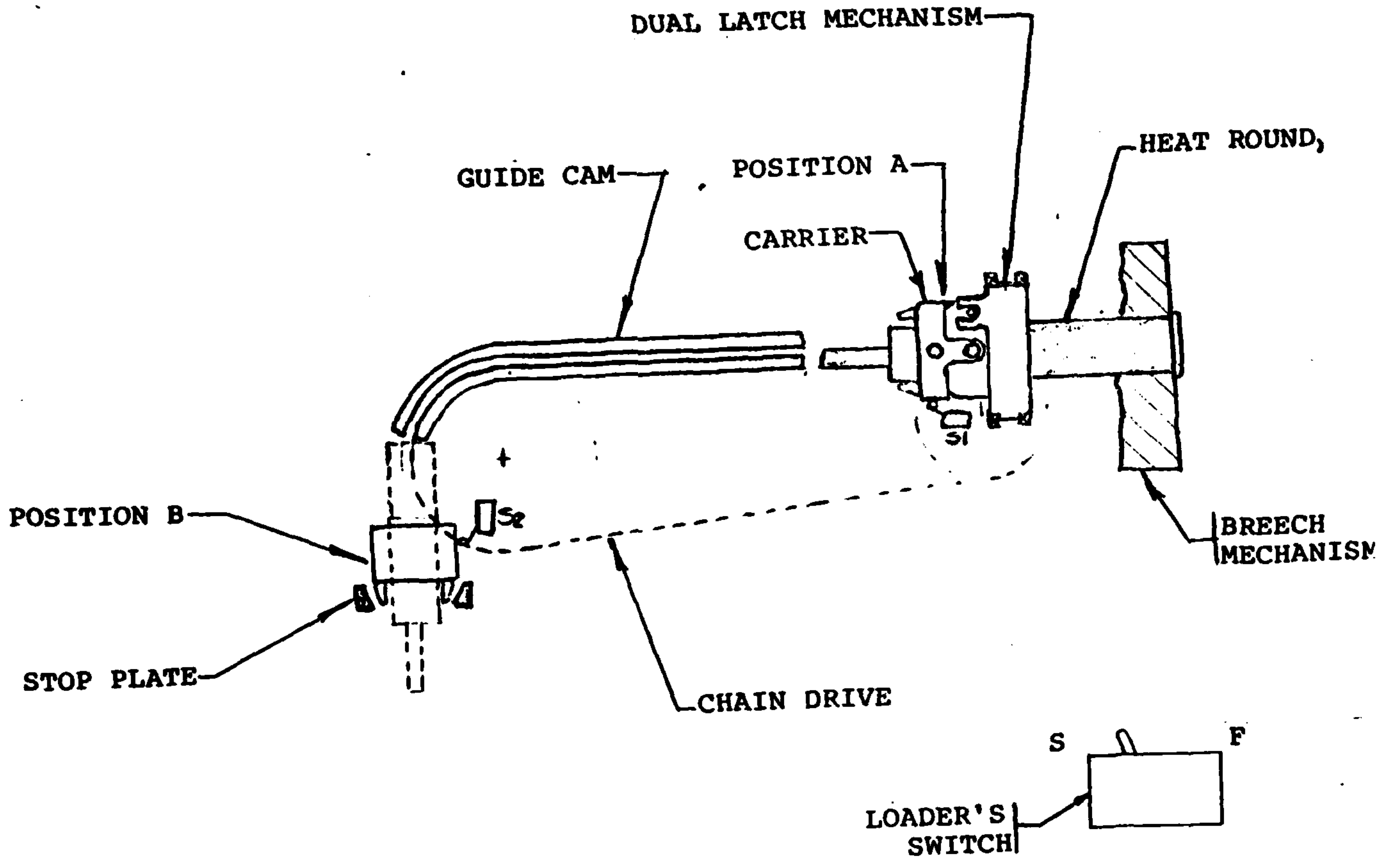


Figure 10-37 Projectile Transport System

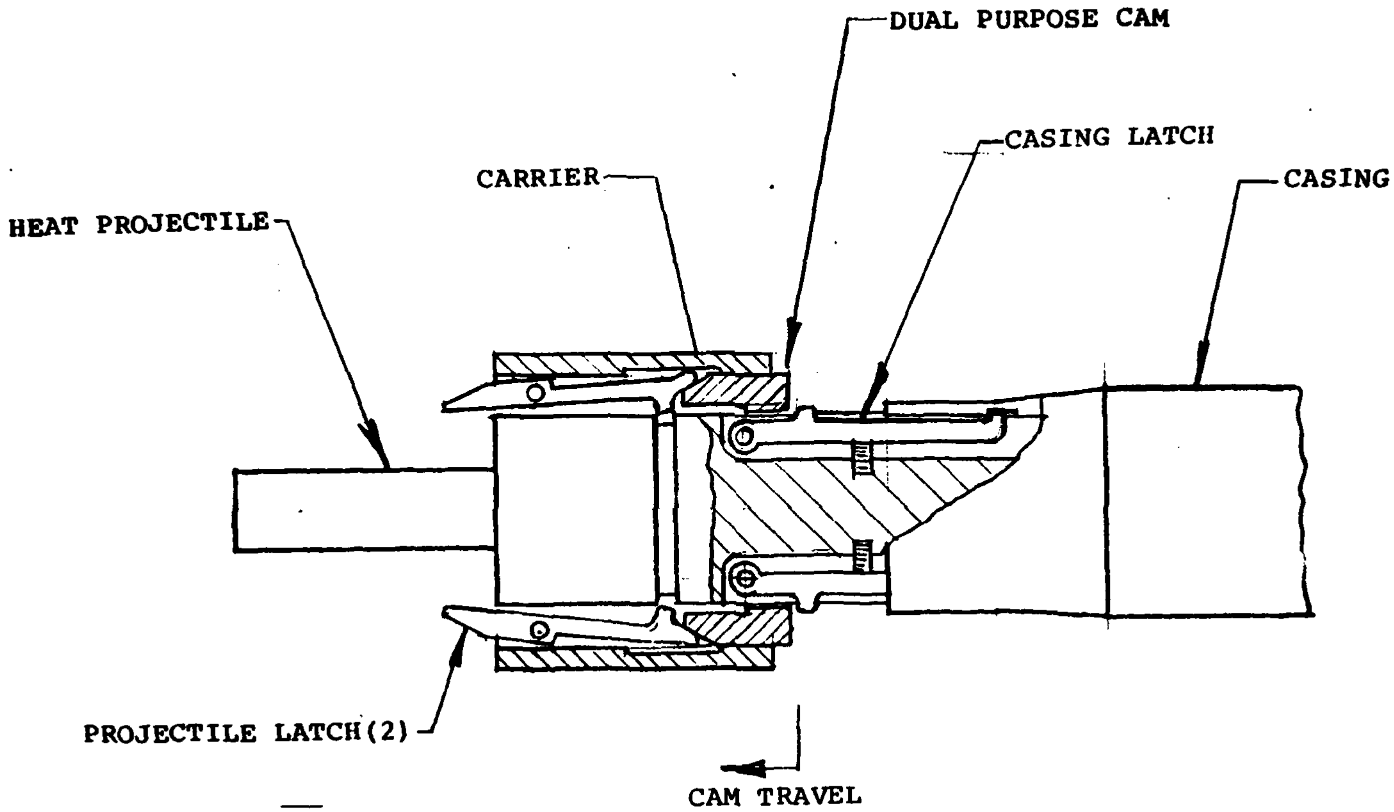


Figure 10-38 Projectile Transport Mechanism (Unlatched)

8) Projectile is decoupled and drops into storage system - guide cam assures this entry is not affected by gun elevation.

9) The carrier mechanism is returned to position "A" - total elapsed time will not exceed 2.5 seconds from the FIRE switch initiation to carrier return.

The dual latching mechanism is shown in Figure 10-37 (Ref.). Its function is to operate the dual cam which in turn latches or unlatches the projectile to or from the carrier mechanism. In doing so, the dual cam alternately latches or unlatches the projectiles and casing as previously mentioned. This device permits a round to be loaded into the gun and a misfire to be simulated at anytime. Position of the mechanism is determined by internal switches wich override transport drive signals.

Tradeoff analysis/selection is presented in Table 10-9.

10.3.2.2.2 Projectile Storage (Figure 10-30). A radial storage system was selected since it offered increased flexibility and compatibility. In addition,it results in more compact integration with the other interrelated systems.

A system has been designed to store a total of 30 projectiles (consistent with most training mission requirements). Each projectile received by the storage mechanism is deposited in an individual storage cell. This cell is designed to receive and guide the projectile into a nested position. Weight, and motion of dropping the projectile, will "seat" this item into the cell snugly. The cell will utilize rubber cushioning material to hold the individual member in position.

The cells are supported by roller balls and driven by a chain drive system as shown in Figure 10-40. Each cell is indexed to the next position upon return to position "A" of the transport mechanism. An electric motor/servo system provides the position and velocity. Tradeoff analysis/selection is presented in Table 10-10.

10.3.2.2.3 Ammunition Identification. A photo scanner system will be utilized to identify ammunition loaded in the weapon. This device will detect a painted dark line as it passes by and can be used to count the number of lines detected. By simple coding with a different number of lines, various ammunition types can be identified. Use of the scanner, instead of the mechanical detector described in Section 10, eliminates misalignment problems which can sometimes occur with switches, and in addition, provides almost unlimited life. Tradeoff analysis/selection is presented in Table 10-11.

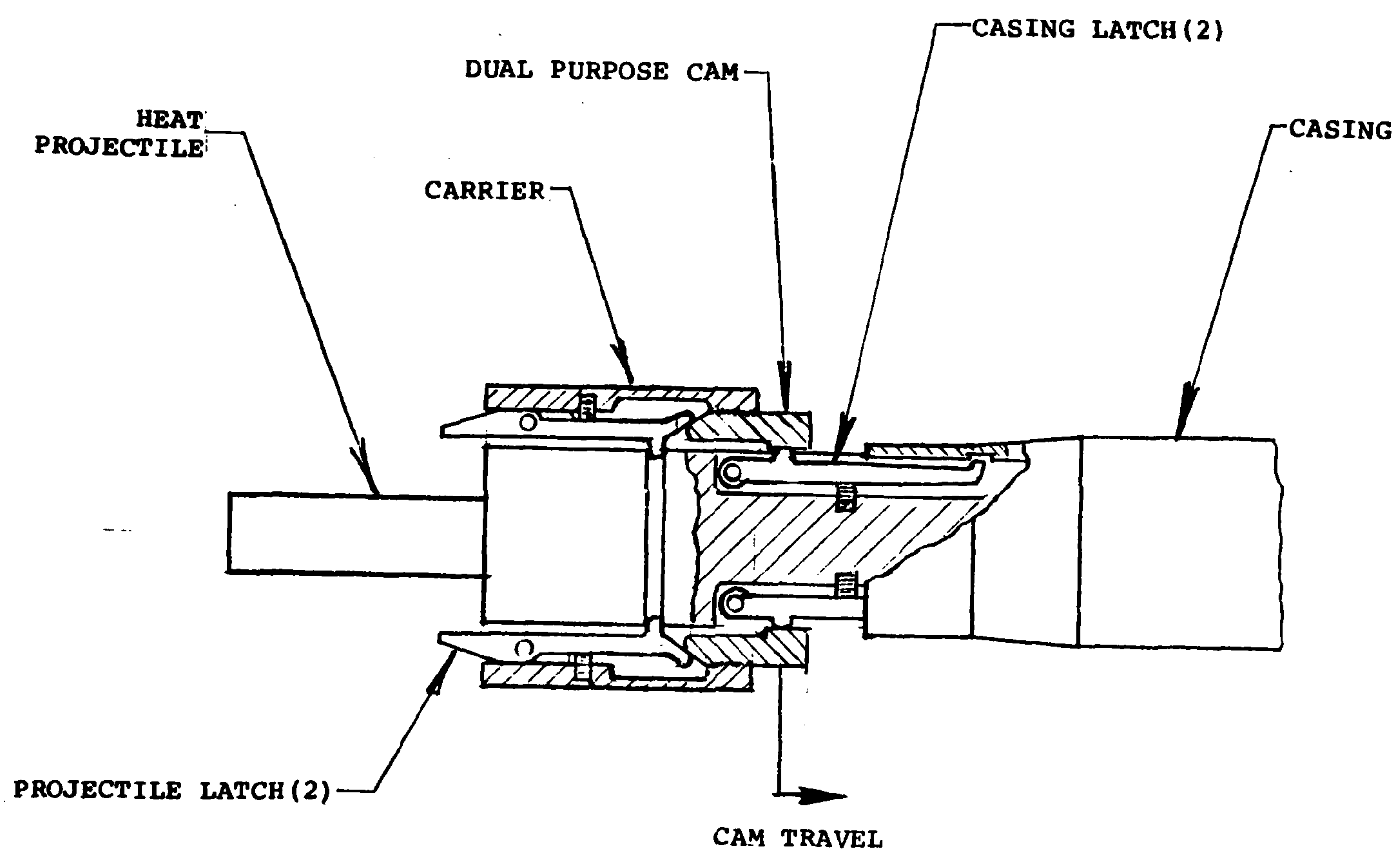


Figure 10-39 Projectile Transport Mechanism (Latched)

TABLE 10-9 TRADEOFF ANALYSIS/SELECTION CHART - SYSTEM: MAIN GUN, SUBSYSTEM: PROJECTILE TRANSPORT MECHANISM

	TRADE-OFF PARAMETERS AND SELECTION CRITERIA	WEIGHTING FACTOR	HYDRAULIC ACTUATOR		CHAIN DRIVE		PNEUMATIC					
PARAMETERS	PERFORMANCE PARAMETERS		EF	FM	EF	FM	EF	FM	EF	FM	EF	FM
	• POSITIVE OPERATION	.7	5	3.5	5	3.5	2	1.4				
	• CONTROL ABILITY	.5	5	2.5	5	2.5	1	.5				
	• CYCLE RATE	.3	5	1.5	4	1.2	3	.9				
	•											
	•											
	PERFORMANCE SUMMATION			7.5		7.2		2.8				
CRITERIA	OVERALL PERFORMANCE			2.5		2.4		.9				
	LOW PROCUREMENT COST	.2	5	1.0	5	1.0	5	1.0				
	LOW OPERATING COST	.5	5	1.0	5	2.5	5	2.5				
	SIMPLICITY	.2	3	.6	3	.6	5	1.0				
	RELIABILITY	.9	5	4.5	5	4.5	1	.9				
	MAINTAINABILITY	.9	4	3.6	4	3.6	5	4.5				
	SYSTEM COMPATIBILITY	.9	5	4.5	5	4.5	3	2.7				
	SYSTEM FLEXIBILITY	.8	5	4.0	5	4.0	5	4.0				
	PRODUCIBILITY/AVAILABILITY	.6	3	1.8	3	1.8	5	2.4				
	SAFETY ASPECTS	.9	4	3.6	4	3.6	3	2.7				
	OVERALL SUMMATION			24.6		26.1		21.7				
	APPROACH REJECTION/SELECTION											

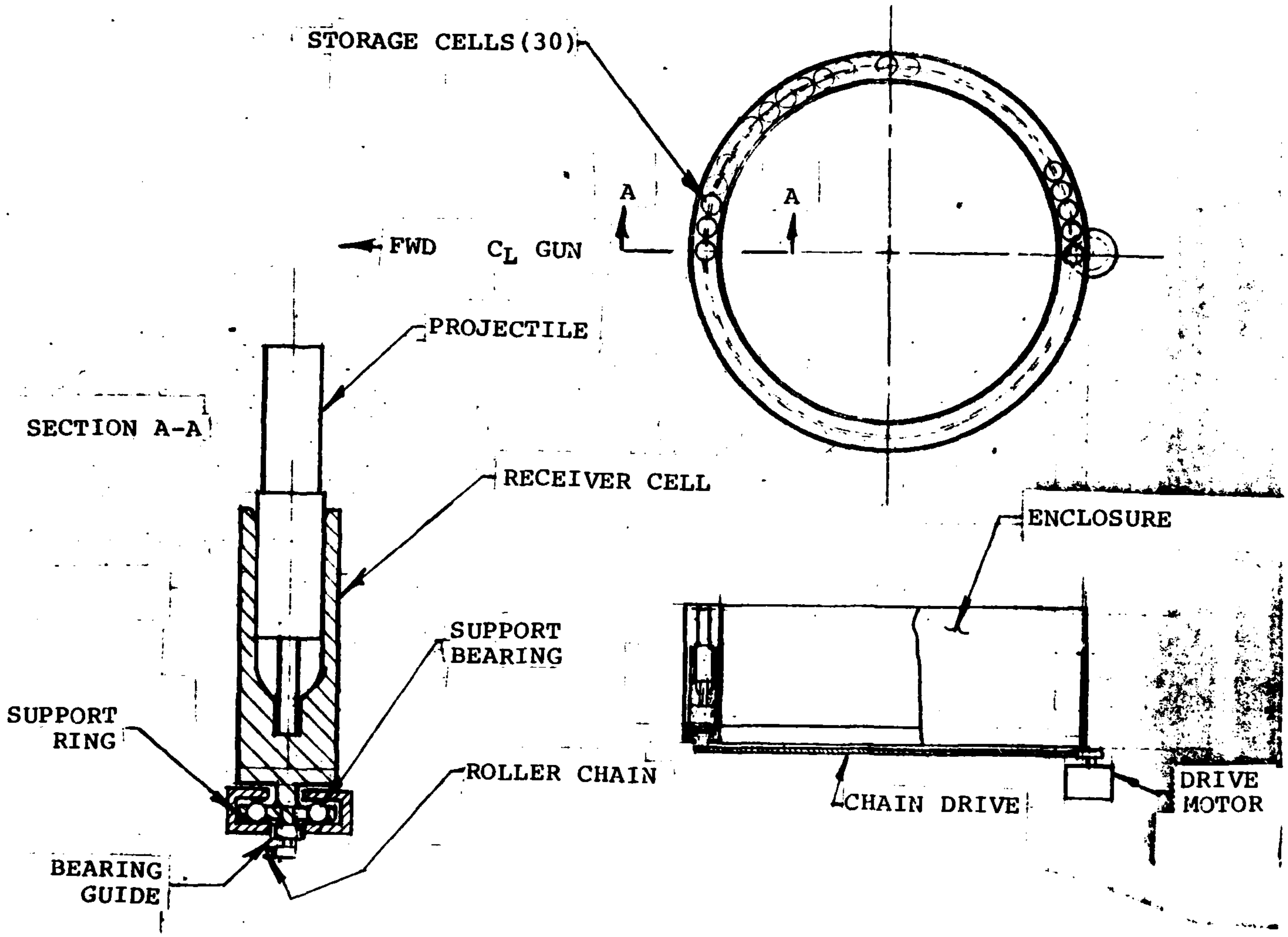


Figure 10-40 Radial Storage System - Drive Mechanisms

AD-A091 426 SINGER CO BINGHAMTON NY LINK DIV F/G 19/3
DESIGN DEFINITION STUDY REPORT. FULL CREW INTERACTION SIMULATOR--ETC(U)
JUN 78 N61339-77-C-0185
UNCLASSIFIED LR-895-VOL-5 NAVTRAEQUIPC-77-C-0185-000 NL

2 2

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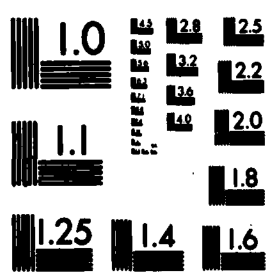

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 10-10 TRADEOFF ANALYSIS/SELECTION CHART - SYSTEM: MAIN GUN, SUBSYSTEM: PROJECTILE STORAGE

	TRADE-OFF PARAMETERS AND SELECTION CRITERIA	WEIGHTING FACTOR	GATLING DRUM		RADIAL ENCLOSURE		FORWARD ENCLOSURE					
PARAMETERS	PERFORMANCE PARAMETERS		EF	FM	EF	FM	EF	FM	EF	FM	EF	FM
	• STORAGE DENSITY	.5	3	1.5	5	2.5	4	2.0				
	• ACCESS	.4	3	1.2	3	1.2	2	.8				
	• OPERATION	.6	3	1.8	4	2.4	2	1.2				
	•											
	•											
	PERFORMANCE SUMMATION			4.5		6.1		4.0				
CRITERIA	OVERALL PERFORMANCE			1.5		2.0		1.3				
	LOW PROCUREMENT COST	.2	2	.8	2	.4	2	.8				
	LOW OPERATING COST	.5	2	1.0	2	1.0	2	1.0				
	SIMPLICITY	.2	5	1.0	5	1.0	2	.8				
	RELIABILITY	.9	5	4.5	5	4.5	2	1.8				
	MAINTAINABILITY	.9	5	4.5	5	4.5	3	2.7				
	SYSTEM COMPATIBILITY	.9	3	2.7	5	4.5	3	2.7				
	SYSTEM FLEXIBILITY	.8	3	2.4	4	3.2	3	2.4				
	PRODUCIBILITY/AVAILABILITY	.6	3	1.8	3	1.8	3	1.8				
	SAFETY ASPECTS	.9	1	.9	5	4.5	3	2.7				
	OVERALL SUMMATION			19.6		25.4		16.7				
	APPROACH REJECTION/SELECTION					X						

TABLE 10-11 TRADEOFF ANALYSIS/SELECTION CHART - SYSTEM: MAIN GUN, SUBSYSTEM: AMMUNITION IDENTIFICATION

	TRADE-OFF PARAMETERS AND SELECTION CRITERIA	WEIGHTING FACTOR	MECHANICAL DETECTOR		PHOTO-SCANNER DETECTOR							
PARAMETERS	PERFORMANCE PARAMETERS		EF	FM	EF	FM	EF	FM	EF	FM	EF	FM
	• ALIGNMENT	.6	3	1.8	5	3.0						
	• INTEGRITY	.4	3	1.2	5	2.0						
	•											
	•											
	•											
	PERFORMANCE SUMMATION			3.0		5.0						
CRITERIA	OVERALL PERFORMANCE			1.5		2.5						
	LOW PROCUREMENT COST	.3	3	.9	3	.9						
	LOW OPERATING COST	.3	4	1.2	4	1.2						
	SIMPLICITY	.5	3	1.5	5	2.5						
	RELIABILITY	.9	2	1.8	5	4.5						
	MAINTAINABILITY	.9	2	1.8	5	4.5						
	SYSTEM COMPATIBILITY	.7	3	2.1	5	3.5						
	SYSTEM FLEXIBILITY	.5	3	1.5	5	2.5						
	PRODUCIBILITY/AVAILABILITY	.8	5	4.0	5	4.0						
	SAFETY ASPECTS	.3	4	1.2	5	1.2						
	OVERALL SUMMATION		16.0		24.8							
	APPROACH REJECTION/SELECTION				X							

10.3.2.3 Machineguns

10.3.2.3.1 7.62mm Machinegun. This gun will be mounted to the simulated main gun as in the actual tank. The ammunition box, supply chute, and a belt loaded with dummy ammunition will provide realistic loading and unloading of the weapon.

The gun will be modified by adding micro-switches to detect the operation of safety, manual firing trigger, etc. This will permit the weapon to be operated in the manual or electrical firing mode since operation of the triggers can be detected and proper aural cues generated. The position of the switches can be also monitored at the instructor's station to determine the condition of the weapon.

Modifications will not affect utilization of the gun for other tasks and the additional wiring required will be accommodated by a larger connector.

10.3.2.3.2 .50 Caliber Machine Gun. Requirements for sensing the condition of the gun will be met in a manner similar to that of the 7.62MM machinegun.

10.3.2.4 Grenade Launcher. Two pushbutton switches used to select right or left grenade patterns, ON-OFF power switch, and indicator light will be furnished. Operation will consist of turn on, selection and firing and suitable audio/visual effects.

10.3.2.5 Ballistic Computer. Simulation requirements for accurate ballistic computer equations were described (10.3.1.5.) and basic implementation approaches were presented. Since there is no significant variation in performance capability between approaches, system compatibility and cost are the factors to be analyzed in the determination of the optimum approach for a particular simulator configuration.

Figure 10-41 illustrates primary Ballistic Computer System components and associated subsystems that interface with the computer unit. Implementation of each of these systems' elements is briefly discussed in the following paragraphs to determine the most compatible ballistic computational approach.

In a system configuration, operational or designed hardware must be employed for the gunner control and ammunition selection units. However, as indicated in 10.3.1.5, outputs from these units must be interface via the mainframe computer to facilitate mission record/playback. Switch position signals from commander and gunner hand controls must be similarly interfaced. Crosswind (as an environmental factor) is to be instructor-controlled via the mainframe computer. This variable must also be recorded. Cant must be derived from software implementation of equations of motion.

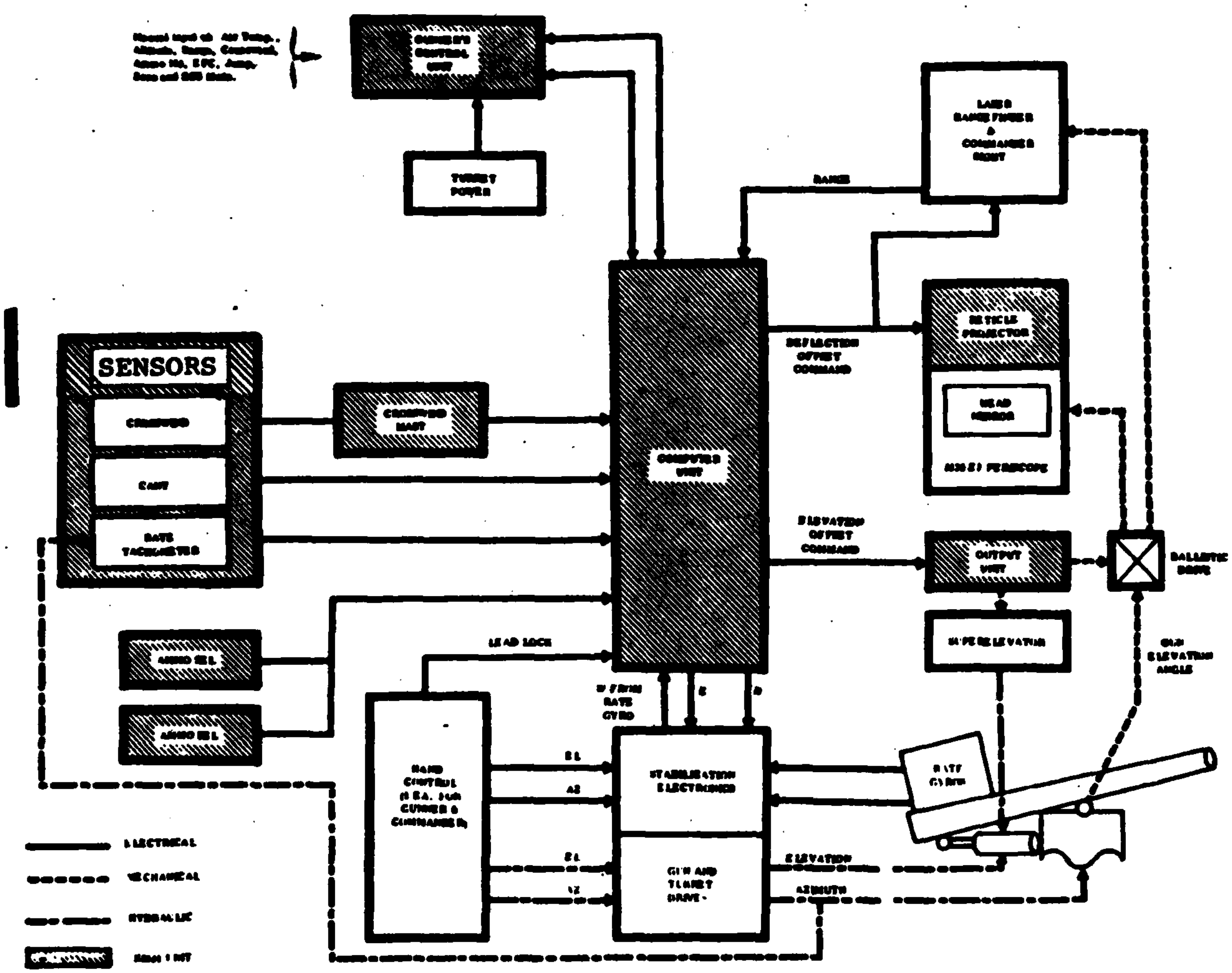

Figure 10-41   Ballistic Computer System - Block Diagram

As a result of the fixed turret configuration (Section 9) and motion, visual, and record/playback/replay requirements, turret and gun traverse management is most readily implemented by software. The turret rate (Rate Tachometer) will therefore be software generated. Gun elevation must be controlled via the mainframe computer due to record/playback requirements. Software management is advantageous, since gun elevation is required in the software determination of line of sight for ranging (in conjunction with the visual system), and for developing accurate ballistic trajectories. The use of actual gun rate gyros is obviously not feasible. Gun traverse and elevation rates must therefore be determined by the gun management programs. Stabilization is also most readily implemented in software. This approach also minimizes problems associated with simulating stabilization closed-loop operation.

As described in Section 8, simulated laser ranging is determined by generating a Laser Rangefinder line-of-sight (LOS) vector which is to be used by the DIG (visual system) to calculate the distance to the nearest object intersected by the LOS. The LOS vector must be generated from gun management parameters and as as result should be software implemented. This approach also permits insertion of statistically developed, multiple range returns. It should be noted that, as a stand-alone system, the DIG visual system is most adaptable to interfacing with other simulator systems via the mainframe computer. Laser Rangefinder and M35 periscope reticles will be generated by the DIG. Ballistic deflection offset signals should therefore be interfaced via the computer.

Superelevation and ballistic drive simulation will be contained in the gun management and reticle control programs, respectively. The ballistic elevation offset command must therefore be interfaced via the mainframe computer. An operational or simulated output unit is required to house the mil counter necessary to perform test and tactical operations. The ballistic drive telescoping shaft, driven by the output unit, may be connected to enhance simulator realism.

An overview of the system configuration developed so far reveals two relevant compatibility factors: most system elements must interface via the main frame computer and numerous elements require software simulation. These factors indicate, as described in 10.3.1.5, that software implementation of ballistic equations is the most desirable approach to achieve system compatibility. An additional advantage obtained through this approach is associated with the simulator requirement for ballistic trajectory software. Ballistic trajectory computations may be considered the reverse of ballistic computer computations. In the simulated system, correlation of these computations must be carefully managed to achieve associated training objectives. Software implementation of the ballistic computer equations is the optimum method for correlation management and also allows for the feasibility of program interaction and for partial format duplication in a manner that reduces simulator design and/or cost requirements.

System compatibility of a software implementation is represented by a high evaluation factor (EF) in the Ballistic Computer Tradeoff Analysis Selection Chart, (Table 10-12). The importance of system compatibility is reflected by the respective weighting factor. This factor is higher than that of cost criteria since it must reflect the total cost of additional interface requirements associated with the less compatible approaches. For example: an unmodified XM21 has a low procurement cost. However, the procurement cost criteria does not reflect the fact that a high-cost interface system would have to be developed. Consequently, the unmodified XM21 approach has the lowest system compatibility EF. The modified XM21 and dedicated processor approaches each have a higher compatibility EF than the previous approach, since these approaches would be designed for interface compatibility with the mainframe linkage system.

A weighting factor of 0.8 has been assigned to each of the basic cost criteria. Included are: procurement cost, life cycle cost, reliability, maintainability, and producibility/availability. Note that procurement cost relates to prototype hardware and initial design costs. It may also be noted that the low EF for maintainability of a modified XM21 is related to the complicated documentation package that would evolve in implementing this approach. Again it should be realized that the EF's indicating maintainability/reliability of the various approaches, relate only to the respective computational implementation and do not reflect criteria established for associated interface hardware. Although the table contains equal basic cost totals for the unmodified XM21 and software simulation approaches, the overall cost of implementing an unmodified XM21 would be significantly higher as reflected by system compatibility ratings.

Simplicity and system flexibility are considered auxiliary cost criteria and have been assigned low weighting factors. Since there are no significant differences in the complexity of the appraoches, simplicity is given a low rating. System flexibility is rated low since few change requirements are anticipated.

It should be noted that, since software implementation is inherently flexible, it may be readily changed to reflect modifications made to the XM21.

Safety is assigned a low weighting factor in relation to a tradeoff, since the danger potential is minimal in all approaches.

In summary, Table 10-12 illustrates not only that software simulation is the most desirable overall approach, but also that the merits of software simulation equal or surpass those of the alternate approaches in each of the criteria categories (system compatibility, basic cost, auxiliary cost, and safety).

TABLE 10-12 TRADEOFF ANALYSIS/SELECTION CHART - SYSTEM: PRIMARY DIRECT FIRE CONTROL, SUBSYSTEM: BALLISTIC COMPUTER

	TRADE-OFF PARAMETERS AND SELECTION CRITERIA	WEIGHTING FACTOR	UNMODI-FIED WITH BALLISTIC COMPUTER		MODIFIED WITH BALLISTIC COMPUTER		LINK* DEDICATED PROCESSOR		SOFTWARE SIMULA-TION			
			EP	FM	EP	FM	EP	FM	EP	FM	EP	FM
PARAMETERS	PERFORMANCE PARAMETERS											
	• ALTERNATE APPROACHES											
	• CAPABLE OF PERFORMING											
	• IDENTICAL TO UNMODIFIED											
	• XM21											
	•											
	PERFORMANCE SUMMATION			---		---		---				
CRITERIA	OVERALL PERFORMANCE			---		---		---				
	LOW PROCUREMENT COST	.8	5	4.0	3	2.4	2	1.6	4	3.2		
	LOW OPERATING COST	.8	5	4.0	4	3.2	4	3.2	5	4.0		
	SIMPLICITY	.5	4	2.0	2	1.0	3	1.5	4	2.0		
	RELIABILITY	.8	4	3.2	4	3.2	4	3.2	5	4.0		
	MAINTAINABILITY	.8	4	3.2	3	2.4	4	3.2	5	4.0		
	SYSTEM COMPATIBILITY	1.0	3	3.0	4	4.0	4	4.0	5	5.0		
	SYSTEM FLEXIBILITY	.5	4	2.0	3	1.5	3	1.5	5	2.5		
	PRODUCIBILITY/AVAILABILITY	.8	5	4.0	4	3.2	4	3.2	4	3.2		
	SAFETY ASPECTS	.5	4	2.0	4	2.0	4	2.0	5	2.5		
	OVERALL SUMMATION			27.4		22.9		23.4		30.4		
	APPROACH REJECTION/SELECTION		X		X		X		✓			

* NOTE: EP'S REPRESENT SUBAPPROACH WITH HIGHEST OVERALL SUMMATION (DIGITAL, WITHOUT MICRO-PROCESSOR IMPLEMENTATION).