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LEVEL II

DETAILED DESIGN AND FABRICATION OF A HELICOPTER GROUND MOBILITY SYSTEM (HGMS)

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APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

This report was prepared by Vehicle Systems Development Corporation and describes the detailed design and fabrication of two sets of a Helicopter Ground Mobility System (HGMS) conceived under a previous contract with the Applied Technology Laboratory. Hardware descriptions are essentially limited to the changes required to accomplish fabrication of the preliminary design described in USAAMRDL Technical Report 77-35 dated September 1977. The acceptance tests at the contractor's facility are described, along with predictions of the reliability, maintainability, logistics, and production unit costs of a production HGMS.

The acceptance tests at the contractor's facility were performed using a fabricated simulation of the applicable wheeled helicopter models and a hulk of an early model UH-1. Subsequent tests at Fort Eustis on actual helicopters revealed the necessity for numerous minor changes to the HGMS skid helicopter adapters to permit HGMS usage. Continued testing and modification will be necessary to optimize the HGMS.

This report has been reviewed by the appropriate technical personnel of the Applied Technology Laboratory (AVRADCOM) who concur with the content. The US Army Project Engineer for this effort was Mr. R. L. Campbell, Sr., of the Aeronautical Systems Division.

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This report presents the results of a program for the design, fabrication, test, and demonstration of two identical engineering models of the Helicopter Ground Mobility System (HGMS). The design was based on a concept developed under an earlier HGMS concept formulation and selection program also performed by VSDC under contract to ATL.

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The program effort was divided into five complementary tasks: Task I - Detailed Design and Analyses; Task II - HGMS Fabrication and Assembly; Task III - HGMS Acceptance Tests; Task IV - Reliability, Maintainability, Logistics and Cost Predictions; and Task V - Technical Manual. Expanding on the preliminary concepts developed in the earlier study program, Task I resulted in a complete, detailed and documented design for the HGMS prime mover, skid-equipped helicopter adapter, and flotation track assemblies. In Task II, the design was converted into hardware which, along with a device simulating the wheel-equipped UH-60A (Black Hawk) and YAH-64 (AAH) helicopters, was tested in Task III to demonstrate compliance with the requirement and specification for the HGMS. Minor changes, the need for which emerged from the test activity, were incorporated in the engineering models and design data during Task III, which culminated with the approval and acceptance of the HGMS by the technical representative of the ATL Contracting Officer. In Task IV, the contractor prepared assessments of HGMS reliability and maintainability as well as estimates of requirements for logistics support. VSDC also prepared production cost estimates for quantities of HGMS units, and proposed a support program for the follow-on Army field trials during which the HGMS concept and prototypes will be evaluated under operational conditions. Task V provided for the development of a draft technical (Operating and Maintenance) manual which was also validated during the Task III testing.

The total program described in this final report produced systems which clearly indicate that Army helicopters, both wheeled and skid-equipped, can be successfully transported between a forward area landing zone and a concealed laager area with no surface preparation and with a minimum of equipment and personnel. Moreover, the program demonstrated that a lightweight and helicopter-transportable HGMS answers the Army's long-standing need for helicopter ground mobility.

PREFACE

This program was conducted for the Applied Technology Laboratory (ATL), U.S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia, under Contract DAAJ02-77-C-0077.

Technical direction for ATL was supplied by Mr. Robert L. Campbell, Sr. The program effort was an outgrowth and continuation of the concept and feasibility investigations performed earlier for ATL under Contract DAAJ02-76-C-0037.

The Vehicle Systems Development Corporation (VSDC) personnel principally involved in the prototype development program were: Robert W. Forsyth, president and chief engineer; John P. Forsyth, vice president and manufacturing specialist; Nathan N. Shiovitz, senior design engineer; and Laurence E. Reinhart, PhD, engineering systems specialist.

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INTRODUCTION

BACKGROUND

In the tactical employment of utility and attack helicopters in the likely European operational areas, the U.S. 7th Army, in the early 1970's, concluded that it was essential to have an effective means for moving helicopters on the ground in forward areas from landing zones into concealed positions for rearming and servicing. This led to the approval of a Required Operational Capability (ROC) document defining the requirement for a ground mobility system for the skid-equipped helicopters then in service. Although concepts and equipment were developed and tested with varying degrees of success, no really suitable or effective mobility device emerged.

Additionally, although the new UH-60A Black Hawk utility helicopter and YAH-64 attack helicopter are fitted with wheeled landing gear, their relatively high-pressure, small-footprint tires are not satisfactory for local ground movement in the rough terrain and soft-soil conditions found in unprepared laager areas.

Consequently, in mid-1975 the Applied Technology Laboratory (ATL), U.S. Army Research and Technology Laboratories (AVRADCOM), then the Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, initiated a program to develop a Helicopter Ground Mobility System (HGMS) for the wheeled YAH-64 and UH-60A helicopters. As the program evolved, it was determined that an opportunity also existed to adapt the system to provide local ground mobility for the Army's inventory of skid-equipped helicopters. The first phase of the overall development program, HGMS concept formulation and selection, was conducted under Contract DAAJ02-76-C-0037 and is documented in Reference 1. This effort, which examined some 30 potential HGMS concept approaches through a series of comparative evaluations, identified one concept with sufficient potential for continued study and development. The selected concept was further refined and documented with preliminary design layouts and a Critical Item Development Specification.

This report describes the effort and summarizes the results of the second phase of the HGMS program - the design, manufacture, and demonstration of HGMS engineering models tc

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1. R.W. Forsyth and J.P. Forsyth, HELICOPTER GROUND MOBILITY SYSTEM (HGMS) CONCEPT FORMULATION AND SELECTION, USAAMRDL-TR-77-35, Eustis Directorate, US Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, September 1977, AD A047507.

evaluate the selected concept with actual aircraft under field conditions.

PROGRAM REQUIREMENTS

In the course of this program effort the contractor, Vehicle Systems Development Corporation (VSDC), accomplished the detailed design, fabrication, and assembly of two identical Helicopter Ground Mobility Systems, and demonstrated system compliance with the controlling specifications by conducting a series of acceptance tests. The contractor prepared a test program plan for approval by the Contracting Officer, and incorporated into the system engineering models those changes or modifications dictated by system performance during the acceptance program. These changes were, in turn, verified by retesting as required.

The final configuration system design was documented with drawings, parts lists, analyses and the supporting data necessary to accurately define and describe the systems as delivered. A technical manual describing the systems and containing detailed operating, service and maintenance instructions was also prepared. As with the equipment it describes, the manual was verified during the acceptance tests and revised where required to accurately reflect the final system configuration and operational characteristics.

Finally, the contractor conducted studies and investigations to estimate the reliability, maintainability, and logistical support requirements for the HGMS engineering models for the Army field trials program. The results of these investigations are included in this final technical report along with predictions of HGMS unit production costs for subsequent procurements. These costs are based on a total procurement of 218 skid adapter units and single lots of 216 and 434 prime mover units. The period of production, in all cases, is three years. The contractor also developed a support plan for the Army field trials and tests, including the supply of spare parts and technical services (up to 12-man-months) over a two-year period following delivery of the engineering models.

PROGRAM ORGANIZATION

The program was divided into five task areas corresponding to the contract's Statement of Work. Task I, Detailed Design and Analyses, included the design effort and production release on all fabricated and purchased major components. Purchasing effort was initiated and a draft of the technical manual and draft of the proposed test plan were prepared. In Task II, Fabrication and Assembly Operations, purchased components were received, inspected, and installed. Fabrication and assembly of the prime movers led the effort in this task, and was followed by assembly of the two adapter units.

Task III, Acceptance Testing, consisted of the specification compliance testing effort and included implementation of test-identified requirements for hardware modifications. Following acceptance by the Contracting Officer's Technical Representative, the two complete systems were repainted, serviced, and prepared for delivery to ATL. In Task IV, Reliability, Maintainability, Logistics and Cost Predictions, the required analyses were prepared drawing on the experience gained during performance of the earlier tasks. Task V, Technical Manual - Operating and Servicing Instructions, consisted of finalizing the preliminary draft of the technical manual, and this report.

The total program defined by these five tasks was originally scheduled for completion within a 12-month period. Wherever possible, hardware purchasing actions were initiated at the earliest point consistent with the design, fabrication, and assembly processes.

The detail design effort was directed toward providing comprehensive documentation of the as-built system engineering models. In the early design stages, the preliminary design was validated and long-lead items identified and released for procurement. These items included the engine, hydraulic pump, and hydraulic drive motors, as well as the final-drive castings and the basic prime mover welded structural assemblies. Selection of system components not already identified in the specification was similarly expedited in an effort to guarantee timely receipt of the required parts and materials.

Despite these efforts, certain delays affecting the planned schedule were experienced. Although essentially an "off-the-shelf" item, the hydraulic motors required almost five months for delivery. The drive selector valve originally ordered was still not available six months after placement of the order. Consequently, a more readily available substitute valve was selected. Difficulties and delays were also experienced with the aluminum castings and the flotation track assemblies. Although the delay in delivery of the tracks did not interfere with the fabrication and assembly schedule, it delayed the acceptance test (Task III) effort which, in turn, impacted the balance of the program schedule. The delay in track delivery stemmed from two sources. First, the design of the UH-60A helicopter landing gear underwent changes which necessitated a major redesign of the track. Second, delays were encountered in receipt of the tracks from VSDC's subcontractor because of the schedule delays experienced in the drawing release of the final design.

All elements of the systems, when subjected to acceptance testing, performed generally as predicted and required only minor post-test modification and adjustment prior to acceptance by the Contracting Officer's Technical Representative. The two complete engineering models of the Helicopter Ground Mobility Systems were shipped to ATL on 24 April 1979.

ENGINEERING MODEL DESIGN

PRELIMINARY DESIGN CONCEPT

The preliminary design concept basic to the HGMS program was developed in the initial phase of the overall ATL HGMS development program and is illustrated in Reference 1. The design was documented in the Critical Item Development Specification (CIDS) for Helicopter Ground Mobility System (HGMS) which was referenced in the contract governing this detailed design and fabrication program.

The CIDS established performance requirements as well as the desired general configuration and dimensional limits, and denoted certain specific components to be used in the detailed design. The conceptual system consists of three major components: the HGMS prime mover, shown in Figure 1; the HGMS skid-equipped helicopter adapter, shown in Figure 2; and the HGMS flotation track assemblies, shown in Figure 3.

FINAL DESIGN

The final design of the system engineering models, while based on the specification and drawings noted above, differs somewhat in detail as a result of the comprehensive functional and structural analyses performed as an integral part of the detailed design process. These changes and their rationale are discussed in the following paragraphs.

HGMS Prime Mover. The finalized prime mover design differs from the preliminary design (Reference 1) in three areas: the steering and control assembly; the engine cover (hood); and the hinge-pin connection between front and rear elements.

The controls for the winch and jacks were relocated from the steering handle assembly to a position at the side of the load platform. This change, while retaining the functional grouping of controls which are used together, placed the operator in a position where he could better view and control the loading of the aircraft tailwheel and the operation of the jack cylinders and trailing arm locking pins. From the same position one operator could, while operating the winch, also secure the towing bridle in the towing pintle jaw. In addition to improving functional operation of these controls, their repositioning mechanically simplified their design and integration.

A review of the assembly and operation of the steering handle suggested that the conceptual method of telescoping the handles for storage and adjustment was both mechanically complicated and excessively heavy. Furthermore, telescoping the handles to accommodate a shorter operator also reduced the effective steering lever arm and, consequently, made steering more difficult for the smaller operator. In the redesign,

Figure 1. HGMS Prime Mover

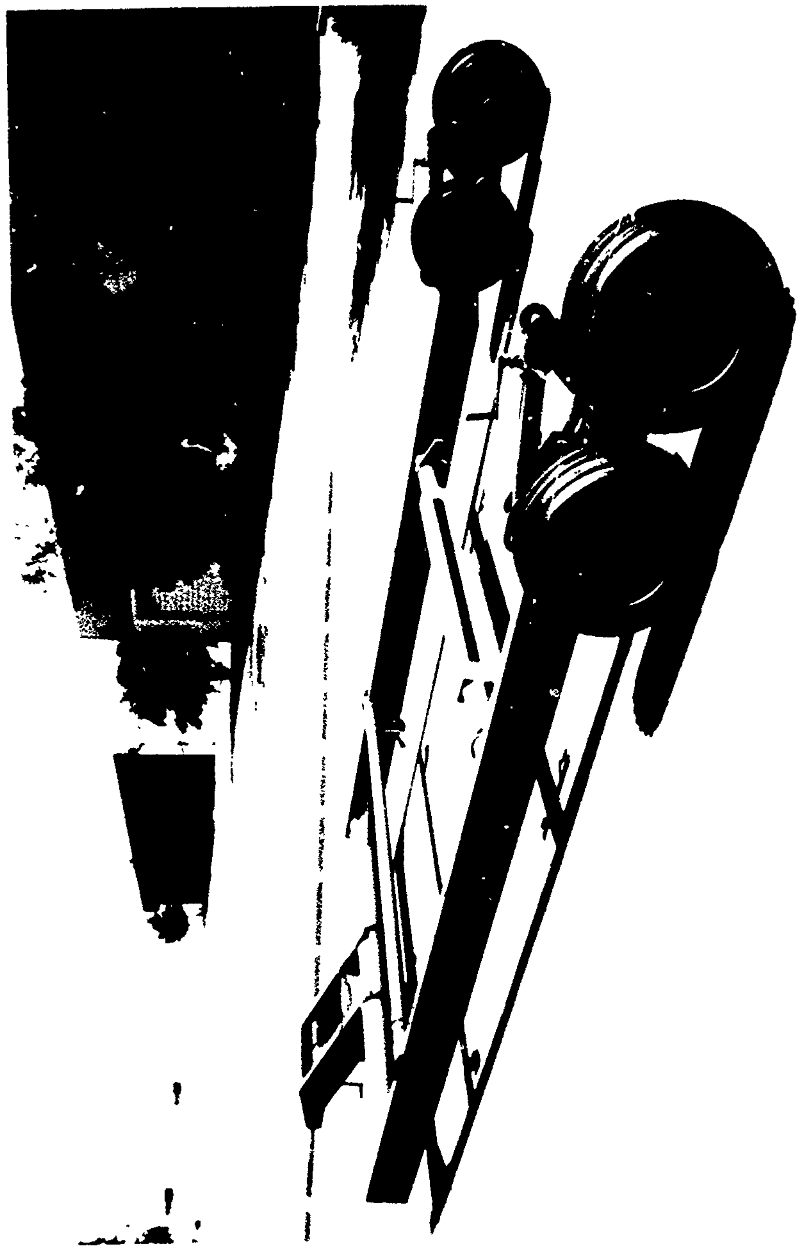

Figure 2. HGMS Skid-Equipped Helicopter Adapter

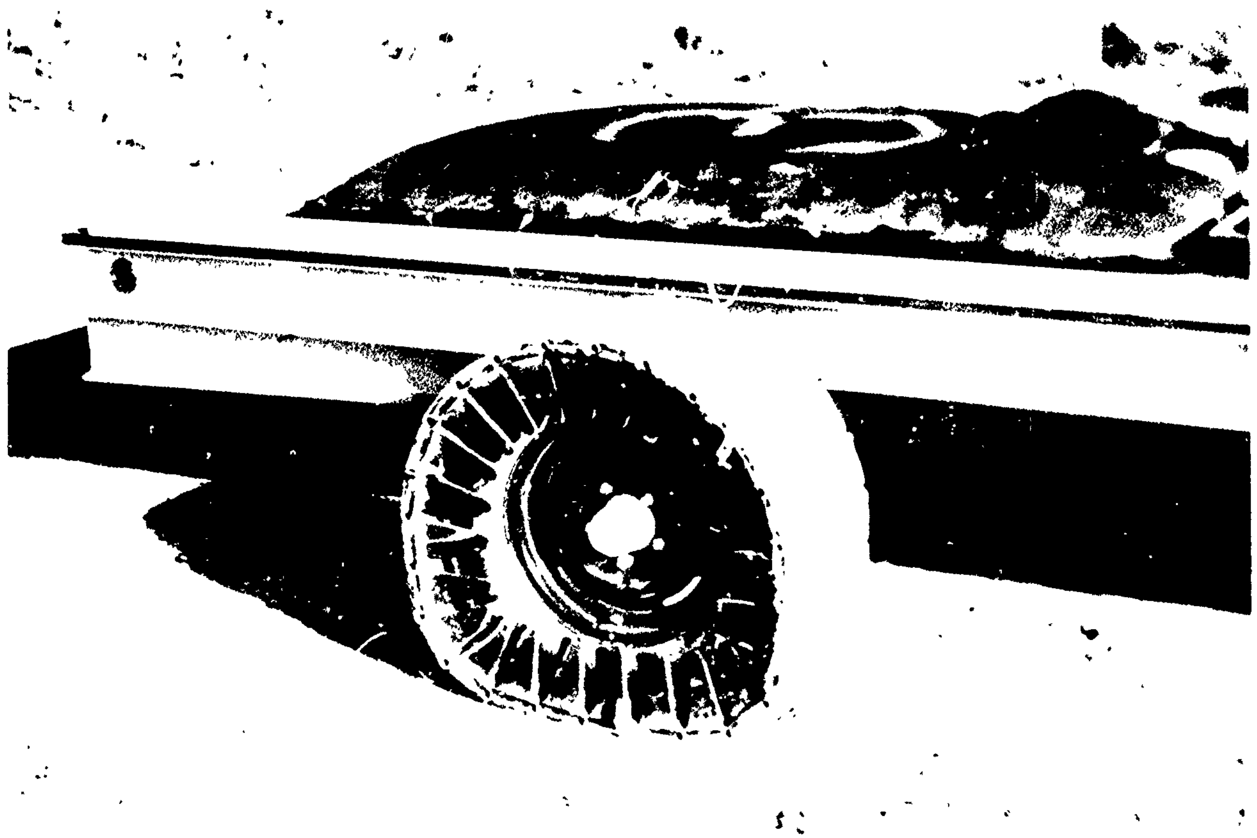

Figure 3. HGMS Flotation Track

the handle assembly was pinned to the forward end of the prime mover, which simplifies the adjustment procedure and, in fact, slightly increases the lever arm for the shorter operators. The lower, outer tubes were also shortened by approximately 8 inches and the intermediate steering handle crossmembers on which the winch and jack controls had been mounted were eliminated entirely to reduce weight and complexity. These design changes also reduced the overall length of the prime mover with the handles stowed.

The two-piece, top-opening hood assembly employed in the preliminary design was changed to a one-piece, tilt-type configuration hinged at the lower front (Figure 4). This change simplifies hood construction and provides greater access to the engine compartment. In the original design, the hood was a very lightweight sheet-metal assembly. The final design added an internal structural frame to the hood, thereby permitting its use as an aircraft work platform if that should prove desirable. An engine hour-meter was also added to the instrument panel.

Finally, the rigorous structural analysis to which the design was subjected resulted in questions on the ultimate reliability of the connection between front and rear elements under certain conditions of extremely severe loading. In the final design, therefore, this area was redesigned to provide a simple, very reliable and superior connection between elements with the necessary articulation freedom in yaw (steering) and roll.

Although not identified in the specification, it was originally intended that the prime mover incorporate selective two- or four-wheel drive. This approach was not employed in the final design, which utilizes a less sophisticated, full-time four-wheel drive arrangement because of the marginal utility of the two-wheel drive configuration which became evident during early developmental testing with the first prime mover. During this period VSDC also experimented with a hydraulic cylinder to stroke the hydraulic pump which is the means of varying the prime mover speed and direction. This cylinder proved to be unnecessary since the pump could be stroked manually and it was consequently eliminated. The maximum measured weight of the prime movers was 1460 pounds.

<u>HGMS Skid-Equipped Helicopter Adapter</u>. The prototype skid-equipped helicopter adapter depicted in Figure 5 differs from the preliminary design of Reference 1 in several minor details. The principal changes resulted from an analysis of the strength and deflections of the basic structure and center on an increase in the size of the frame side-rail sections and the pickup beam. The forward skid support was also redesigned into a tubular form to provide greater strength and simplify the helicopter skid tie-down procedure.

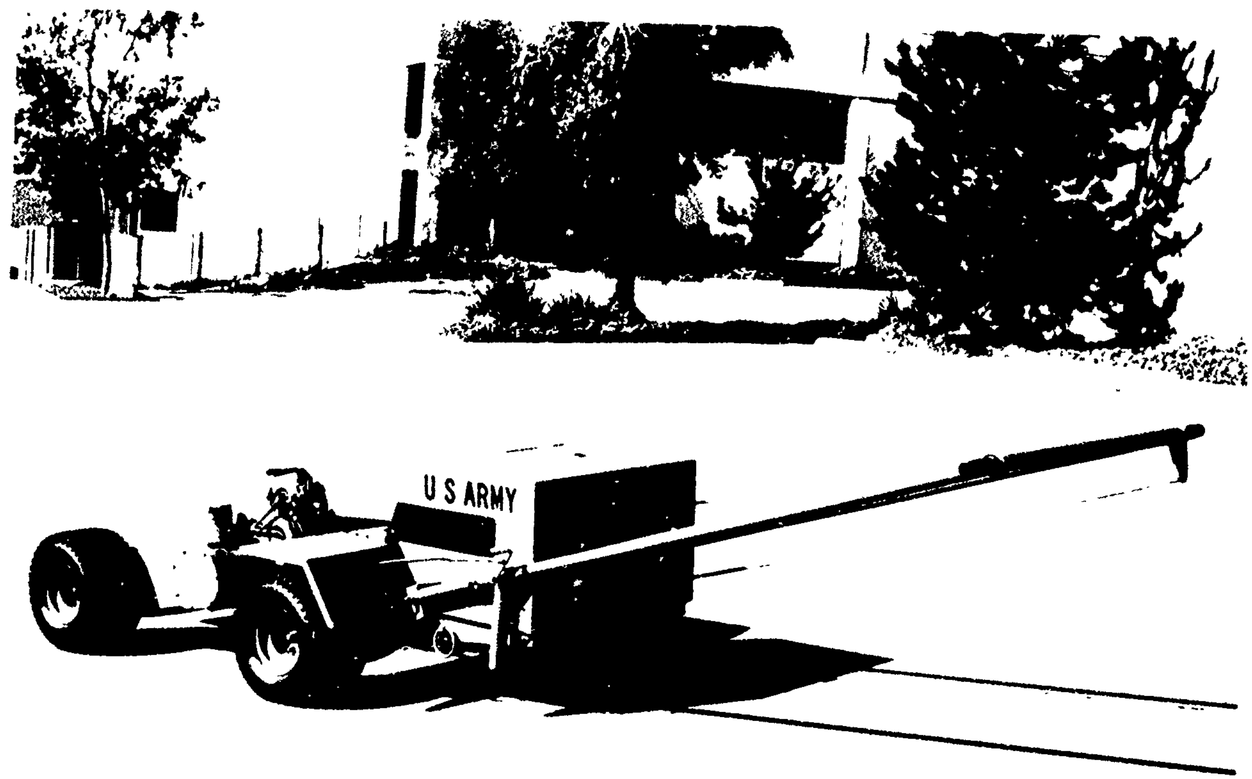

Figure 4. HGMS Prime Mover Tilt-Type Hood

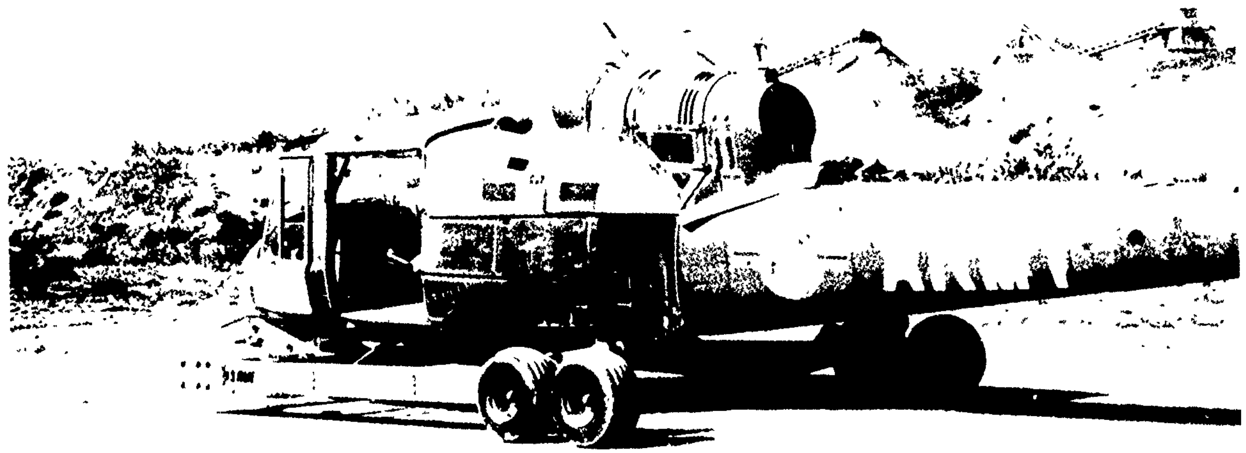

Figure 5. Skid-Equipped Helicopter Adapter With UH-1B Test Hulk

Design changes in the gooseneck also improved its strength and stiffness, and simplified the side-rail/gooseneck interface connection. These design improvements did not alter the functional characteristics of the skid adapter or the operational procedure for its use. The structural changes did, however, result in a weight increase of approximately 80 pounds over the originally estimated weight. The maximum measured weight of the skid adapters was 1175 pounds. Figure 6 shows the skid-equipped helicopter adapter with the AH-1 loaded aboard for movement.

<u>HGMS Flotation Track Assemblies</u>. The limited technical data available to VSDC on the geometry of the Black Hawk (UH-60A) helicopter landing gear resulted in a track preliminary design which was strictly conceptual, and required substantial redesign when firm data finally became available. For example, the minimal clearances between the aircraft tire and the drag strut and shock strut fairing in the helicopter final design forced changes in the width of the track shoes and the shape of the track guides. In the final design (Figure 7) the width was reduced to 12.5 inches (from 15.0) and the outboard track guide was made flexible to normally cant inward. This latter feature was incorporated to force the track shoes outboard on the wheel, providing for maximum clearance between the inner track guide and the fixed aircraft structure. Another design improvement not related to aircraft landing gear changes was incorporation of three quick-release track pins in each track assembly. These pins eliminate the need for tools to open or close the track loop and assure that one pin is always conveniently located for removal regardless of the position of track on the wheel. The average measured weight of the flotation track was 50 pounds per assembly (100 pounds per set of two).

Figure 6. Skid-Equipped Helicopter Adapter with AH-1

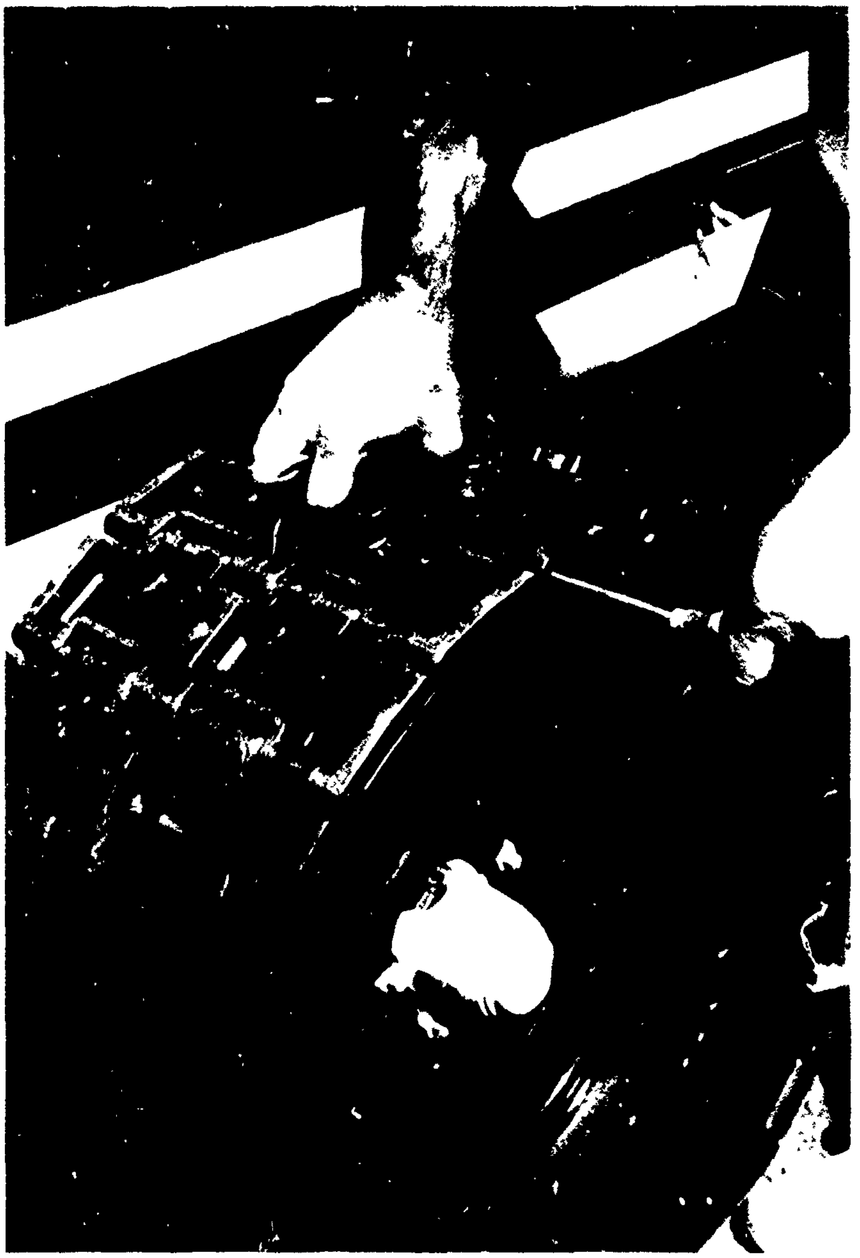

Figure 7. Three-Pin Flotation Track

ENGINEERING MODEL DEVELOPMENT

FABRICATION AND ASSEMBLY

Completion of the detailed part and assembly drawings and the receipt of purchased parts permitted initiation of the fabrication and assembly phase (Task II) of the program early in 1978. Representing the more complex effort, early activity centered on the build-up of both HGMS prime movers. Structural assemblies for both the front and rear prime mover elements were fabricated along with the engine mounts and covers, the fenders, and the steering and control handles. The modular design concept permitted bench assembly of subsystems such as the complete power module and final drives, followed by a final assembly of the complete unit with a minimum requirement for adjusting or shimming. Fabrication and assembly proceeded generally as planned and scheduled, once the final-drive castings were received, and was monitored directly by VSDC engineering personnel to assure that the drawings were adequate, complete, and correct. Several minor changes in detail parts to improve assembly access or handling were made and immediately incorporated into the affected drawings. No significant assembly or fabrication problems were encountered, however, and the design drawings were demonstrated to be adequate.

In one area, fabrication and assembly led the design. The hydraulic interconnection circuitry was developed and installed on the first prime mover. Decisions as to tube versus hose lines were made, and appropriate hose sizes, lengths, and end fitting configurations were determined and the required parts ordered. Tubes in appropriate sizes were fabricated to complete the circuits, following the best available routing. The use of Aeroquip Versa Flare fittings minimized the hose-end fitting and adapter types required and simplified the introduction of improvements in the routings. With the tube/hose arrangement optimized on the first unit, it was duplicated for the second, and the required detail drawings were completed.

Initial start-up and operation of the hydrostatic system revealed a discrepancy between the Sundstrand pumping unit as delivered and the pump drawing supplied by the manufacturer. After a few minutes operation both motor shaft seals and one pump shaft seal evidenced massive failures. Examination of the pump revealed that, although the drawings and descriptive materials indicated the pump drain ports were internally connected, this was not the case. Following usual practice the motor drains had been piped to one pump drain and the second pump drain connected to the reservoir. Because the pump drains were not interconnected, unrelieved charge pump pressure was introduced into the pump and motor cases, resulting in seal failure. The seals were replaced and an external pump case drain installed, effectively eliminating the problem as indicated by continued trouble-free operation of both engineering models.

Fabrication of the skid-equipped helicopter adapters followed prime mover completion. No significant problems in fabrication, assembly or test operation were encountered and the design drawings again proved adequate and complete.

Following the completion of HGMS engineering models, effort was directed toward fabrication of a device to simulate the wheeled helicopters during the Task III acceptance testing. This trailer-like device (Figure 8) was built without formal design documentation, following regular commercial practice and using readily available running gear components.

TEST AND DEMONSTRATION

During the fabrication and test phase of the program, tests of components and subsystems were conducted as required. These tests were intended to demonstrate compliance with requirements and compatibility with co-functioning parts. Following assembly, the prime mover engineering models were operated in stages, accumulating approximately 20 hours of operation each, to "run-in" operating components and verify system performance. No significant problem or need for major modification was evidenced as a result of initial operation. Similarly, the skid-adapter assemblies were exercised to assure that they functioned as required and that the walking beam assemblies were interchangeable and reversible as designed.

After approval of the acceptance test plan, the complete Helicopter Ground Mobility System, as embodied in the two system engineering models, was demonstrated in an area exhibiting the required operating conditions (Figure 9). The prime mover was operated in conjunction with the wheeled-helicopter simulator, ballasted and with the flotation tracks installed. Using a UH-1B helicopter hulk, operation of the skid-equipped helicopter adapter was demonstrated using both the HGMS prime mover and a commercial pickup truck as the towing vehicles. The adapter proved difficult to maneuver in reverse with any precision when using the articulated prime mover. It was demonstrated, however, that employment of simple yaw lockouts between the adapter and the prime mover rear element substantially improved reverse directional control and spotting maneuvers.

Specific test items and the results of the tests are presented in the appendix of this report. With minor exceptions, the HGMS engineering models demonstrated compliance or exceeded the requirements of the Critical Item Development Specification. With the modifications described, the HGMS engineering

Figure 8. Wheeled Helicopter Simulator

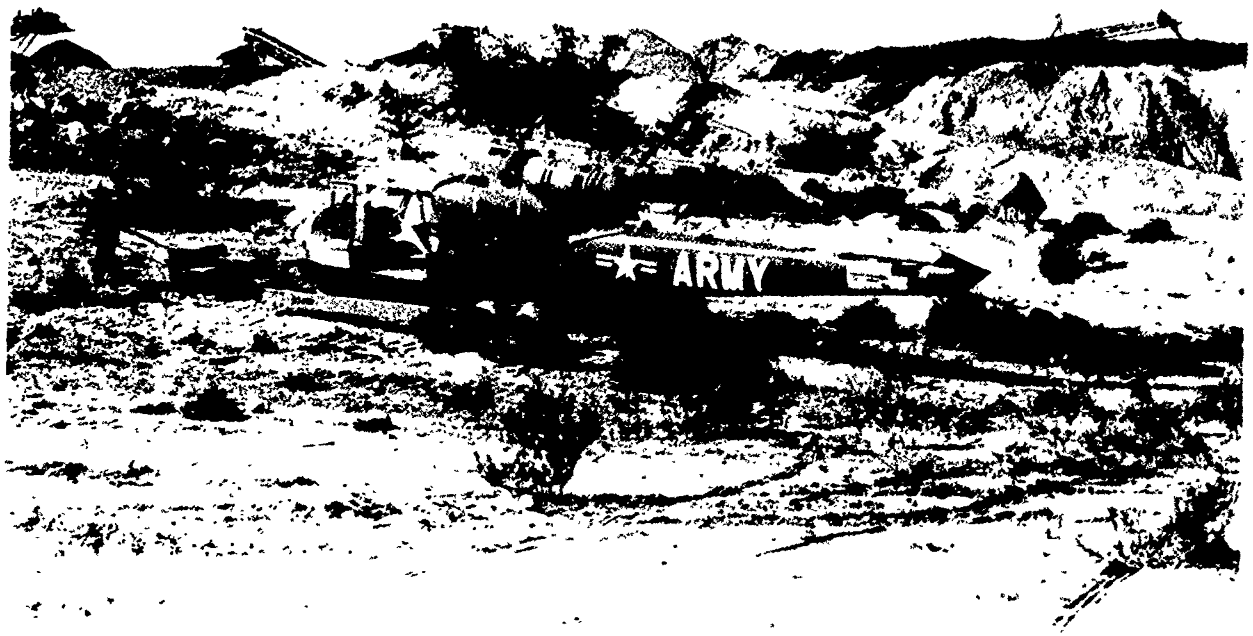

Figure 9. HGMS Field Demonstrations

models were accepted by the Contracting Officer's Technical Representative.

ENGINEERING MODEL REFINEMENT

Although th. HGMS engineering models demonstrated substantial compliance with the requirements of the specification, certain items were identified as requiring modification and/or improvement. In the prime mover, it was necessary to establish and mark the optimum fluid level on the hydraulic reservoir level gauge and add a flight-line flag holder to the hood. The previously mentioned lockout units to facilitate reverse operation control with the skid-adapter were designed, fabricated, and installed, requiring only minor modification to the prime movers and skid-adapter units. On the skid-adapter it was necesary to add fastening provisions for the forward skid support to accommodate the AH-1 and OH-6/58 helicopter positions and to provide lock-on studs in all three locations in place of the pip-pin retainers of the original design. While the pip-pin retainers had proven adequate, the contractor elected to employ lock-on studs for convenience in a field environment. All quick-detach lock pins on the adapter and prime mover were fitted with lanyards and adequately secured to prevent loss. All necessary placards, instruction plates and nameplates were permanently installed. The pickup arms on the skid-adapter pickup beam were modified to provide a transverse locking screw and retainers for the OH-6/58 helicopters (narrow tread), and the pickup beam side-rail ramps were lengthened. The quick-removable, flotation track pin retainers were modified to provide more positive locking and retention.

Finally, all components were cleaned, lubricated, and overhauled as necessary, repainted and marked with their weights, center of gravity locations, and tire pressures, and prepared for shipment. Final inspection and acceptance was accomplished at the contractor's facility on 26 - 28 March 1979.

The major requirement for change arising from the acceptance test program concerned the draft of the Operating and Maintenance Manual. Operational experience with the skid-equipped adapter during the helicopter loading and unloading procedures indicated a need for reordering of the procedural sequences. Proper sequencing was established during the acceptance tests, and the manual was revised to correctly describe the procedure. Additional cautions and safety notes were incorporated in the test along with procedures for the sling-lifting of both units.

UNIT PRODUCTION COST ESTIMATES

BASIS FOR ESTIMATES

As specified in the program contract, VSDC developed unit production costs for the HGMS prime mover and flotation track systems for wheeled helicopters on the basis of a production quantity of 216 units over 3 years and, alternatively, a production quantity of 434 units over 3 years. Likewise, the contractor has developed unit production costs for the HGMS skid-equipped helicopter adapter on the basis of a production quantity of 218 units over 3 years. The production quantities were furnished by the Army based on the projected number of aviation units and numbers of aircraft by model. The starting point for the development of these costs was VSDC's cost experience documented during the design and production of the HGMS engineering models.

VSDC maintained records of engineering labor expended on the development of the detailed design for the HGMS engineering models, shop labor expended on the fabrication and assembly of the prime mover, flotation tracks and the skid-helicopter adapter, engineering labor expended on data production (the technical manual, acceptance test procedure, parts listing, and this report), and engineering and shop labor expended in the performance of the acceptance testing of the HGMS engineering models. However, it was not practically possible, particularly with respect to the prime mover, to maintain a breakdown of shop labor allocated to the major subsystems; for example, the prime mover frame and secondary structure, the power train, running gear, and auxiliary systems such as the winch and tailwheel pan jacks and related hydraulic circuits. The difficulty lay in the fact that there was no reliable way to segregate labor costs because of the inevitable overlap of fabrication, assembly, and installation work in process between the subsystems. Consequently, it was only possible to subcategorize costs by purchased major components and purchased parts which generally represented only a relatively small percentage of the total subsystem cost.

Since the HGMS engineering models were fabricated and assembled in 1978, and approximately 95 percent of the major components, parts, and raw materials were purchased in the same calendar year, the unit production cost predictions that follow are presented in 1978 dollars. Appropriate cost escalation factors can be applied to account for inflation depending on which year would be selected for the start of production of the HGMS.

QUANTITATIVE BACKGROUND

As specified in the contract, nonrecurring design engineering costs (these costs approximated 46 percent of total costs), data preparation and reproduction costs, and acceptance test costs are excluded from these predictions of HGMS unit production costs. Additionally, because of the difficulty of accurately forecasting their impact, no attempt has been made to account for the cost effect of future design changes and modifications. The contractor's cost experience, adjusted as noted, in manufacturing the engineering models of the HGMS is summarized below:

Cost Element	Prime Mover (2 ea) and Tracks (2 sets)	Skid Adapter (2 ea)
Shop Labor	$5,572 (796 hrs.)	$2,086 (298 hrs.)
Purchased Parts	$8,467	$2,255
Raw Materials	1,082	1,674
Misc. Small Parts	610	86
Paint & Primer	210	235
Subcontracts	18,986	20,458
Tooling	10,550	-
Overhead/Indirect	8,382	3,138
Total Costs	$53,859	$29,932

Analyzing the prime mover data first to build up production costs, it is necessary to extract those costs associated with the flotation track assemblies and to derive the costs associated with one prime mover. The track assemblies accounted for $7,200 of the tooling costs and $3,905 of the subcontract costs. Additionally, they absorbed 45 hours of shop labor for the quick-release pins and track assembly. The remaining tooling cost of $3,350 represents the patterns and molds developed for the cast-aluminum, final drive housings for the prime mover. For a production quantity of 216 prime movers over 3 years (or a rate of 1.4 units per week) the existing aluminum-casting tooling would be adequate; however, for a production quantity of 434 units over 3 years (or 2.8 units per week) it would be necessary to double the tooling, increasing its cost to $6,700. The amortization in both cases would be approximately $16 per unit.

The purchased parts figure includes the cost of the engine, hydrostatic transmission, gears, axles, drive chains, gauges, etc., that comprise the power train with a cost for two units of $5,763; the remaining purchased parts cost of $2,704 represents the running gear, wheels, tires, bearings, etc. Since the maximum production quantity is 146 units per year, no significant savings would be obtainable on purchased parts; consequently, the cost per unit will be $4,234, derived from ($5,763 + $2,704) ÷ 2. Likewise, unit raw material costs for the frame and secondary structure would be $541, miscellaneous small parts would approximate $305, and paint and primer would be $105. Subcontract costs for the final-drive castings, per prime mover, would approximate $1,038. Summarizing these unit costs, which are the same for the two production quantities, results in the following figures:

Material and Tooling Cost Elements	Prime Mover Per-Unit Cost
Purchased Parts	$4,234
Raw Materials	541
Misc. Small Parts	305
Paint & Primer	105
Subcontracts	1,038
Tooling Amortization	16
Total	$6,239

The shop man-hours expended for fabrication, installation, and assembly work on each HGMS prime mover was $2,632 for 376 hours, and the unit overhead and indirect costs were $3,954. Both of these cost elements would be sensitive to quantities produced, as would subcontract costs for precision machine work and sheet-metal work, and would reflect the impact of a production learning curve and the greater spread of indirect costs. The latter amounted to $6,503 for each of the prime mover engineering models, so the total of costs experienced on one engineering model (subject to a learning curve) would be $13,089 ($2,632 + $3,954 + $6,503). This would drop to a unit cost of approximately $4,530 for the 200th prime mover for an average cost for each of 200 units of $5,912, assuming an 85 percent learning curve. Adding this to the previous total results in an average unit cost of $12,151 for materials, labor and tooling ($6,239 + $5,912) for a production quantity of 200 HGMS prime movers (the error involved in rounding off the production quantity to 200 units to simplify the learning curve analysis is insignificant).

For 400 prime movers (again the production quantity is rounded off) the labor, indirect and subcontract costs would drop to approximately $3,870 on the 400th unit, or an average cost of $5,050 per unit; added again to the previous cost element total ($6,239 + $5,050), this results in an average unit cost of $11,289 for a production quantity of 400. The addition of sustaining engineering costs, calculated at 5.5 percent of unit cost for 200 units and at 3 percent for 400 units, and production acceptance test costs calculated at

0.8 percent of unit cost, results in the following predicted unit production costs for the two quantities:

Total Cost Elements	Prime Mover 216 Units	434 Units
Production Costs	$12,151	$11,289
Sustaining Eng'g.	668	339
Acceptance Testing	97	90
Total Unit Cost	$12,916	$11,718

The flotation track assemblies can be subjected to a similar analysis. However, production units would require a change to an injection-molding process for the track segments as contrasted with the flow-molding process used for the engineering models. This would require new patterns and matched metal molds with an estimated cost of $27,000 for tooling, with unit amortization costs of $125 per track set for 216 sets and $62 per set for 434 sets. Because of the nature of the injection-molding process and the high proportion of material costs, track segment costs would not vary appreciably for the two production quantities, so a learning curve analysis can be applied only to attachment pin fabrication and track assembly labor. This would drop from the 22 hours per set experienced on the engineering models to 7.6 hours per set for 200 sets and to 6.5 hours per set for 400 sets. The cost-per-set figures for the two production quantities would be as follows:

Total Cost Elements	Flotation Tracks 216 Sets	434 Sets
Track Segments	$960	$960
Direct Labor	53	46
Overhead & Indirect	80	68
Tooling Amortization	125	62
Total Cost Per Set	$1,218	$1,136

The analysis of production costs for a quantity of 218 skid-helicopter adapters over a 3-year period (or 1.4 units per week) follows the same pattern as that for the prime mover and flotation tracks. However, in reviewing the historical figures for the two engineering models, it should be noted that subcontract costs were disproportionately high because it was necessary to have the aluminum frame welded by a subcontractor because of VSDC's high workload. Consequently, for this analysis, $8,600 of cost is removed from the subcontract element and included in the shop labor and overhead and indirect elements. The costs for one unit, recorded for the manufacture of the engineering models, which would be relatively unaffected by quantity production are summarized below:

Material Cost Elements	Skid Adapter Per-Unit Cost
Purchased Parts	$1,128
Raw Materials	837
Misc. Small Parts	43
Paint & Primer	118
Total	$2,126

The purchased parts consisted primarily of the running gear, the wheels, tires, bearings, etc., and the jack assemblies. Material costs reflect the use of relatively expensive special aluminum structural shapes. The cost elements sensitive to the influence of a production learning curve include direct shop labor and subcontracts for machined parts and the shearing, piercing and forming of sheet metal and plate. Overhead and indirect costs would follow the same trend as a function of quantities produced per year. For one engineering model these costs totaled $12,845. Rounding off the production quantity to 200 units and employing an 85 percent learning curve, these costs would be approximately $4,400 for the 200th unit, resulting in an average cost of $5,742 for each of the 200 units. Adding this to the previous figure of $2,126 for purchased parts, raw materials, etc., results in an average total unit cost of $7,868 for a production quantity of 218 mobility adapters. The calculation of sustaining engineering at 3 percent of unit cost and production acceptance test costs at 0.8 percent of unit cost provides the following final figure:

Total Cost Elements	Skid Adapter Per-Unit Cost
Production Costs	$7,868
Sustaining Eng'g.	236
Acceptance Testing	63
Total Unit Cost	$8,167

The foregoing HGMS production unit cost analyses are summarized in Table 1. It must be remembered that the figures developed in the production analyses are cost figures. The actual acquisition prices would be higher by a factor of 8 to 15 percent, representing the typical manufacturer's profit or fee.

TABLE 1. HGMS ESTIMATED PRODUCTION UNIT COSTS (CY 78 $)

Three-Year Prod. Quantity	Prime Mover	Flotation Tracks (Set)	Skid Adapter	System
216 Units	$12,916	$1,218	-	$14,134
434 Units	$11,718	$1,136	-	$12,854
218 Units	$12,916	-	$8,167	$21,083

RELIABILITY, MAINTAINABILITY, AND LOGISTIC SUPPORT

SYSTEM RELIABILITY

The HGMS Critical Item Development Specification contains a Service Life and Reliability requirement which is defined as a functional mean-time-between-failures (MTBF) of at least 500 operating hours and an ultimate service life of 2,000 operating hours. In order to assure that this requirement would be met, VSDC implemented a reliability program following the guidelines provided by MIL-STD-785A, "Reliability Program for Systems and Equipment Development and Production".

The prediction of reliability and operating life is based on analysis of the rate at which the equipment is expected to fail in service. For a normal part, a plot of failure rate versus operating time typically consists of three phases as shown in Figure 10.

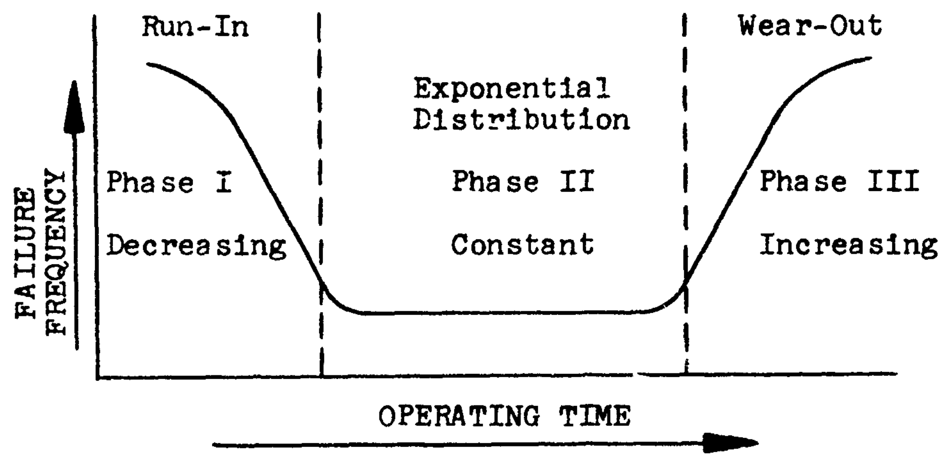

Figure 10. Characteristic Failure Rate Plot

The decreasing failure rate in Phase I reflects manufacturing and quality control considerations and is usually minimized by tightening manufacturing quality controls and by component conditioning, or "run-in". The increasing failure rate of Phase III is the result of component aging and wear and is controlled by proper maintenance/overhaul/replacement schedules and by derating or overdesign to compensate for wear.

The constant failure rate of Phase II (useful life) represents unpredictable and random failures typically caused by sudden stress accumulations beyond the design strength. This phase follows an exponential distribution described by the equation

$$R = e^{-\lambda t} \quad \text{or} \quad R = e^{-t/MTBF}$$

Where R is reliability, or probability of the unit operating without failure; λ is failure rate; t is operating (or mission) time; and MTBF is mean time between failures. For mechanical systems such as the HGMS, the wear-out failure rate (Phase III) typically follows a normal, Weibull, or gamma distribution.

The reliability equation provides a means of demonstrating compliance with the specification requirement. Applying the specified MTBF of 500 hours and the ultimate service life of 2,000 hours as factors, the required system reliability is

$$R = e^{-\frac{2000}{500}} = 0.018 \text{ or } 2\%$$

Assuming that ten subsystems of equal reliability make up the system, their required level of reliability would be given by

$$R^{10} = .02$$

and

$$R = .68 \text{ or } 68\%.$$

Increasing the number of components and subsystems to 100,

$$R^{100} = .02 \text{ and } R = .96 \text{ or } 96\%$$

These required values of component reliability are not unusually high or demanding in the HGMS context where the design and operation of the system requires only conservative performance levels from proven components. In any case, the contractor has taken adequate steps to produce HGMS engineering models exhibiting the highest possible levels of reliability.

Because most of the critical components of the HGMS (for example, the engine, pump, motors, and axles) were purchased commercial items and consequently not directly subject to VSDC quality-control procedures, and because little formally maintained reliability data was available on these components, VSDC emphasized the use of conservative safety factors, stress and performance derating factors, stress/strength analyses, and system/component redundancy in the detailed design of the HGMS. This had to be accomplished within the constraints of specified system size, weight, and maintenance requirements.

Complementary to this effort, VSDC initiated a reliability analysis program based on a functional modeling of the HGMS as configured for three specific tasks or missions. The system models are in the form of functional block diagrams showing the subsystems required for performance of the assigned task, and are shown in Figure 11. Task I, moving a skid-equipped helicopter, is shown in diagram (a); diagram (b) shows Task II, moving a wheeled helicopter on a firm surface;

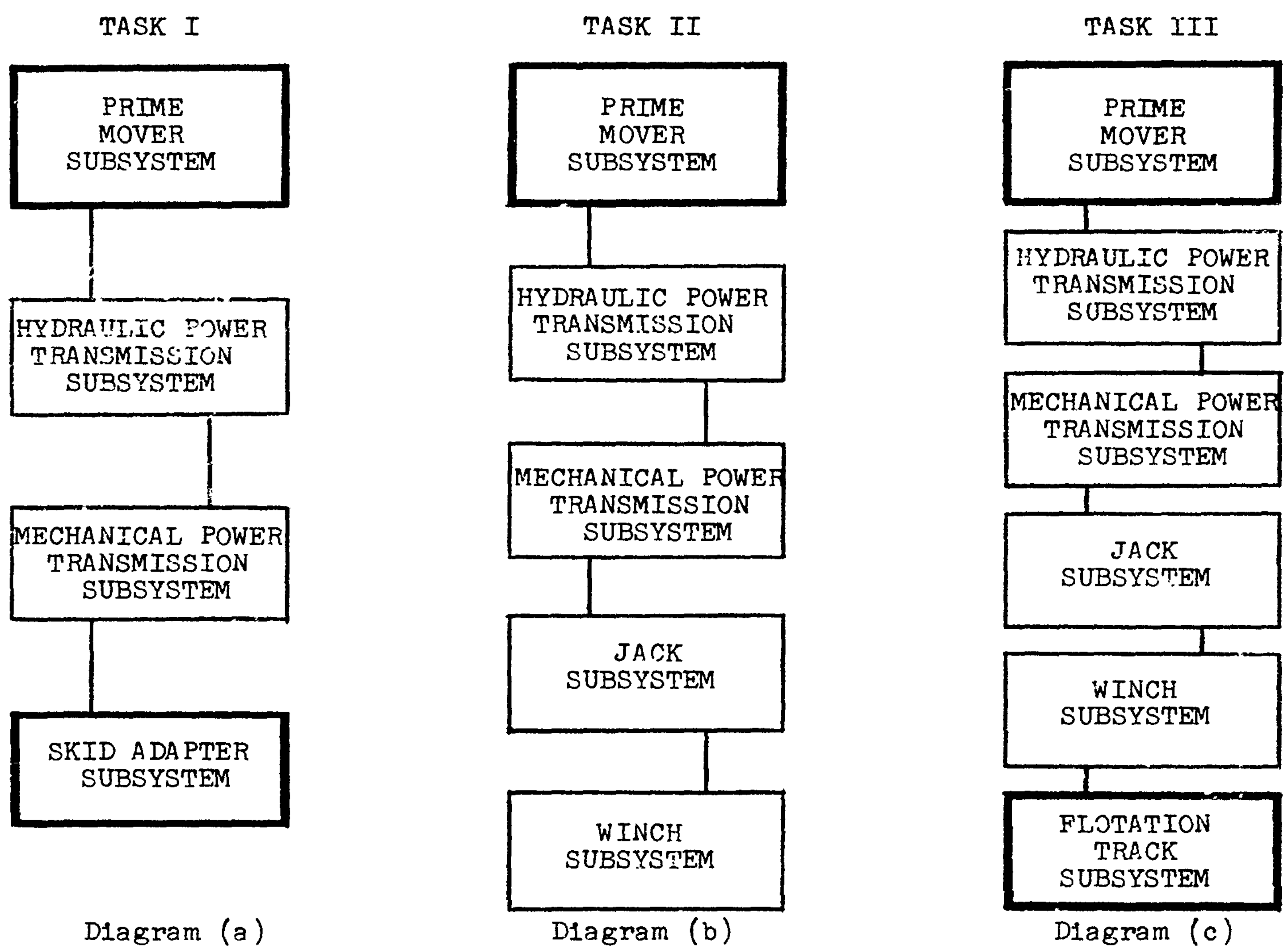

Figure 11. Task Block Diagrams

TABLE 2. SUBSYSTEM RELIABILITY

MAJOR COMPONENT		SUBSYSTEM INVOLVED							
		Prime Mover	Hyd. Pwr. Trans.	Mech. Pwr. Trans.	Jack Subsys	Winch Subsys	Helo. Adapter	Track Ass's.	Derating Factor %
Battery		X							
Starter		X							15
Ignition		X							10
Alternator		X							25
Fuel Filter		X							50
Air Cleaner		X							10
Engine		X							25
Hydraulic Pump			X						50
Hydrostatic Drive			X						75
Drive Belt			X						75
Hoses			X						75
Differential				X					50
Final Drive				X					90
Tires				X					65
Hydraulic Jacks					X				80
Valve					X				50
Hoses					X				50
Winch						X			25
Adapter Frame							X		80
Mechanical Jacks							X		50
Tires							X		70
Tracks									80
								X	75
Subsystem Reliability	Max.	99	99	99	99	99	99	99	
	Min.	98	95	98	95	95	98	97	

TABLE 3. TASK RELIABILITY

Subsystem	RELIABILITY - %					
	TASK I		TASK II		TASK III	
	Max	Min	Max	Min	Max	Min
Prime Mover	99	98	99	98	99	98
Hydraulic Power Trans.	99	95	99	95	99	95
Mechanical Power Trans.	99	98	99	98	99	98
Jack Subsystem	-	-	99	95	99	95
Winch Subsystem	-	-	99	97	99	97
Skid Adapter	99	98	-	-	-	-
Track Assy's.	-	-	-	-	99	97
Task Reliability	96	89	95	84	94	82

and diagram (c) depicts Task III, moving a wheeled helicopter on a soft surface which requires the use of the flotation tracks. For purposes of the analysis, these models were defined in terms of the major components of each subsystem. Seven subsystems incorporating a total of 22 major components were identified and are shown in Table 2. The table also presents maximum and minimum values for the predicted reliability of each subsystem and the component derating factors used in assessing reliability. HGMS maintenance frequency and material recommendations are presented in Table 4. Table 3 summarizes the predicted reliability of the HGMS in each of the three tasks postulated and shows the effects of the number of subsystems involved and their individual reliability characteristics. The block diagrams indicate a series-type relationship between subsystems/components. Therefore, the task reliabilities are linear products of the individual reliabilities.

To the extent possible, considering its short duration, the acceptance test program results supported the reliability evaluations reported above.

MAINTENANCE EVALUATION

The Maintainability section in the Critical Item Development Specification requires that adequate access to all service points and critical components be provided and establishes a mean-time-to-repair (MTTR) of not more than 1 elapsed hour. The ratio of maintenance man-hours to operating hours (MMH/OH) is set at .004, exclusive of routine servicing.

Maintenance considerations played a major role during the detail design and manufacturing program. The maintenance planning stressed accessibility to service points and assured that servicing and component replacement could be accomplished rapidly and without special tools. Moreover, operation of critical components below their rated capacity minimizes the level and frequency of service and component replacement.

The acceptance test program included both an overall evaluation of the maintenance characteristics of the HGMS engineering models and timed demonstrations of the removal, replacement, and interchangeability of selected components. The times and the procedures were recorded, and, together with system operating time and other required maintenance/servicing activity, are shown in the appendix. On the basis of this assessment an MTTR of 33 minutes 35 seconds was calculated for nine maintenance (remove-replace) operations of differing degrees of complexity. The necessarily limited test activity, however, did not permit an opportunity for the extended operation and/or maintenance activity needed to develop a finalized MMH/OH.

The anticipated maintenance operations, frequencies, and materials are shown in Table 4. These operations can be accomplished by personnel trained in general automotive and GSE-type operation and maintenance using standard tools and equipment. No aspect of the HGMS maintenance and/or servicing requires either tools or training peculiar to the HGMS.

SPARE PARTS AND LOGISTIC SUPPORT REQUIREMENTS

The HGMS prototype design and development program placed major emphasis on achieving a high level of reliability with a minimum of maintenance and servicing. To that end, the major subsystems were selected and/or designed to operate at stress and performance levels well below their rated capacities. The engine, for example, is required to operate at a constant governed speed of only 3,000 rpm - well below the manufacturer's maximum recommendation of 3,600 rpm - while developing a relatively constant power output, again well below its rated capacity of 16 horsepower. Similarly, the hydrostatic drive subsystem pump and motors operate at a maximum system pressure of approximately 3,000 psi although capable, by design, of operating in excess of 4,500 psi, and also operate at speeds well below the recommended maximum. The pumps and motors, too, by virtue of their axial-piston design and closed-loop circuitry, are long-lived and relatively free of wear-associated maintenance.

Basic structural elements of the prime mover are of steel construction with ample factors for safety based on a worst-case analysis of operational conditions and procedural errors in tailwheel loading. The skid-equipped helicopter adapter and track assemblies, while constructed of other materials, also reflect this conservative design philosophy.

Although exercising the maximum care and attention to reducing the requirements for maintenance and component replacement, VSDC recognized that no system can be completely free from logistic considerations. Consequently, and in compliance with contractual requirements, VSDC prepared an assessment of the system spare parts necessary to support the HGMS in operational field use. These replacement components are identified in Table 5 which also indicates quantities per HGMS system.

TABLE 4. MAINTENANCE FREQUENCY AND MATERIALS

Subsystem/ Component	Procedure	Material: Type	Material: Grade/Spec	Amt.	Frequency: AR	Frequency: AO	Frequency: Oper. Hrs
Engine: Crankcase Oil	Drain & refill	Engine Oil SAE 30 ① SAE 5W-20 ② SAE 10W ③	Detergent Type MS (SC SD or SE acceptable)	3.5 pt		X	100
	Check & add	do	do				Daily
Fuel Filter	Replace					X	
Air Cleaner	Wash pre-cleaner	Water	-			X	100
	Paper cartridge (clean out or replace)					X	500
Pistons & Valves	Remove carbon				X	X	
Spark Plugs	Clean & regap			.030" gap	X		100
	Replace	Resistor Long Plug	R-46; AR80 or RJ-8		X	X	
Hydrostatic Drive	Drain & refill	Auto.Trans. Fluid	Type F			X	1,000
	Check & add						Daily
	Filter change	Lenz Company	Model 8-03			X	500
	Clean tank breather					X	1,000
	Clean or replace tank strainer	Lenz Company	Model 49-10			X	1,000
Differential	Check & add	SAE 140		1 qt			100
Gearbox & Chain Cases	Drain & refill	SAE 90	Type EP	1 pt (each)		X	1,000
Wheel & Mechanical Jack Bearings	Repack	Multi-purpose grease	NCLI Grade 1			X	1,000

AR - As Required; AO - At Overhaul (2,000 hrs.)
① Above -40°F; ② Between °F and -40°F;
③ Below 0°F

TABLE 5. SPARE PARTS AND SUPPLIERS

Subsystem	Qty.	Nomenclature	Source P/N	Source/Manufacturer
Engine	1	Fuel Pump Repair Kit	393393	Briggs & Stratton Milwaukee, W. 53201
	1	Fuel Pump Body	280197	
	1	Spark Arrester Screen	392154	
	2	Spark Plug (Resistor Long)	AC #R46 or Autolite #A R 80 or Champion # RJ-8	Various
Hydraulic Pump	2	Lip Seal	9008000-7505	Sundstrand Hydro-Transmission Ames, Iowa 50010
	2	O-Ring	9004101-1530	
	6	O-Ring	9004201-3100	
	2	Pin	9004875-0013	
Hydraulic Motors	2	Shaft Seal	151-27451	Webster Electric Co. Fluid Power Division Racine, Wi. 53403
	2	O-Ring	29761-034	
	2	Sealing Ring	38247	
Hydraulic System Reservoir	1	Filter Cartridge	803	The Lenz Co. Dayton, Ohio 45401
	1	Sump Strainer	49-10	
Running Gear	2	Tubeless Tire (Terra-Tire) 18x9.50-8HNS	4 PR "ST" Tread	Goodyear Tire & Rubber Company Akron, Ohio 44316
	2	Tubeless Tire (Terra-Tire) 26-12.00-12HNS	4 PR "ST" Tread	
	4	Tire Valve (Snap-in)	TR413	Various
Hydraulic System Lines	6	VersaFlare Tube Nut	F[illegible]75-04S	Aeroquip Corporation Industrial Division Jackson, Mi. 49203
	6	VersaFlare Tube Nut	FC2875-06S	
	6	VersaFlare Tube Nut	FC2875-08S	
	6	VersaFlare Tube Ferrule	FF9605-04S	
	6	VersaFlare Tube Ferrule	FF9605-06S	
	6	VersaFlare Tube Ferrule	FF9605-08S	

ADDITIONAL APPLICATIONS FOR THE HGMS

The HGMS provides a building block making it possible to develop functional modules such as forklifts, ordnance loaders, and helicopter equipment handling devices which could be mounted on (and draw hydraulic power from) the basic system. With this in mind, VSDC accomplished an extensive independent engineering effort to define a family of functional modules which are briefly described in this section of the report. Associated with this is the possibility of incorporating provisions in the HGMS prime mover for a seated operator and power steering. These changes would permit an increase in maximum speed and would complement the expansion of the prime mover's use for additional tasks in forward laager areas. The modifications of the HGMS to obtain added capabilities could be developed around the existing engineering models depending on their availability for this purpose.

The company-funded work VSDC has carried out with the objective of expanding the HGMS' capabilities for additional Army aviation GSE roles has resulted in the preliminary designs for "add-on" function and mission modules for the system illustrated in Figures 12 through 15. These designs include:

- A Pioneer Earth/Snow Dozer
- A Refuel/Rearm System Prime Mover
- Helicopter Equipment Handling Crane with a Load Positioner
- Modular Aircraft Recovery System (MARS) Prime Mover
- High-Mobility Forklift
- Ordnance and Stores Loading Device
- Ground Power Unit (GPU) Mobilizer

As a review of these designs indicates, there is a real potential for utilizing the HGMS prime mover as the basis for systems for all forward laager area GSE requirements, thereby achieving significant gains in overall cost-effectiveness and greatly simplifying the logistic support of such Army aviation equipment.

Additional utility can be achieved with the HGMS skid-equipped helicopter mobility adapter by combining it with VSDC's "Helipallet" concept. Shown in Figure 16 as a sling-load under a UH-1 helicopter, the Helipallet is designed to serve as a basic cargo platform for use in the air-transport of equipment and supplies and is configured to utilize the mobility adapter's helicopter attach points to form a lightweight, mobile, load-carrying system on the ground.

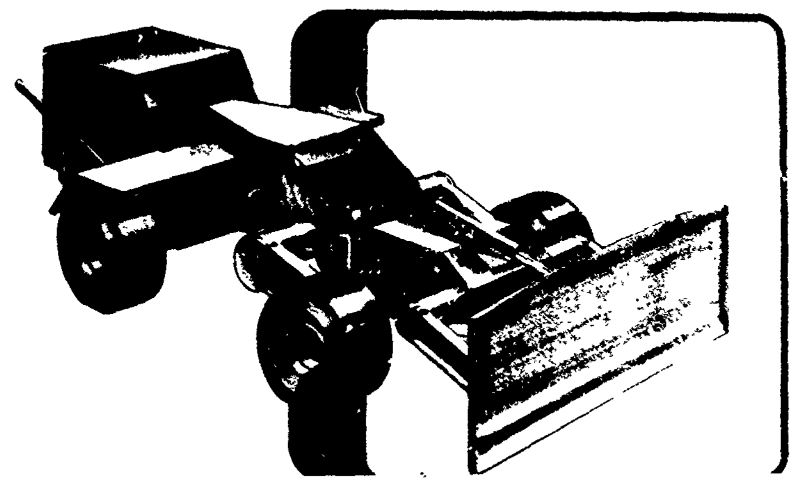

Figure 12. Pioneer Earth/Snow Dozer

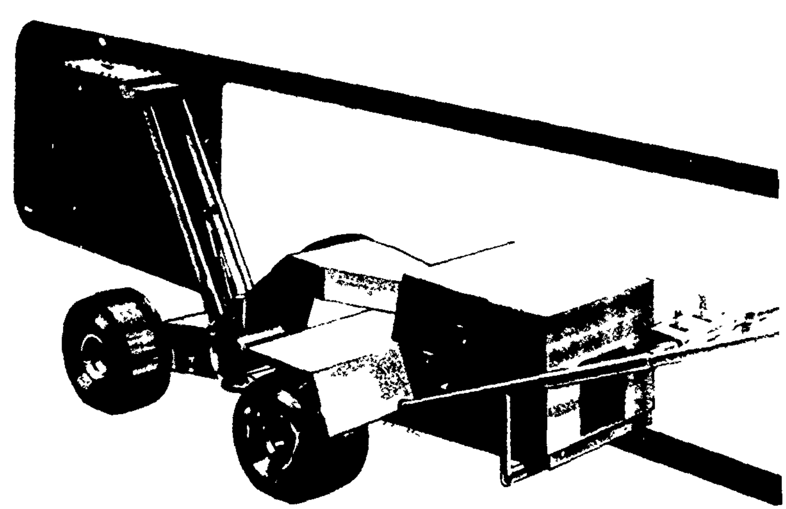

Figure 13. Ordnance Loader with Load Positioner

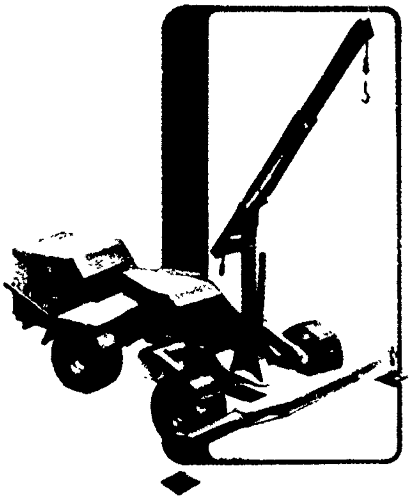

Figure 14. HGMS Maintenance Handling Crane Module

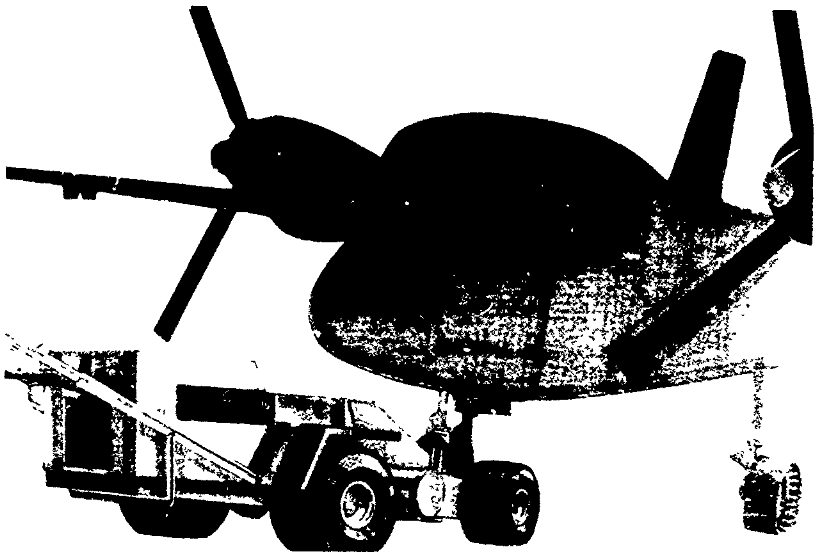

Figure 15. Prime Mover and Flotation Tracks Provide OV-1 Mohawk with Local Ground Mobility

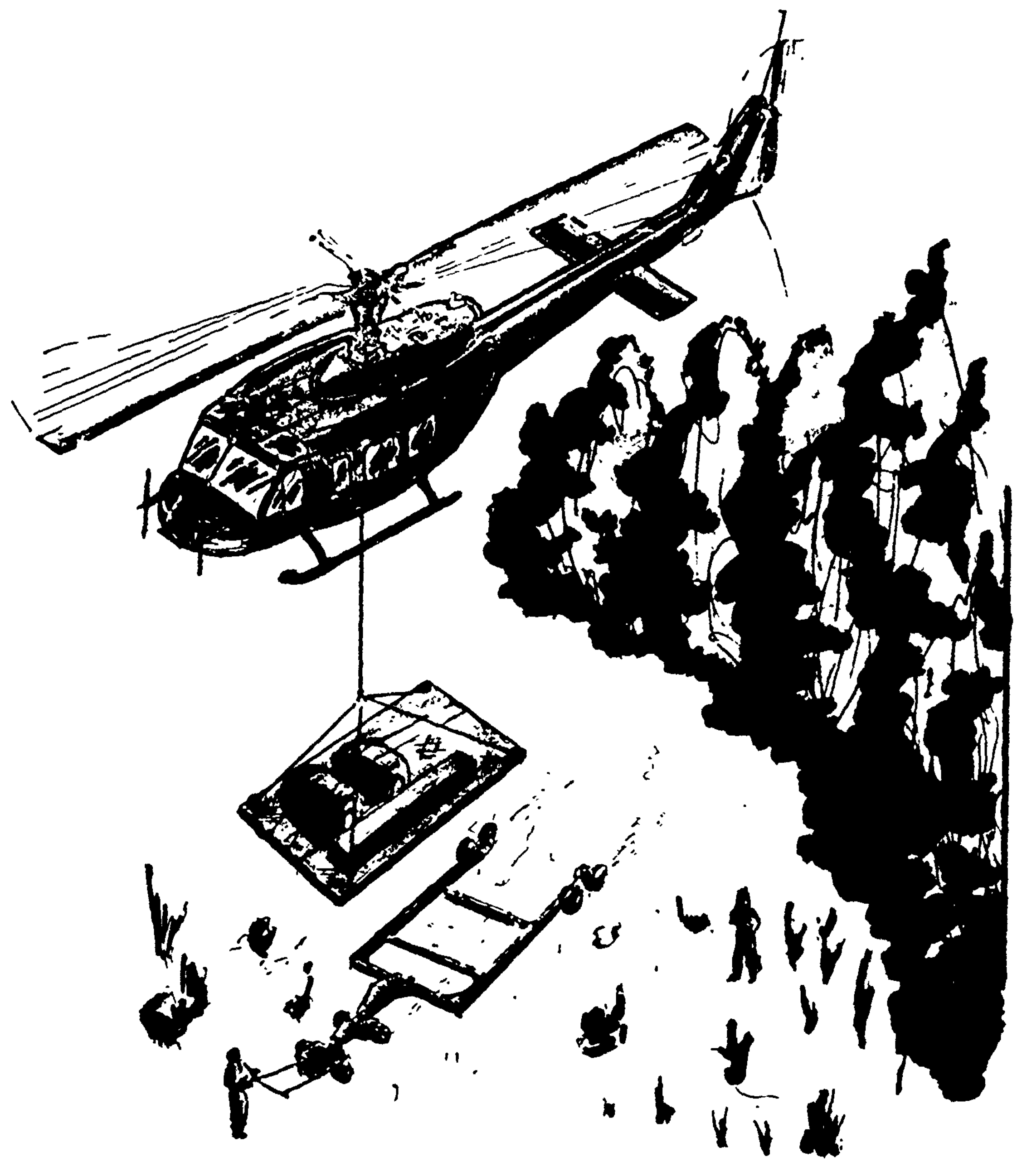

Figure 16. HGMS Helipallet Concept

CONCLUSIONS AND RECOMMENDATIONS

The Helicopter Ground Mobility System (HGMS) engineering models produced under this program have been demonstrated to be in compliance with the Critical Item Development Specification prepared and approved under Contract DAAJ02-76-C-0037. Although of relatively short duration and having required simulations of the specified helicopter payloads, the acceptance testing of the engineering models conducted by VSDC demonstrated that the HGMS is a sound and viable solution to the Army's long-standing problem of helicopter ground mobility in soft soils and over unprepared rough terrain. It also showed that a reliable and maintainable system can be produced at relatively low cost.

Applying the HGMS to a range of helicopters under field conditions will provide additional data on system performance, indicate where design improvements can be incorporated, and afford an opportunity to evaluate its overall utility in the context of Army aviation operations.

APPENDIX

ACCEPTANCE TEST DOCUMENTATION

The HGMS acceptance tests were performed by VSDC personnel and witnessed by the Contracting Officer's Technical Representative, Mr. Robert L. Campbell, Sr. In those instances where the HGMS engineering models required modification in order to satisfy test requirements, the necessary changes were incorporated by VSDC and verified by retest and/or inspection. The draft technical manual for the system and engineering drawings were also modified to reflect finalized operating procedures and the post-test configuration of the system. The acceptance test requirements and results are documented in the worksheets included in this appendix.

Final approval and acceptance of the HGMS engineering models was received from the Contracting Officer's Technical Representative on 27 March 1979, and both units along with the helicopter simulator were prepared and shipped to the Applied Technology Laboratory, Fort Eustis, arriving there on 2 May 1979, in good order.

HELICOPTER GROUND MOBILITY SYSTEM
ACCEPTANCE TEST WORKSHEET

PM - Prime Mover
SA - Skid Adapter
FT - Flotation Tracks
(1) HGMS C.I.D.S. (3) MIL-A-8421F
(2) MIL-STD-1472B (4) MIL-STD-209E
(5) MIL-STD-814A

Test Operator: [signature]
Name: John P. Forsyth
Title: VP Vehicle Systems

Witness: [signature]
Name: Robert L. Campbell
Title:

Test Period: 1/29/79 – 2/10/79

TEST NO.	APPLICABILITY PM	SA	FT	REQUIREMENT & SOURCE	TEST OPERATION	REMARKS/RESULTS	DATE TIME	INITIALS TO	WIT
1a	X		X	PM/FT Useable on any armament configuration of YAH-64. (1) 3.2.1.2.1	Dimensional check of applicable dwgs. and data	Compares per check Hughes Dwgs 7-211100001. Shows 8½" + clearance between Hellfire pod & tracks	2/2 3.15 pm	[initials]	[initials]
1b		X		SA Useable on AH-1, UH-1, OH-6, OH-58 (1) 3.1	Inspect SA, measure width, length & pick-up beam assy.	SA#1 / SA#2: 69 7/8" / 69 3/4"; 75 7/8" / 75 7/8"; 102 3/4" / 102 7/8". Pickup beam hanger usable spread is well within manufacturer's ground handling wheel attachment points	2/2 3.30 pm	[initials]	[initials]
1c	X	X		PM/SA Negotiate 11.5° (C-130) 14° (C-141), & 17° ramps (3) 3.2, 3.3, 3.3.3 & 4.2.2	Demonstrate compliance with layout dwgs.	PM alone complies, PM & SA together will not negotiate 11½° ramp. SA with helicopter requires lifting device for C-130 and C-141 ramps.	2/2 4.00 pm	[initials]	[initials]
1d	X	X		PM/SA Sling legs converge over CG, max. 24 ft sling apex to bottom of unit w/legs at 45° (4) 4.1.2.2(a) & 4.1.2.2(b)	Demonstrate with calculations & layout dwgs.	Complies per layout to scale showing apex over PM is 3 ft (45° legs), apex over SA is 8'9" (105") with sling legs at 45°	2/2 3.30 pm	[initials]	[initials]
2a	X	X	X	PM/SA/FT Commercial quality materials, design & construction (1) 3.3.1	Visual inspection	All engineering models (PM/SA/FT) satisfactory, no defects noted.	1/30 2.00 pm	[initials]	[initials]
2b	X	X		PM/SA Paint color conforms to Color 34087, Fed. Std. 595a (1) 3.3.3	Match paint on PM & SA w/color strip	Visual check against paint chip from Fed Std. 595a shows compliance.	1/31 11.00 pm	[initials]	[initials]
2c		X		SA adapted to towing by PM & other suitable military vehicles (1) 3.1	Measure towing eye location on SA, check against PM & vehicle pintle data	#1 High position 25 1/8"; Low position 13 7/8", 19 3/4". Fits pintle of any Army vehicle (used with larger vehicle, SA requires steering [illegible])	1/30 11.30 am	[initials]	[initials]

TEST NO.	APPLICABILITY PM	SA	FT	REQUIREMENT & SOURCE	TEST OPERATION	REMARKS/RESULTS	DATE TIME	INITIALS TO	WIT
2d	X		X	Provisions on PM for stowing FT (1) 3.2.6.3	Demonstrate stowage of FT on PM	Demonstrated truck stowage on PM; stowage arrangement should be illustrated in manual	1/30 4:00 pm	SF	[illegible]
3a	X	X	X	Dimensional conformance of PM/SA/FT to eng'g. dwgs. (1) 3.2.2.1	Inspect units, measure & compare to dwgs.				
3b	X	X		Max. width over tires on PM/SA of 105-in 0 to 5-in above ground line (3) 3.3.1.1, 3.2, 3.3 (1) 3.2.6.1	Inspect & measure units	SA#1 97 1/8" PM#1 58 1/4" over fender; SA#2 97 1/2" PM#2 58 1/4" COMPLIANCE DEMONSTRATED	1/31 10:00 am	SF	[illegible]
3c	X	X		Max. overall width of PM/SA 118-in (1) 3.2.6.1 & (3) 3.3.1.1, 3.2, 3.3	Inspect & measure units	Max. overall width of 118-in for SA permitted by (1) conflicts with (3) PM's 58 1/4" SA's 117 5/8" with cinch strap.	1/31 10:00 am 3:00 pm	SF	[illegible]
3d	X	X		Max. overall width of PM/SA 111-in (3) 3.3.1.1	Inspect & measure units SA#1 110 3/4" SA#2 111 1/4"; disassy. SA 76"; PM's 58 1/4"	Conflicts with 3c above and (1), can only be obtained by disassy. of SA	1/30 1:15 pm	SF	[illegible]
3e	X	X		Max. overall height of 102-in. for PM/SA (3) 3.3.1.1	Inspect & measure units	PM#1 50 5/8" top of cowling; 41 1/2" top of handle; SA#1 32 1/8" over gooseneck.	1/30 10:30 am	SF	[illegible]
3f	X	X		Min. of 4 tie-downs on PM/SA capacity 3g fwd, 1.5g aft, 1.5g lateral, tie-downs marked (3) 3.3.5.3, 3.3.4 & 3.4.1.1		Requirement combined with 4a, 4c and 4f; no test required			
3g	X	X		Shipping weights & CG locations identified & marked on PM/SA (2) 5.13.2 (3) 3.4.1.2	Inspect units for compliance	Incorporated prior to shipment to Fort Eustis	9/16	SF	
3h	X	X	X	PM adapted to UH-60A internal load (71-in W x 54.25-in H x 74-in L) or sling load (1) 3.2.6.2 & 3.1; SA adapted to sling load	Inspect & measure PM in transport configuration	SA SLING LOAD CAPABILITY DEMONSTRATED. PM with steering/control arms stowed has a length of 91 3/4"; a length of 85 3/4" with arms removed. PM wheelbase is PM length means it would require the doors of the UH-60A to be open to carry PM as internal load. Complies with spec.	1/30 3:15 pm	SF	[illegible]

TEST NO.	APPLICABILITY PM	SA	FT	REQUIREMENT & SOURCE	TEST OPERATION	REMARKS/RESULTS	DATE TIME	INITIALS TO	WIT
4a	X	X		PM/SA Incorporate integral lifting eyes, min/max 3-in ID opening (4) Fig. 1 (1) 3.2.6.2	Inspect and measure tie-down eyes	PM's & SA's meet requirement	1/30 11:00 am	JF	[illegible]
4b	X	X		PM/SA Incorporate tie-down eyes, min/max mat'l. cross-section 0.433-in/0.787-in, min ID 1.969-in, breaking strength 5,000 lbs (4) Fig. 1 (1) 3.2.6.2	Inspect units & measure tie-down eyes, calculate breaking strength	Per (4) 5.2.1, Fig. 1 specifies 3-in. min. ID for eyes PM eye cross section 0.495" SA eye cross section 1.0"x.526" Minimum calculated shear strength PM tie-downs 4,100# and SA tie-downs 12,000#.	2/2 4:30 pm	JF	[illegible]
4c	X	X		Minimum of 4 multipurpose sling-load/tie-down eyes on PM/SA (4) 4.1.1, (1) 3.2.6.2	Inspect units for compliance	PM's & SA's meet requirement [illegible] (PM) for tie-down not for sling load; mark & note in manual.	1/30 1:00 pm	JF	[illegible]
4d	X	X		Minimum of 1-in clearance between sling/tie-down cables & equipment structure (4) 4.1.2.1, (1) 3.2.6.2	Inspect units & measure clearance simulated cables	PM's & SA's satisfactory; slight contact twd sling with engine cowling in test setup; layout shows clearance with sling apex 2' to 24' above [illegible]	1/30 10:00 am	JF	[illegible]
4e	X	X		Sling-lift & tie-down eyes on PM/SA rounded chamfered & smooth (4) 4.14, (1) 3.2.6.2	Inspect tie-down eyes on units	Tie-down/lift eyes on PM and SA comply	2/1 4:00 pm	JF	[illegible]
4f	X	X		Each sling-lift/tie-down eye withstand .8 GW load w/o permanent deformation, & a 1.5 GW ultimate (4) 5.1.1.1 (1) 3.2.6.2	Lift unit by each eye, hold for 90 sec., measure with load cell; calculate ultimate strength	1-in lift/tie-down eyes on PM's & SA's comply, see attached summary sheet	1/30 10:30 am to 2:45 pm	JF	[illegible]
5a	X	X		Minimum of 3 tie-down eyes per side PM/SA with minimum ID 3.5-in to accept 3 tie-down straps (5) 5.1.1 & 5.1.3, Table I, (1) 3.2.6.2	Inspect and measure	See 4a and 4b above Conflicts with 4a above; 4a applies.	1/30 11:00 am	JF	[illegible]
5b	X	X		Yield strength PM/SA tie-down eyes 5,000 lbs minimum (5) 5.1.2, (1) 3.2.6.2	Same as 4f	Same as 5a Conflicts with 4b & 4f above; 4b & 4f apply	1/30 11:00 am	JF	[illegible]

TEST NO.	APPLICABILITY PM	SA	FT	REQUIREMENT & SOURCE	TEST OPERATION	REMARKS/RESULTS	DATE TIME	INITIALS TO	WIT
5c	X	X		Total tie-down sys. strength PM/SA 4 x GW fwd, 1.5 GW aft/lateral, 2 x GW vertical (5) 5.1.3 & 5.4	Calculate and present data	Same as 5a PM 20,000# total sys. strength available, 5840# req'd. SA 42,000 total sys. strength available, 4700# req'd. Units comply	2/2 4:45 pm	JNF	[illegible]
5d	X	X		Minimum of 4 suspension points on PM/SA, ultimate strength of suspension points 1.65 x limit load (5) 5.2.3 & 5.2.4	Inspect units	Same as 5a Units comply PM ultimate strength of lift rings is 11,160#, 3614# req'd. SA ultimate strength of lift rings is 12,000#, 2908# req'd.	2/2 4:45 pm	JNF	[illegible]
5e	X	X		Extraction provisions on PM/SA - pintle or lunette, min. 1 1/16-in ID on CL of unit, yield strength 1.5 x load limit, ultimate 1.65 (5) 5.3.1, 5.3.3, 5.3.2 & 5.3.4	Inspect and measure	Same as 5a Lunette eyes on SA Ordnance P/N B7041347 rated at 15,000# capacity. Pintles on prime movers (PMs) Ordnance P/N 7601399 rated at 10,000# capacity. Complies with requirement.	2/2 [illegible] pm	JNF	[illegible]
6a	X			Clear, correct, contrasting labeling of controls on PM (2) 5.4.1.4.5 & 5.4.3.2.1	Inspect unit for compliance				
6b	X			Satisfactory & complete gauges & instruments (2) 5.2.1	Inspect unit for compliance	Satisfactory arrangement and location, yellow line to be placed on hydraulic fluid sight gauge for optimum fill level.	1/31 10:30 am	JF	[illegible]
6c	X	X		Adequate placarding of operating & maintenance hazards on PM/SA (2) 5.9.9.3 & 5.13.2	Inspect units for compliance				
6d	X	X		Adequate & contrasting access & maintenance instructions on PM/SA (2) 5.5.6 & 5.5.2	Inspect units for compliance	Incorporated prior to shipment to Fort Eustis	4/16	JF	
6e	X			Minimum dia. throttle palm grip on PM 1.5-in to 3-in (2) 5.4.2.2.1 & Fig. 6	Inspect unit and measure	Throttle palm grip measures 1 11/16" diameter; complies with spec.	1/31 10:45 am	JF	[illegible]

TEST NO	APPLICABILITY PM	SA	FT	REQUIREMENT & SOURCE	TEST OPERATION	REMARKS/RESULTS	DATE TIME	INITIALS TO	WIT
6f	X			PM throttle knurled & clearly marked for rotation & vehicle movement (2) 5.4.2.2.3 & 5.4.2.2.4	Inspect unit for compliance	Complies with spec; better definition of directional arrow is required.	1/31 11:00 am	[illegible]	[illegible]
6g	X			Minimum of 2-in separation between throttle & wheel ramp controls (2) 5.4.3.2.1 & Fig. 13	Inspect unit for compliance	Complies with spec.	1/31 11:00 am	[illegible]	[illegible]
6h	X			PM controls adjustable to 5th/95th percentile man (1) 3.2.2.2, (2) Table XI	Inspect unit, adjust & measure	Steering control arms comply with spec.; adjustable to waist height, 5th – 95th percentile man.	1/31 3:30 pm	[illegible]	[illegible]
7a	X	X		Maintenance access to all service points w/o special tools or equipment (1) 3.2.4.1, (2) 5.9.5	Inspect units & demonstrate access provisions	Complies with PM/SA spec., a service/lube point chart required for PM & SA in operators manual.	1/31 11:30 am	[illegible]	[illegible]
7b	X	X	X	Access to repair and/or replace critical components & make repairs w/o special tools or equipment (1) 3.2.4.1, (2) 5.9.4.1	Demonstrate & clock removal/replacement times for engine, hydraulic pump/motor, battery, wheel & tire, FT segment, SA wheel & tire, walking beam & jack	Removal/replacement of referenced components demonstrated satisfactorily. See attached appendage for summary of time requirements.	2/1 & 2/2 1:00 to 5:00 pm	[illegible]	[illegible]
7c	X	X	X	Part & component interchangeability on PM/SA unit to unit (1) 3.3.2	Demonstrate by switching components during Test 7b	Compliance determined by physical inspection.	2/2 9:00 [illegible]	[illegible]	[illegible]
7d	X	X		Major components provided with lifting eyes as necessary (2) 5.9.11.3.1.1 & Table XXI	Inspect components & demonstrate compliance	Comply with specifications; engine (90#) has two lifting eyes; hyd pump 60#, hyd. motor 22#, axle 65# do not require lift eyes.	1/31 3:00 pm	[illegible]	[illegible]
8a	X		X	Max. empty weight of PM 1,600 lbs (1) 3.2.2.1	Weigh PM & record wt.	PM#1 1455# 1/2 tank fuel, oil and all lubricants PM#2 1460# 1/2 tank fuel; oil and all lubricants	1/30 2:30 pm	[illegible]	[illegible]

TEST NO.	APPLICABILITY PM	SA	FT	REQUIREMENT & SOURCE	TEST OPERATION	REMARKS/RESULTS	DATE TIME	INITIALS TO	WIT
8b		X		Max. empty weight of SA 1,090 lbs (1) 3.2.2.1	Weigh SA & record wt	SA #1 1175# SA's do not SA #2 1170# comply with spec. Exception to spec. approved.	1/30 1:30 pm	DF	[illegible]
9a	X			10,000-ft density altitude, $-20^{\circ}F$ +0 $+125^{\circ}F$, snow/sand blowing at 40 mph (1) 3.2.5	No test req'd				
9b	X			PM operation in rain intensity of 5.5 in/hr. (1) 3.2.5	Operate PM engine under spray from garden hose	Compliance by operation in rain and under garden hose spray.	2/2 9:00 am	DF	[illegible]
9c	X			Provisions incorporated in PM for Type II winterization kit (1) 3.2.5	Inspect unit for heat input provisions	PM's meet requirement; single engine air inlet permits SINGLE POINT INJECTION OF HOT AIR	1/31 2:00 pm	DF	[illegible]
10a	X			Operating controls on PM configured to MIL-STD-1472B direction control movement coincides w/PM movements; control location starting, fwd/aft movement configured for walking operator (1) 3.3.5, 3.1, & 3.2.2.2 (2) 5.1.3.8, 5.1.3.9 & 5.4.1.2.1	Demonstrate by operation of PM	PM's satisfy requirement; demonstrated fwd. & reverse movement with walking operator.	1/31 2:30 pm	DF	[illegible]
10b	X			Four-wheel drive, articulated steering, 10-ft turning radius, "dead-man" control (1) 3.1 & 3.2.1.2.2 (2) 5.4.1.8.5	Demonstrate by operation of unloaded PM	Demonstrated in shop area; turning radius is [illegible] feet, "dead man" control is operative.	1/31 3:00 pm	DF	[illegible]
10c	X			2 to 30-lbs resistance on PM throttle & wheel ramp controls (2) 5.4.3.2.1 & Figure 13	Operate PM & measure resistance	All PM controls comply with requirement.	1/31 3:00 pm	DF	[illegible]

TEST NO.	APPLICABILITY PM	SA	FT	REQUIREMENT & SOURCE	TEST OPERATION	REMARKS/RESULTS	DATE TIME	INITIALS TO	WIT
10d	X		X	PM/FT Useable on UH-60A & YAH-64 w/o mods, helicopter mod, or PM reconfiguration; attach times/detach times to helicopters no more than 3 min.; wheel ramp stability (1) 3.1, 3.2.1.2.1 & 3.2.2.2	Demonstrate by timed attachment/detachment helo. simulator, up/down ramp actuation	Attach 2:17 2:45 3:13 Detach 2:23 2.37	2/6 to 2/9	[illegible]	[illegible]
10e	X		X	Negotiate 3% grade, soil CI 50, w/random obstacles, w/ helo simulator weights for UH-60A & YAH-64 (1) 3.2.1.1	Demonstrate by operation on measured test course	Complies, use test 10g data	2/6 to 2/9	[illegible]	[illegible]
10f	X		X	Negotiate 15% grade, soil CI 125, w/random obstacles w/ helo simulator weights for UH-60A & YAH-64; lateral stability on 15% side slope (1) 3.2.1.1 & 3.2.1.2.3	Demonstrate by operation on measured test course ≈ 3,500# load	19.5% rocky with gulley	2/6 to 2/9	[illegible]	[illegible]
10g	X		X	Attain minimum 3 mph on dry, level terrain CI 125, minimum 1 mph on rough terrain CI 50 fwd & rev., (1) 3.2.1.2.2	Measure HGMS velocity with UH-60A & YAH-64 helo simulator weights	2.25 mph 2.33 mph 2.43 mph CI 93 avg 2.39 mph 2.47 mph CI 200 avg. 2.16 mph CI 72 avg.	2/6 to 2/9	[illegible]	[illegible]
10h	X		X	Integral means braking, speed, & directional controls, "dead-man" controls for walking operator (1) 3.2.2.2 (2) 5.4.1.8.5	Check & demonstrate control operation during tests 10d, 10e, 10f, 10g & 10h with helo simulator	Satisfactory	2/6 to 2/9	[illegible]	[illegible]
101	X		X	No overstress helicopter, hazardous instability or undue personnel hazards during HGMS operation (1) 3.3.4.1 (2) 5.9.6.2, 5.13.5.4 & 5.13.7.2.1	Check by observation during tests 10d, 10e, 10f & 10g	Satisfactory Caution note on PM pan on winch operation	2/6 to 2/9	[illegible]	[illegible]

TEST NO.	APPLICABILITY PM	SA	FT	REQUIREMENT & SOURCE	TEST OPERATION	REMARKS/RESULTS	DATE TIME	INITIALS TO	WIT
11a	X	X		Useable on UH-1 airframe, attach times/detach times no more than 3 minutes UH-1, AH-1, OH-6, OH-58; max. 50-lbs force operate SA jacks (1) 3.1 & 3.2.1.2.1 (2) 5.4.2.2.2.3 / Fig. 7	Demonstrate by timed attachment/detachment PM/SA to UH-1 airframe, measure force	Attach: 6:45, 6:07, 9:09, 3:31 / Detach: 5:00, 3:37, 4:34, 4:45	2/6 to 2/9	JDF	[illegible]
11b	X	X		Negotiate 3% grade, soil CI 50 w/random obstacles w/SA carrying UH-1 airframe (1) 3.2.1.1	Demonstrate by operation on measured test course	Complies, use test 11a data	2/6 to 2/9	JDF	[illegible]
11c	X	X		Negotiate 15% grade, soil CI 125 w/random obstacles w/SA carrying UH-1 airframe, lateral stability on 15% side slope (1) 3.2.1.1 & 3.2.1.2.3	Demonstrate by operation on measured test course	Complies 15% slope	2/6 to 2/9	JDF	[illegible]
11d	X	X		Attain minimum 3 mph on dry, level terrain, CI 125, minimum 1 mph on rough terrain CI 50; fwd. & rev., measure turning radius PM/SA (1) 3.2.1.2.2	Measure HGMS velocity with SA carrying UH-1 airframe	See 10g CI 93 2.56 mph CI 72 2.14 mph Turning radius PM/SA 28.5 feet	2/6 to 2/9	JDF	[illegible]
11e	X	X		Integral means braking, speed, & directional controls, "dead-man" controls for walking operator (1) 3.2.2.2, (2) 5.4.1.8.5	Check & demonstrate control operation during tests 11a, 11b, 11c & 11d	Complies	2/6 to 2/9	JDF	[illegible]
11f	X	X		No overstress helicopter, hazardous instability or undue personnel hazards during HGMS operation (1) 3.3.4.1, (2) 5.9.6.2, 5.13.5.4 & 5.13.7.2.1	Check by observation during tests 11a, 11b, 11c, 11d & 11e	Complies	2/6 to 2/9	JDF	[illegible]

Turning radius PM/SA 28.5 feet

TEST NO.	APPLICABILITY PM	SA	FT	REQUIREMENT & SOURCE	TEST OPERATION	REMARKS/RESULTS	DATE TIME	INITIALS TO	WIT
12	X			Minimum 2 hrs PM operation w/o refueling, minimum 8 hrs operation w/o adding oil (1) 3.2.1.2.3	Record fuel & oil use against hour meter times during tests 10 & 11	Added approximately 7 gallon after 14.9 hours operation. No oil required.	2/6 to 2/9	[illegible]	[illegible]
13a	X	X	X	Minimum service life of 2,000 hrs., minimum 500 hrs MTBF, no TBO components (1) 3.2.3	No specific tests, record all wear & failures vs. hour meter times during operational tests, calculate data	Service life – complies. MTBF 7.2 hrs. During test assume break-in failures. TBO engine mfg. recommends 500 hrs. for overhaul, however will be done "on-condition"	2/6 to 2/9	[illegible]	[illegible]
13b	X	X	X	Maximum MTTR of 1 hour (1) 3.2.4.2	Data from test 7b plus records of all remove/replace/repair times occurring during operational tests	Complies, calculated from tasks, Test 7b is 35 min 55 seconds (elapsed)	2/6 to 2/9	[illegible]	[illegible]
13c	X	X	X	Maximum MH/OH of .004 exclusive of routine service (1) 3.2.4.2	Calculate from total maintenance manhours vs. hour meter time for all operational tests	Estimated in Final Technical Report Failures: 1. Hydraulic pump seal 2. Fuel pump diaphragm Maintenance Errors: 1. Failure to tighten hydraulic fittings Operator Errors: 1. Turned PM/SA too sharply, overrode tire & hyd. cylinder [illegible]	4/23	[illegible]	

Para. 7b Test Data: HGMS Test Worksheet Appendage # 2

Test Articles: HGMS Prime Mover S/N 001 Skid Adapter S/N 001

Maintenance Tasks Performed	No. of Men	Sub-Task Times Man-Min.	Sub-Task Times Elapsed Min.	Total Task Times Man-Min.	Total Task Times Elapsed Min.
		Measured Data			
1. Control Handle and Engine Cowl - remove & replace					
a. Removal	2	2:35	2:05		
b. Reinstall	2	8:13	5:16		
c. Total				10:48	7:21
2. Gas Tank - remove & replace					
a. Removal	2	5:42	2:51		
a(1) Incl. task 1a.		8:17	4:56		
b. Reinstall	2	6:38	3:19		
b(1) Incl. task 1b.		14:51	8:35		
c. Total (tasks 2a(1) & 2b(1))				23:08	13:31
3. Engine - remove & replace					
a. Removal	2	9:40	4:50		
a(1) Incl. tasks 1a & 2a		17:57	9:46		
b. Reinstall	2	16:18	8:09		
b(1) Incl. tasks 1b & 2b		31:09	16:44		
c. Total (tasks 3a(1) & 3b(1))				49:06	26:30
4. Battery - remove & replace					
a. Removal	1	1:23	1:23		
b. Reinstall	1	6:27	6:27		
c. Total				7:50	7:50

Para. 7b Test Data: HGMS Test Worksheet Appendage # 2 (Cont'd.)

	No. of Men	Sub-Task Times Man-Min.	Sub-Task Times Elapsed Min.	Total Task Times Man-Min.	Total Task Times Elapsed Min.
5. Hydraulic Pump - remove & replace (Note 1)					
a. Removal (Note 2)	1	18:22	18:22		
a(1) Incl. tasks 1a, 2a, 3a, & 4a		37:42	29:31		
b. Reinstall (Notes 2 & 3)	1	20:12	20:12		
b(1) Incl. tasks 1b, 2b, 3b & 4b		57:48	43:23		
c. Total (tasks 5a(1) & 5b(1))				1:35:30	1:12:54
6. Hydraulic Motor - remove & replace					
a. Removal	1	13:43	13:43		
b. Reinstall	1	14:17	14:17		
c. Total				28:00	28:00
7. Skid Adapter - wheel removal & replacement					
a. Removal	1	1:15	1:15		
b. Reinstall	1	1:15	1:15		
c. Total				3:30	3:30
8. Skid Adapter Walking Beam - remove & replace (wheels on)					
a. Removal	1	0:36	0:36		
b. Reinstall	1	0:36	0:36		
c. Total				1:12	1:12

Para. 7b Test Data: HGMS Test Worksheet Appendage # 2 (Cont'd.)

	No. of Men	Sub-Task Times Man-Min.	Sub-Task Times Elapsed Min.	Total Task Times Man-Min.	Total Task Times Elapsed Min.
9. Float Track Pin - remove & replace					
a. Removal	1	0:11	0:11		
b. Reinstall	1	0:36	0:36		
c. Total				0:47	0:47
10. Skid Adapter Re-configuration Normal use configuration to aircraft (e.g. C-130 insertion configuration)	1			2:04	2:04

NOTES:

1. Most efficient approach for hydraulic pump replacement is to first remove the control handle, cowl, gas tank, engine and battery.
2. One man performed hydraulic pump remove/replace tasks. Use of two men could cut elapsed task time approximately in half.
3. Hydraulic pump and/or motor remove/replace also calls for hydraulic pump recharge by motoring the engine (spark plugs disconnected) for approximately one to two minutes. Hydaraulic motor or cylinder remove/replace may call for hydraulic system air bleeding by loosening the cylinder input line nut with the engine
4. No special tools required for any of the above tasks.
5. Unweighted (for frequency) MTTR is 0:35:55 elapsed time for first nine tasks above.

Para 4f test data: HGMS Test Worksheet appendage.

HGMS TEST ARTICLE

Test Parameter	Prime Mover S/N 1				Prime Mover S/N 2				Skid Adapter S/N 1				Skid Adapter S/N 2			
Measured total weight	1455 lb.				1460 lb.				1175 lb.				1170 lb.			
Individual lift eye min. capability	1164 lb. (min.)				1168 lb. (min.)				940 lb. (min.)				936 lb. (min.)			
Lift eye location	Left Frnt	Rt. Frnt	Left Rear	Rt. Rear	Left Frnt	Rt. Frnt	Left Rear	Rt. Rear	Left Frnt	Rt. Frnt	Left Rear	Rt. Rear	Left Frnt	Rt. Frnt	Left Rear	Rt. Rear
Measured Test Weight (lbs.)	1205	1250	1175	1200	1375	1245	1225	1245	1040	1100	1030	970	1100	950	1050	1000
Lift eye and support structure condition (Post-test inspt.)	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.

Notes:
1. No lift eye or support structure damage or deformation noted on any post-test inspection.
2. Measured HGMS wheeled-helicopter flotation track assembly weight was 50 ± 1/2 lb. (each).
3. Measured skid adapter "lift-off" corner weight was (a) 450 lb. at rear lift eye and (b) 415 lb. at fwd lunette

Test Operator [signature] Date 1/30/79

Witness [signature] Date 1/30/79