Direct Reporting Program Manager
Advanced Amphibious Assault

Program Office Response to AAAV Prototype
Early Operational Assessment (EOA) of Land Mobility

August 2002

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Executive Summary

The Direct Reporting Program Manager, Advanced Amphibious Assault (DRPM AAA) considers the insight of the operational Marine forces to be of the utmost significance as the end-users and ultimate customers of the Advanced Amphibious Assault Vehicle (AAAV) system. The information garnered through the early operational assessments combined with developmental testing information has been exceptionally valuable to the program in driving the focus of next-generation designs. The Land Mobility Early Operational Assessment (EOA) was the first formal exposure of the Program Definition and Risk Reduction (PDRR) first generation prototypes to the operational fleet in mechanized operations. The PDRR prototype proved to be a highly capable combat vehicle by demonstrating strong performance on open ground during the EOA. However, the prototype experienced difficulty in such areas as track durability, habitability (internal space, heat, noise, vibration), and overall system reliability. These early design deficiencies have been addressed in the design of the second generation System Development and Demonstration (SDD) prototypes currently undergoing assembly. The less durable experimental aluminum lightweight track used in EOA has been replaced with a stronger lightweight steel design. The effective seating area has been enlarged and optimized with improved seats and stowage; and thermal and noise insulation has been added to the drivetrain bulkheads to better separate Marines from heat and noise sources. The SDD second generation prototypes have a higher performance hydraulic, air conditioning, and vehicle cooling systems that will deliver more capacity with improved reliability. The program has concentrated effort on improving the reliability of the system by identifying and fixing the root causes of reliability drivers. Overall the SDD prototypes will be better in every respect of operational effectiveness and operational suitability, and will incorporate improvements in other key areas such as maintainability, survivability, and safety, that will allow the design to make greater advancements towards the final production configuration. This report details the lessons-learned and deficiencies from the first generation prototypes identified in the Marine Corps Operational Test, Evaluation & Activity (MCOTEA) EOA report and provides information on how the next generation prototypes correct the lessons-learned and deficiencies.

I. AAAV Acquisition Discussion

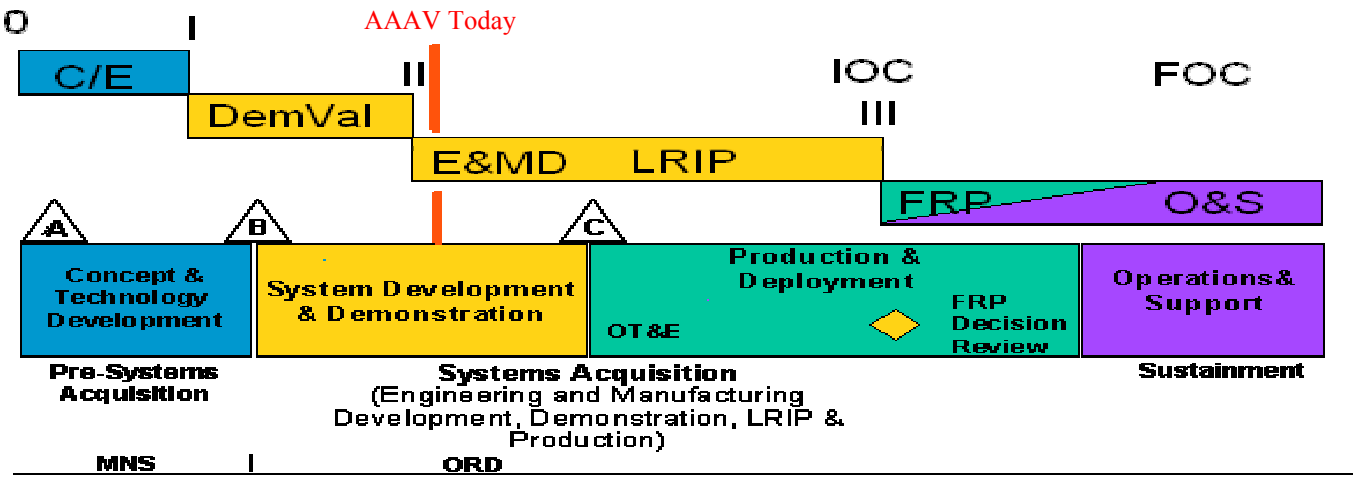
System Overview

The Advanced Amphibious Assault Vehicle program is the Marine Corps' largest and most significant ground combat development program. Designed to replace the current Assault Amphibian (AAVP7A1), as the principal means of tactical surface mobility for the Marine Air Ground Task Force (MAGTF) during both ship-to-objective maneuver and subsequent combat operations ashore as part of the Navy and Marine Corps concepts within the Expeditionary Maneuver Warfare capstone. The AAAV will provide the Marine Corps with the capability to execute the full spectrum of military missions from humanitarian operations to conventional combat operations. The capabilities integrated into the AAAV design represent a revolutionary step forward in Marine warfighting capabilities with "leap-ahead" advancements in water mobility, firepower, integrated and interoperable Command and Control systems, and survivability characteristics unparalleled in the US combat vehicle inventory. The AAAV is ensuring the Marine Corps sustains a dominant presence in amphibious and land warfare capability relevant to the emerging and future combat missions of the 21st Century.

AAV7A1	Performance	AAAV
5,000 Yards	Sea-Launch Distance	25 Nautical Miles (nm)
6 Knots	Water Speed	20-25 Knots
45 MPH	Land Speed	45 MPH
300 Miles (25 MPH/Land) 7 Hours (2,600 RPM) 270 Miles after a 5,000 Yard Waterborne Movement	Range	300-350 Miles (25 MPH/Land) 65nm (20 Kts/Water) or 150-200 Miles after a 25nm High Water Speed Transit
Hand Held GPS and Stand Alone PLRS	Navigation	Integrated GPS, INS, Compass and PLRS/EPLRS (Digital Map Displays)
M2 .50 Cal HB MG & Mk 19 Mod 3 40mm MG	Firepower	Mk 44 Mod 1 30mm Automatic Gun and 7.62mm Coax MG, Fully stabilized, Full Ballistic Solution, Laser Range Finder & FLIR
14.5mm (with EAAK Armor Kit)	Armor Protection	14.5mm @ 300 Meters 155mm Frag @ 50 Feet
None	NBC Protection	NBC Overpressure System (Crew & Embarked Personnel Protected)

AAAV and the Acquisition Timeline

The AAAV's acquisition is in accordance with the latest Department of Defense Directive for Major Defense Acquisition Programs, which govern the management, milestone phases and work efforts of the weapons development process. The Program is currently at the midway point of the detailed design phase, known as System Development and Demonstration (SDD), having recently completed the Milestone II process in December 2000. The next Milestone (C on the chart below) in FY2004 represents the entrance into Low Rate Initial Production (LRIP) and will be followed by the final Milestone decision to enter Full Rate Production (FRP) in FY2007. Each of the four development phases will produce a new generation of prototype vehicles incorporating the lessons learned from the previous phases' developmental and operational testing. The designs discussed in this report are the result of lessons learned over the last 34 months of water, land, and firepower testing as they are incorporated into the SDD 2nd generation prototypes under construction today. It should be noted that every finding in this August 2002 EOA report has corrective actions already incorporated into SDD prototype design as a result of the extensive Developmental Testing and Operational evaluations performed prior to the EOA.



Prototype History (PDRR – 1996-2000)

The three existing AAAV PDRR Prototypes (P1, P2, and P3) were designed and built during the PDRR (DemVal) phase. In a radical departure from traditional acquisition practice, each of these early first-generation prototypes was designed and built to contain every subsystem of the objective AAAV, integrated into a complete system. The primary objectives of the PDRR prototypes were to1) Prove the capability of key AAAV technologies on an integrated platform, and 2) Understand and resolve the considerable integration challenges of the brand-new AAAV design while the program was flexible

enough to make improvements relatively cost effectively. The level of detail in these early prototypes is far greater than is normally produced during this initial design phase of development, but were pursued to afford the program greater (and earlier) insight into the whole-system performance and human factors aspects of the system. It should be noted that the PDRR prototypes lack final configuration details (eg heat & noise insulation, seals, etc) with notable effects on human factors and the Marine-Machine Interface. Many of the findings described in the EOA report are a result of these prototype-specific deficiencies that have been aggressively corrected in the 2nd generation (SDD) prototypes.

PDRR PROTOTYPE DELIVERIES

P1 – December 1999

P2 –June 2000

P3 –November 2000

System Development and Demonstration (SDD) Prototypes

The SDD phase is producing 9 second-generation AAAV prototypes (8 P and 1C variant) and one pre-production live-fire vehicle. Similar to the PDRR prototypes but vastly more mature, these SDD prototypes will contain all hardware and software necessary for comprehensive system-level development and operational testing of both the personnel and command variant. The design effort is also concurrently improving the manufacturing and logistics aspects of the design leading to production. These prototypes will undergo extensive engineering and operational evaluations starting in CY03 in support of the CY04 MS C decision. Minor improvements identified through testing will be incorporated throughout the 11 months of SDD vehicle builds such that the final SDD prototypes will production representative for Low Rate Initial Production (LRIP) .

The Land Mobility Independent Assessment characterizes a number of engineering issues in general areas such as habitability, reliability, and suspension, among others. The corresponding engineering corrective actions for each significant finding is detailed in the following sections of the report, organized into common sections for clarity.

SDD Prototypes E1, E2,and C1 Under Construction

II. 2nd Generation SDD Design Improvements as a Result of Testing

The Marine Corps Operational Test and Evaluation Activity conducted a Land Mobility Early Operational Assessment of the AAAV in 1QFY02 at the Marine Air-Ground Task Force Training Center, Twentynine Palms, California. An AAAV prototype participated in events linked to Combined Arms Exercises conducted by 3d Battalion 5th Marines. The AAAV land mobility EOA was intended to provide in-stride operational insights on the early AAAV prototypes to the program manager during development. MCOTEA documented the Land Mobility assessment in an Independent Assessment Report (IAR). This document addresses the findings in that report.

A. Carrying Capacity

EOA Report Comments:

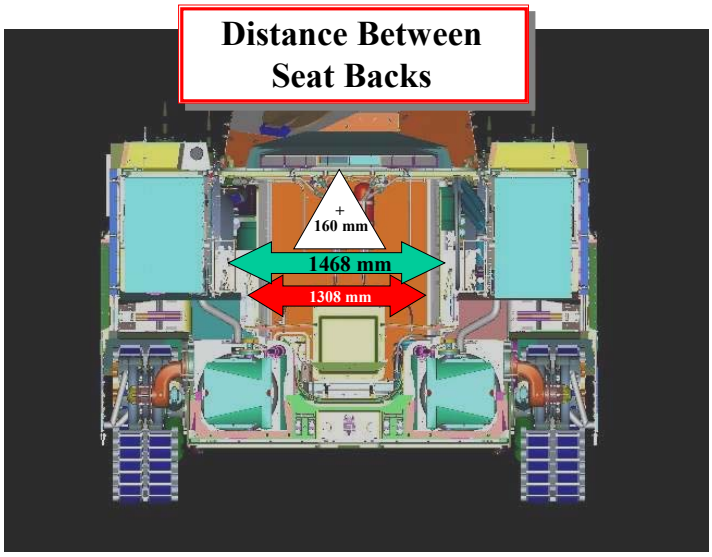
§4.1 "..Carrying the baseline squad is a tight fit. Adding bulky, non-standard equipment to the fighting load is problematic when contrasted with the current design…"
§5.1.a "..Improve the design of the troop compartment, making the focus of effort within the design and not space left over for embarked Marine use…"
§5.1.b "..Specific recommendations include3 maximizing the use of internal space, improving the seat design, …"
§5.1.c "…more space is needed for passengers. Inadequate head, leg, and shoulder room has the potential to adversely impact the ability of the embarked infantry to fight once they reach the objective..".
§5.1.e "..Aisle width was singled out as a limiting factor when debarking the vehicle..."
§7.2.3. "..Concerns surfaced during the Land Mobility EOA as to the ability of AAAVP to carry other loads found in the Marine mechanized task force…"
§8.2.1 "…The current seats do not provide adequate width and depth space for embarked personnel to sit properly while wearing their individual gear, …"
§8.2.2.a "…The aisle width does not allow for quick or easy embarkation and debarkation of troops..".
§8.2.2.b "…To enter the aisle seating, the troops must first face aft upon reaching sea 7 or 10, and then back into the aisle seating area…"
§8.2.2.c "…For Marines seated in the aisle, the width of the aisle at seat 7 and 10 is only 10 inches at the narrowest point at knee level…This choke point is further complicated by the storage of packs …"
§8.2.3 "…There needs to be more head space at the aisle seats…"
§8.2.4.a "…A detailed stowage plan needs to be developed for personal gear, weapons systems and ammunition to include appropriate strap down material…"
§8.2.4.b "…there were no load plans for the 81mm and 60mm mortars…[where would] the weapons and ammunition be stored and …safely and securely strapped down during vehicle movement?…"

Design Improvements

Internal Space Redesign:

Early in the User Jury evaluations of PDRR Prototypes, the program office realized the occupied space inside the AAAV needed to be better optimized for Marine habitability. Each of the above listed issues was identified through testing prior to MS II and work began months ago on optimizing the SDD internal space layout. As a result, the SDD design and prototype fabrication effort is focused on improving and preserving the Marine space claims (internal space for Marines was also a PDRR design priority, but was diminished during the fabrication process of the PDRR prototypes while locating the hydraulic, large cooling circuit, bilge, and AFES piping)

The *entire* occupied space of the AAAV has been redesigned and optimized to maximize space for the infantry and their prescribed loads. Every critical seating dimension has been stretched as far as physical constraints would allow, and the surrounding components have been precisely located so as not to affect Marine space. In addition, the stowage plan for Onboard Vehicle Equipment is being revised to make additional room for the Marines by moving items outside the occupied space. A summary of the overall dimensional changes are in figure 1 below. Without changing the overall vehicle envelope (limited by transportability), the SDD prototypes have wider aisleways (102 mm at the shoulders, 25 mm at the seats), rear troop seats 160 mm farther apart, increased headroom, lengthened effective rear seating area, completely redesigned seats (see seat discussion below) that are staggered to allow more shoulder and hip room, and have had the various egress catch/pinch points eliminated. A user jury will be conducted on the SDD configuration at the first opportunity (in CY2002) with an SDD prototype with all components installed.



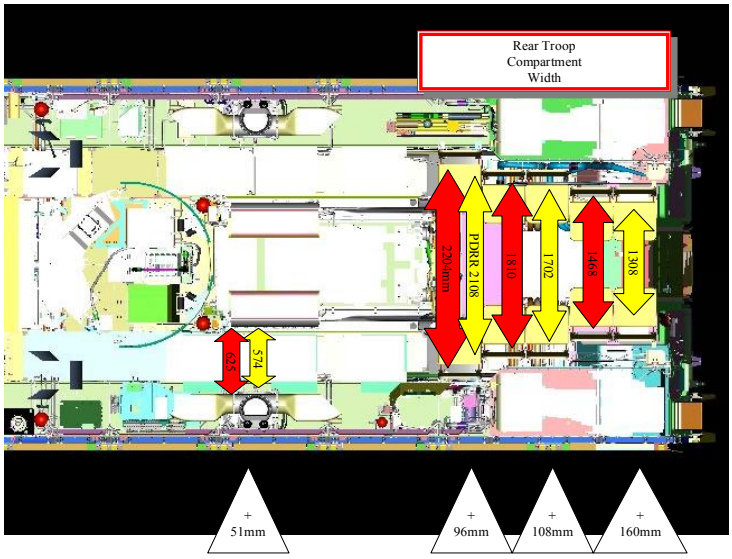
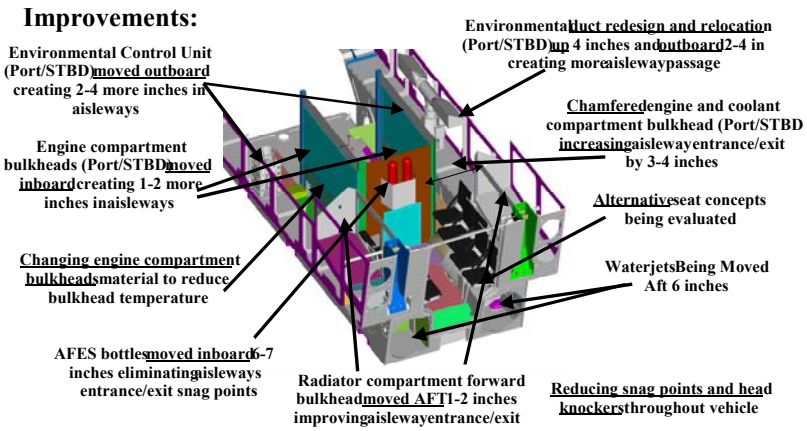


Figure 1 Troop Space / Comfort

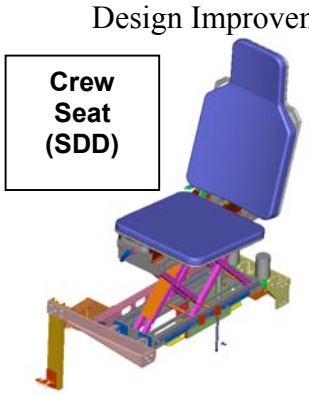


Seats

EOA Report Comments

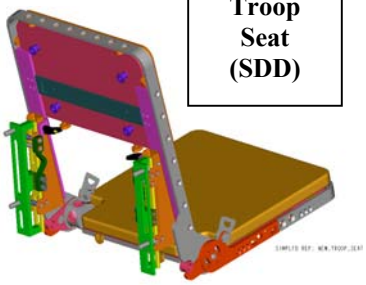
§5.1.d "..The Haagland seat received many negative comments when exposure was more than a few minutes..".
§8.2.1 "..The current seats do not provide adequate width and depth space for embarked personnel to sit properly while wearing their individual gear, …This gear prevents the individual Marine from sitting all the way back in the seat and also interferes with the Marine sitting on his right or left who have on the same gear.."
§8.9.3 "..The personal restraint system in the vehicle cannot be utilized when embarked personnel are wearing full gear…straps did not remain tight while traveling in the vehicle…"
§8.9.9 "…For the crew stations, it was recommended that the seats be able to lock at variable heights to support operation with closed or partially closed crew hatches..."

Design Improvements



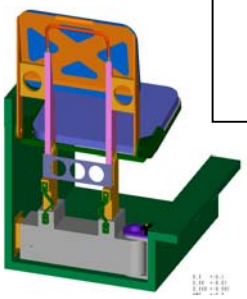
Crew Seats: The main problems identified regarding the Crew Seats dealt with the vertical adjustment mechanism and the restraint system. The limited seat space claim in PDRR resulted in a sub-optimized adjustment mechanism with various binding issues. In SDD, the seats utilize an entirely different scissors mount located directly below the seat. These seats will have up to 12 inches of vertical adjustment, lockable in 1 inch increments. The restraint system is now a proven commercial Federal Motor Vehicle Standard inertial reel that will allow either free or fixed mode operations. Comfort is also improved, as the seats will be designed to isolate and

dampen the vehicle vibration transmitted through the structure. In addition to isolating vibration, the seats have been designed with mechanical energy absorbers to protect the occupant from the effects experienced during a mine blast event.



Rear Troop Seat (SDD)

Troop Seats: The EOA confirmed the earlier findings regarding the inadequacy of the Hagglunds troop seats. The seats were being evaluated as part of a Foreign Comparative Testing program aimed at reducing weight and cost of the seats, however due to the dissatisfaction of the Marines these seats are no longer being considered for use in the AAAV. Instead, the rear troop seats have been redesigned and repositioned to provide more headroom and legroom, more comfortable and operationally suitable seatbacks (with a lower back cutout for the individual's gear), improved pans, and stronger return springs. The aisleway seats are redesigned to be wider, they also include the lower back cutout for the individual's gear, and fold away tighter and more efficiently while remaining operable with a single hand. These modifications combined with the other design enhancements result in an increased aisleway space of: 102 mm at the shoulders, 102mm of headroom, and an 25mm (~1 inch) wider but much cleaner aisleway for egress. Prior to the next assessment, an extensive user jury will evaluate this new seat design to ensure all major issues have been resolved with this design. Both troop seats are provided with mine blast attenuation capabilities similar to the crew seats.



Aisle Troop Seat (SDD)

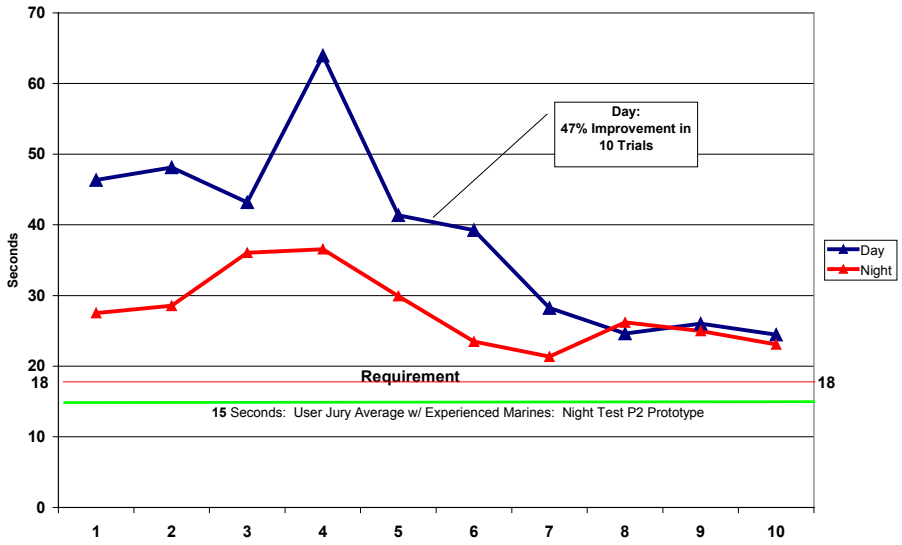
<u>EOA Testing Considerations</u>

The results of egress trials vary from the predicted performance, which may have been caused by unfamiliarity with the AAAV Prototype and it's specified loading / egress procedures and techniques. For example, due to necessary positioning of the water propulsion units the AAAV ramp will never be able to facilitate speed/volume egress of the AAV, however it is adequate based on established requirements and demonstrated performance of experienced Marines under similar conditions. The following are some of the lessons learned regarding the other factors of the test that affect performance:

Training and Experience:

The effects of training and experience are apparent in the egress times. Over the course of the EOA test, the data showed a significant improvement in egress times as the infantry familiarized with the AAAV as shown in Figure 2 below. During User Juries on the same prototype with the same loads (17 Marine Rifle Squad/MachineGun team, corpsman), experienced and motivated infantry were able to egress at night on average of 15 seconds with nearly identical loads. Future assessments will emphasize training and egress practice to allow Marines to familiarize with the AAAV.

Figure 2: EOA Egress Times with P2 Prototype



Load Planning and Load Outs:

The AAAV is similar to aircraft in the sense that the design is sensitive to loading configuration and distribution. To maintain an acceptable Longitudinal Center of Gravity (LCG) for hydrodynamics, loads must be carefully planned and executed in accordance with established load plans. For EOA the program had defined the basic load plans for the 17 Marine Rifle /Machine Gun/Corpsman squad. The 60/81mm Mortar and Javelin teams load plans are a work in progress and were not complete at the time of the EOA. Testing of the 60/81mm Mortars and the Javelin team were to support the development of load out plans, which will be done for all future SDD assessments. The EOA identified specific issues with the stowage of the camouflage net. The camo net intended for the AAAV will be specially configured to be stowed along the perimeter of the top deck and vertical edge of the vehicle. That net is being developed and was not available for the EOA. Should the intended camo net not prove to be feasible/available for future operations, a standard configuration camo net will be used and will most likely be stowed on the rear of the turret using straps and footman loops . The stowage of the camo net was not considered by the Program Office to be a major issue at the time in the face of other priorities. This was explained to MCOTEA and DOT&E at the Test Readiness Review prior to the EOA. However, DOT&E directed the stowage of nets inside the vehicle at EOA despite this explanation and an agreed upon test limitation precluding camo net stowage on the prototype at any time. EOA findings corresponding to the interferences with the stowed camo net are not addressed in this report, although it is known that results were adversely effected by the DOT&E mandated use of these items in the loads.

B. Reliability of Prototypes

EOA Report Comments

§4.2.a The reliability and durability of the vehicle demand further attention and improvement.
§4.2.b The vehicle never completed carrying the baseline squad from the Assembly Area to the objective during the four OMPs attempted.

In terms of overall Reliability management, the AAAV program is working towards demonstrating the ORD requirements for Mean Time Between Unscheduled Maintenance (MTBUM) of 30 hours and Mean Time Between Operational Mission Failure (MTBOMF) of 70 hours. At this early stage of the program's development, the PDRR prototypes are simply expected to provide an initial starting point for the reliability growth program such that the subsequent design iterations and prototype performance will, by the time the AAAV goes to production, demonstrate the necessary reliability goals to meet the ORD requirements. The causes of the low initial PDRR prototype reliability are a product of the steep initial learning curves in the areas of quality, fabrication, maintenance, and operator experience that any new design must overcome. To accelerate the program's understanding and corrective actions to these early "burn-in" issues with fabricating and testing prototypes, the SDD design effort has focused on the specific areas of the design that were identified as reliability drivers. As a result of the extensive testing and documentation of test incidents, the program has highly detailed reliability information down to the piece part level to identify specific reliability drivers affecting the system performance. For SDD, corrective actions are in place for major prototype reliability drivers, and already the PDRR prototypes have experienced a threefold improvement in overall system reliability due to these efforts since the start of testing. In addition, the findings of higher-than-required Mean Corrective Maintenance Time are due to the learning curve and completeness of the Integrated Electronic Technical Manuals (IETMs)as well as the inexperience of the crews, all of which are being improved through continuous User feedback and verification and validation of the AAAV IETMs. Only a small subset of the AAAVs IETMs were developed for the Early Operational Assessment (EOA) so an evaluation could be made on the technical manual content and presentation of information. The IETM plan is to generate a complete, validated and verified IETM package for the Initial Operational Test and Evaluation (IOT&E).

In the case of the EOA events, the primary reliability failure can be grouped into three general areas: hydraulics failures, track failures, and electrical malfunctions. The hydraulics failures are likely due to contamination from field repairs. Failure investigation indicates EOA Marines (which included one Marine from the program office) introduced dirt into the hydraulic system while changing out a radiator cooling fan during routine maintenance. It is highly likely this contamination led to follow-on failures in the cooling fan, track tensioning mechanism, hydraulic pump, and ramp lowering problems over the course of the EOA. A detailed discussion of the corrective actions is in the hydraulics section below. The track and suspension failures fit the known failure modes. The corrective actions for the track failures are discussed in detail in the Suspension and Land Mobility section below. The third EOA reliability driver was electrical power management. The PDRR prototypes have developmental electronics boxes (not yet fully qualified), that have difficulty with low voltage

and high temperature operation. This was noted early in developmental testing . Selected fixes were implemented but not all required to resolve the total power management issue. Details of the corrective actions are in the electrical discussion below.

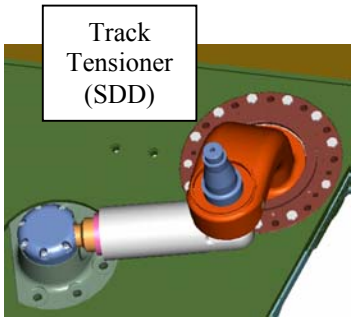
C. Suspension & Land Mobility

EOA Report Comments

§4.2.c The track and suspension failed numerous times when operating over difficult terrain encountered at FINEX….These track and suspension failures included the track disintegrating, the suspension not holding tension, and the track falling off the vehicle.

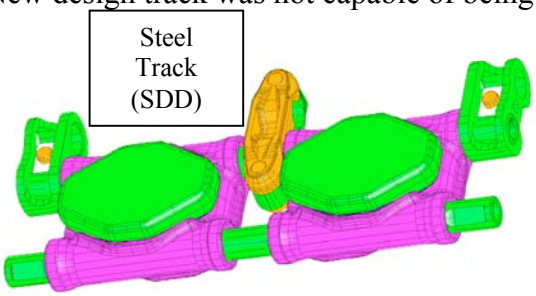
§5.3.a Improve the suspension of the vehicle…
§5.3.b …the AAAV prototype performed well on flat and open ground, but as the difficulty of the terrain increased, it was unable to stay up with the M1A1 or AAV RAM/RS.
§5.3.c …fix delamination problems on idler and road wheels…
§5.3.d …improve durability of track…
§5.3.e …provide crew with feedback when HSU or ITTs are not functioning as designed.
§7.2.2.a The prototype track and suspension lacked the durability to negotiate rough terrain…crossed by both M1A1 and AAV RAM/RS.
§7.2.2.b Suspension and track problems were interrelated and combined to reduce AAAVP system reliability to the point that it never completed and OMP.
§8.4.a The suspension of the vehicle must be improved to maintain travel speeds with the M1A1 MBT on cross-country terrain.
§8.4.b …the AAAVP had difficulty in maintaining pace while traveling over cross-country terrain…the AAAVP dropped back 100m for every 1000m traveled.
§8.4.c. The aluminum track must be improved to be more durable and reliable.
§8.4.d … the track was thrown four separate times and caused extensive damage.
§8.4.e The #1 HSU must be better designed to absorb more shock. This HSU becomes worn quickly and tension is lessened.
§8.4.f The idler wheels and road wheels tended to become delaminated.
§8.4.g …there is no automatic error message that is prompted on the Driver Display Panel (DDP) when there is a failure of #1, #2, or #7 HSU and ITT.
§8.4.h The track shroud pins need to be redesigned so that they will not become unseated during vehicle movements. …these pins came loose and fell off.

Design Improvements:



The track used on the P2 prototype during EOA was an aluminum double-pin design optimized for minimum weight. The particular track design had successfully passed a 3,000 mile standardized track durability test at ATC on mixed terrain and was thought to be durable. However, during early DT testing at 29 Palms prior to EOA it became evident that

this particular track design was unsuitable for use on the extremely rocky desert terrain. New design track was not capable of being procured in time to support the EOA. Two sets of backup aluminum track were shipped to the EOA from the program office to support EOA, which also showed unacceptable durability. Two designs are under consideration. First, a new steel track design has been developed which significantly improves durability. The use of steel in place of aluminum provides a significant improvement in fracture toughness allowing high-speed rock impacts without track block damage. The first set of this track is expected in July 03, and will also include design characteristics to improve the ride quality and reduce vibration (see vibration discussion below). It will then be installed on the SDD prototypes, and run through the same terrain as the failed track to ensure the design improvements are sufficient. In the meantime, we plan to conduct testing on a aluminum track of similar design under the Foreign Comparative Test (FCT) program. This track is now in-house and testing will begin in the near future.



Other suspension improvements include changes to the track tensioner, HSU, support rollers, and roadwheel tires. The track tensioning system has a new and improved actuator, idler arm and wheel, which will improve hydraulic reliability. HSU durability has been improved through redesigned retraction seals, an improved connecting rod, a retraction off switch, improved position sensor and pressure transducer, redundant remote intensifiers, and miscellaneous other improvements which will improve suspension reliability. Support roller mounts and the sprocket carriers have been strengthened. Improved tire bonding processes are now being used. Also, new tire materials and bonding processes from two additional vendors are being tested and evaluated. The overall result will be a significant improvement in suspension system reliability, durability and performance.

The AAAV is designed specifically to keep up with the M1A1 in cross-country terrain. Although a front sprocket vehicle (AAAV, AAV RAM/RS) is inherently less capable over rough terrain than a rear sprocket vehicle (M1A1) because it generally must slow down and/or cross-steer over certain terrain and obstacles, prior analyses and limited ride quality testing indicate this requirement can be met. However, the suspension durability problems cited in the report prevented the AAAV from achieving full capability while travelling cross-country. Additionally, ride quality is being improved through optimization of the AAAV's software controlled damping and a stiffer front suspension (higher gas charge in forward HSUs), which will help maintain ground clearance. The specific design solutions described above will address the land mobility durability and performance shortfalls. Comprehensive testing of the SDD prototypes will validate these changes and demonstrate the AAAV's ability to keep up with the M1A1 tank.

D. Internal Heat

EOA Report Comments

§4.2.d ECS unable to keep temperatures within established safety limits
§5.2.a Improve ECS to cool the vehicle below 90°F
§5.2.b Increase the cooling capacity of the ECS
§5.2.c Improve the circulation throughout the troop compartment
§5.2.d Improve the reliability of the ECS
§7.2.1 ECS ineffective in cooling embarked Marines to required safe temperatures…preventing the vehicle from supporting Marines in executing OMFTS and STOM
§8.1 Improve ECS to cool vehicle below 90°F. Marine seated in seat 10 receives a large volume of cool air aimed directly at his head; persons sitting by ramp door receive no air. Distribution and circulation of cooled air needs to be such that all personnel receive cooled air

Design Improvements:

Early on during the initial testing of the PDRR vehicles, it became obvious that there were problems associated with maintaining an acceptable interior heat in the crew compartment of the vehicle during operations. The causes of the high temperatures in the crew compartment were a combination of the following:

- Heat loads in the vehicle from mechanical and electrical components were not well defined and greater than projected.
- The ECS manufactured by Western Design did not provide the amount of cooling required by the specification.
- Insufficient hydraulic fluid flow was available to run the engine cooling fans and ECS simultaneously, at all engine RPM. ECS shifted from cooling to only ventilation when vehicle RPM went below 1350 and turned back to cooling only when the RPM went above 1450 for 10 seconds. This shifting was frequent when operating in the land mode. These RPM limits were for the vehicles equipped with the higher hydraulic flow PDRR pumps.

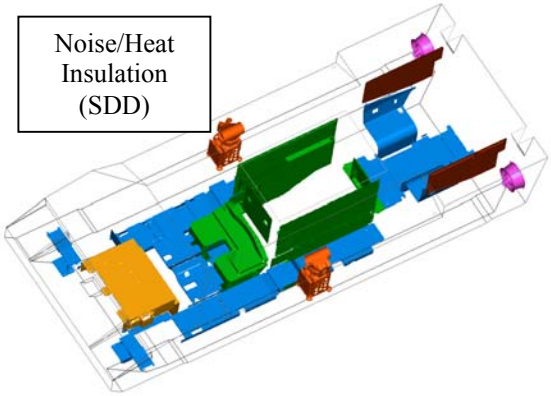
To address this internal heat problem, during the past year emphasis has been placed on improving the design of components throughout the vehicle that in any way effect the generation of heat in the vehicle, contribute to internal environmental control, or are hydraulically powered. Considerable resources have been devoted to this problem since it impacts the health and fighting ability of the vehicle crew and the embarked Marines. These changes will allow for better environmental control to ensure that the internal temperature of the crew compartment can be maintained at or below 85°F. These design changes include the following:

Environmental Control System (ECS):

- A new full and open competition was conducted for the SDD ECS and Fairchild Controls was selected to design and manufacture the system.
- Fairchild Controls has had experience in the design and production of similar systems for military and civilian applications.
- Common and interchangeable Air Handling Units (AHUs) and Compressor Motor Units (CMUs) provide more balanced and uniform airflow in the crew compartment and contribute to the improved RAM-D of the ECS.
- More efficient compressors and motors have reduced the required hydraulic flow for the system from 32 gpm to 23 gpm.
- Adjustable airflow deflectors are being placed in all vents to allow the air to be directed to areas needing increased ventilation or cooling.
- Data from lab acceptance testing of the first SDD ECS units delivered by Fairchild Controls shows that their system meets the requirements.

Other Vehicle Systems:

- Larger capacity hydraulic pumps, 3.75 cu in vs. 3.00 cu in, are being designed and procured. These pumps are also two-speed units that will provide greater flow over a wider range of engine speed and hydraulic demand. This change, along with decreased demand from some vehicle components, should provide the hydraulic capacity to run the ECS at the same time as the cooling fans and provide uninterrupted cooling while in the land mode.
- The PTM and heat exchanger are being designed as an integral part of the engine compartment. This will vent the majority of the heat generated by these components out of the vehicle through the engine compartment.
- Noise and heat insulation are being added to the following to reduce the heat transferred to the crew compartment;
  - PTM Cover
  - Engine Compartment
  - Transmission Compartment
  - Engine Cooling Compartment
- Improved decking will reduce the heat transferred to the crew compartment from the components in the sub-floor.
- Engine cooling fans have been reduced from four to two and the new design of the fans has reduced the required hydraulic flow from 40 gpm to 32 gpm at sea level.
- Engine coolant lines have been rerouted and insulated to reduce the heat transferred to the crew compartment.



E. Noise / Vibration

EOA Report Comments

§8.9.4 Internal vehicle noise needs to be reduced. The embarked troops were required to wear double hearing protection. The noise levels also prevented any verbal communications between the embarked squad, making SA more difficult.

Design Improvements for Noise

Prior to the land EOA, noise measurements were taken inside the PDRR prototypes that were in excess of 100dBA (see "PDRR Land Mode Measured" in figure 3). Based on these measurements suitable double hearing protection for both the crew and embarked infantry was obtained, tested, and finally recommended for use in the AAAV. Compared with data measured in the AAV the AAAV prototype is noisier, however, both vehicles are well above the threshold requiring double hearing protection (100dBA). Therefore, there is a similar operational issue with the AAV.

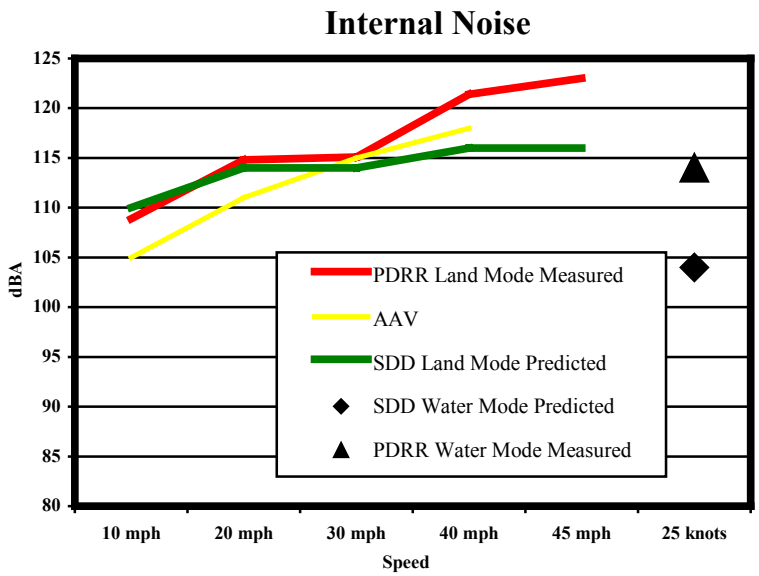


Figure 3

Regardless of how the AAAV prototype compares to the AAV the internal noise must be reduced. To address this several design changes have already been made and will be included in the SDD prototypes:

- Suspension
  - Polyurethane vice soft rubber as a backing material on the track
  - Road pad changed to minimize vibration
  - Spacing between track blocks reduced
  - "Quiet" sprocket tooth profile being designed

- New ECS system from new vendor is much quieter
    - PDRR installed 95 dBA vice 83 dBA for the SDD unit
- Number of cooling fans reduced from 4 to 2
- Engine/PTM will be fully enclosed in an insulated compartment
- Cooling fan compartments and transmission compartment will be insulated

Detailed analysis has been performed on the SDD design and the results show a dramatic improvement (see "SDD Land Mode Predicted" in figure 3). Based on these preliminary analyses further changes are being explored such as changing the stiffness of the engine/PTM mounts and further quieting of the ECS system. Analysis will continue to determine the effect of these additional changes. Sound measurements will then be taken in the SDD prototypes during testing to validate the predictions.

These improvements will greatly reduce the internal noise of the SDD prototypes, however it is expected that the internal noise will be ultimately be comparable to other tracked combat vehicles such as the AAV RAM/RS, AAV P7A1, and M2 Bradley. It is likely that hearing protection will be necessary for occupants of the AAAV. The program will continue to aggressively pursue sound reduction technologies through the remainder of development.

EOA Report Comment

§7.2.4 Several comments from the embarked infantry regarding the problem of limbs falling asleep while sitting in the troop compartment of the AAAVP indicated that additional design refinements are needed.

<u>Design Improvements for Vibration</u>

Efforts to reduce vibration: During developmental testing as well as EOA it was noted that the PDRR prototypes exhibited high levels of vibration during some operational regimes. Following EOA, dedicated vibration testing was performed on the prototypes, which confirmed these observations. This issue is caused by two problems, seat design, which is discussed under the habitability section, and vibration. To address this issue several design changes are being made and will be incorporated into the SDD prototypes:

- Track backing material and roadwheel tire are being made from the same materials
- The sprocket is being redesigned to lower noise and vibration
- The new steel track has been modified to reduce the spacing between blocks and to widen the road pad surface
- Crew and troop seats will be designed to reduce the level of vibration actually felt by the personnel

These improvements should result in significantly lower levels of vibration. However, as with the internal noise, it is unlikely the AAAV's vibration level will be significantly below that of other tracked combat vehicles such as the AAV RAM/RS, M2 Bradley, etc. Analysis will continue to determine the effect of these changes and vibration

measurements will then be taken in the SDD prototypes during testing to validate the predictions.

F. **Hydraulic System**

EOA Report Comments

§8.5.a Improve reliability of the hydraulic system. ITT and HSU tend to lose hydraulic pressure, causing track tension to be lost. It was specifically noted that the valves were not reliable and wore quickly.

Design Improvements

A Revised SDD Manifold installed in E1

Manifold reliability problems can be broken down into four general categories: Valve leakage and failure, leakage at the fittings, contamination, and electronics failures. Valve leakage and failures have been one of the larger reliability concerns with the PDRR prototypes. The SDD design will incorporate more robust seals and back up rings that will reduce leakage past the valves and improve the reliability of the valves. These new designs have recently been retrofitted into the PDRR vehicles and have resulted in a 75 percent decrease in manifold failures in the PDRR prototypes over the last six to eight months. To address leaking at the manifold, fitting assembly and repair procedures have been updated to include proper torque values and procedures. Additionally, intensive training has been provided to assembly and repair personnel. The combination of these two improvements have reduced incidents of line fitting leaks by 80 percent in the PDRR prototypes over the last six to eight months. Contamination is an assembly / maintenance induced failure that accelerates failures throughout the hydraulic system (manifolds, fans, hydraulic motors, etc). Assembly, repair, and maintenance procedures have been aggressively revised to reduce the possibility of introducing impurities into the hydraulic system. To address electronics failures in the SDD manifolds, the electrical hardware has been improved to eliminate shorting and overheating. Additional electronics protection includes fuses and a separate circuit card controlling the engine cooling fan valve, which was a high failure rate item. These changes have been incorporated into the SDD design and are being retrofitted into the PDRR prototypes as schedules allow.

The SDD designs will incorporate more robust pumps with greater flow to better match the operating profile and actual peak demands under extreme conditions. These loads have been verified through a hydraulic load study using PDRR actual measurements. The manifold relief valves are stronger in SDD to match the greater pump capacity. Additionally, the use of hydraulic accumulators is under investigation as a means to absorb the pressure spikes. Hydraulic check valves have been redesigned in SDD, specifically to address the problems experienced with the “drifting” of the ITT actuator.

Many other changes, including bleed vales to purge air and water from the system are being considered as further improvements to the SDD design.

System flush and assembly procedures to ensure the cleanliness of the hydraulic systems are now incorporated into the quality assurance plan and will serve to reduce manifold failures significantly. System flushes will need to be accomplished regularly. The reduction of debris in the system will extend the life of spool valves and reduce the number of pilot valve and solenoid failures. The cleanliness requirements will be applied to all new and modified systems and a predictive maintenance program that includes regular sampling of the hydraulic oil is being evaluated.

A leak detection system capable of identifying and isolating hydraulic leaks is being developed. This system will identify a leak and shut the leaking subsystem down in time to prevent the leak from discharging all of the hydraulic fluid and potentially damaging the hydraulic pumps or manifolds, as well as preserving needed functionality within the rest of the system.

EOA Report Comments

§8.5.b The method for refilling hydraulic fluid needs to be improved so that refilling the hydraulic reservoir can be conducted under ambient conditions.

Design Improvements

The hydraulic system for the AAAV is a pressurized system and the reservoirs cannot be "topped off" as is commonly accomplished on open hydraulic systems. Many other hydraulic systems include reservoirs that are not pressurized including gravity fed hydraulic power units. A charging cart is currently being developed to supply hydraulic fluid to the system under pressure. A manual method of adding fluid, that does not use a manual hand pump, is also being investigated so that the crew can conveniently add hydraulic fluid as needed.

G. Electrical System (Slave Starting, APU, battery charging, etc)

EOA Report Comment

§8.6.1: The vehicle needs the capability to be slave started.

Design Improvement

Concur with the requirement to slave start the vehicle in an expeditious manner. DRPM will confer with MCCDC to clarify the operational requirement, then study the necessary design changes during SDD to implement the clarified requirements for the LRIP design.

EOA Report Comment

§8.6.2: The batteries need to be more reliable.

Design Improvements

Several design improvements in SDD have been made to address the battery failures:

- To mitigate the battery failures due to high temperatures, the batteries were relocated from the port to starboard side of the vehicle to isolate them from the high temperature hydraulics components. Further subfloor heat analysis will be performed during SDD to ensure the batteries used in AAAV match the operating (environmental) requirements.
- The vehicle electronics and auxiliary batteries were separated into individual battery boxes.
- For SDD, the battery negatives are independently wired to eliminate the single point failure of any single battery effecting the entire system.
- The battery terminal attachments have been modified to reduce the vibration damage to the connectors.
- The effects of low battery voltage on overall battery life and recharging with the these type of batteries are better understood and preventive measures to reduce low voltage conditions will be incorporated into the testing and maintenance procedures.
- The AAAV program is exploring other alternative batteries should the need for higher performance batteries be necessary (to be determined during SDD testing).

EOA Report Comment

§8.7.1 The "Power Management Menu" screen must appear when trying to enter Silent Watch mode from the driver or VC display panels.

Design Improvement:

Concur with the operational requirement for the crew to properly enter Silent Watch. DRPM will review the requirement to allow the operator additional power control to selected subsystems during silent watch.

EOA Report Comment

§8.6.3.a The APU will not bring the batteries to a full charge after they have been discharged.

Design Improvements

The APU supplies up to 28 Volts at the batteries, and is, therefore, fully capable of re-charging healthy batteries to a full charge of 24 Volts. When batteries are catastrophically damaged due to vibration, exposure to heat, or improper use (see response to 8.6.2), then it is not possible to fully charge the batteries by any means. In

most incidents, the batteries become drained below the current required to start the engine, in which case the batteries need to be charged. Fifteen minutes of charging should be sufficient to fully re-charge healthy batteries when moderately discharged.

§8.6.3.b …if you operated the APU long enough to bring the batteries to a full charge, the APU would overcharge the batteries and result in their failure.

Design Improvements

The EOA Marines observed that the batteries often became hot when they attempted to charge them with the APU. Initially, they believed that the APU was overcharging the batteries. After investigating the problem, we concluded that the APU does not overcharge the batteries.

H. Misc

<u>BIT / SW</u>

EOA Report Comment

§8.7.4: Soft Reboot Capability: ..The vehicle needs to have the capability to conduct a soft reboot on individual subsystems without affecting other systems.

Design Improvement:

Concur with the need for a capability to conduct an expeditious reset on selected individual subsystems. DRPM is studying the system and subsystem design impacts to the vehicle architecture and power system to evaluate the need and feasibility of incorporating this capability.

<u>Headlights</u>

EOA Report Comment

§8.8.6 The…headlights need to be positioned so that the light will not bleed over the driver, but rather the light should be positioned in front of the driver.

Design Improvement:

Human factors will be reevaluating the headlight positioning and hampering to the driver's vision in the SDD design. Alternative lamps, such as the light emitting diodes (LED) solution, are also being evaluated by human factors.

Egress Lighting

EOA Report Comment

§8.9.7 Recommend the egress lighting concept be kept in the final design…the lighting must cover all troop compartment areas and crew positions.

Design Improvement:

The egress lighting will be incorporated in the final design.

Rear Display

EOA Report Comment

§5.1.f …a flat screen in the back to allow the embarked Marines to view the map display would improve the SA of those Marines prior to exiting the vehicle.
§8.2.5…A flat screen needs to be located in the aft portion of the troop compartment to improve SA of…the troops.

Design Improvement

The requirement for a flat screen display located in the troop compartment is not currently in the AAAV design as it is not in the Operational Requirements Document. DRPM will confer with MCCDC to clarify the requirement and develop Tactics, Techniques and Procedures (TTPs) for FIST teams while embarked aboard AAAV(P)s. Those evaluations will consider a range of solutions from FIST teams operating from a single AAAV(P) to a distributed solution with FIST team members located in multiple vehicles. The addition of a display screen and alternative solutions in the troop compartment will also be reviewed for design and operational impacts.

Improving the TC Station

EOA Report Comment
8.3: The TC station must be improved by moving the TC display screen to the center of the station and be fully operational to include moving map display.

Design Improvement:

Based on Human Factors Engineering (HFE) analysis the display has been redesigned and repositioned for the SDD prototypes. The displays have been located forward and angled to optimize viewing and man machine interface within the constraints of the hull. The display is fully functional providing Situational Awareness (SA) through the Command and Control Personal Computer (C2PC) application mandated in the Marine Corps C4I architecture and fielded within the Marine Corps operating forces.

Dust In the Driver's face

EOA Report Comment

§8.8.2 During forward movement, dirt and dust is channeled from the top front part of the track into the back of the bow flap and ultimately is discharged into the driver's face. This reduces the driver's visibility.

Design Improvement

The root cause of this problem is thought to be a gap between the bowflap and the track skirt. Other contributors are being investigated to influence the final configuration of all dust shields and gap fillers and will be in the SDD design configuration. The P2 prototype used in the EOA did not have the proper components installed, however video, pictures, and operator interviews regarding this issue are being used to shape the final configuration of the components needed to prevent this phenomenon on future prototypes.

Driver's Display:

EOA Report Comment

§7.2.4 The driver's thermal sight…still requires refinements…

Design Improvement

The Driver's Thermal Viewer currently uses the sensor procured by the Army under an omnibus contract for night driving vision enhancement. Deficiencies have been noted and efforts will begin early in FY 03 to identify and procure next generation systems for use on the SDD vehicles, as technology and cost constraints permit.

Bustle Rack

EOA Report Comment

§8.8.7 A bustle rack needs to incorporated with the weapons station that can be used for the netting system or sustainment packs and gear.

Design Improvement

The optimal configuration for on-vehicle-equipment is being finalized for SDD. The solution will involve a mix of interior and exterior stowage in accordance with the signature requirements of the AAAV. The program office's desire is to be able to stow all gear interior to the vehicle to support water operations. Exterior stowage for extended land operations is being explored. A bustle rack is among the alternatives under consideration.

I. Fuel Tanks – sensors, external protection

EOA Report Comment

§8.7.3 The embarked crew had no means of determining the vehicle's fuel level from inside the vehicle.

Design Improvements

AAAV P-2 did not have operational fuel sensors at the time MCOTEA conducted their assessment. Since EOA every PDRR prototype vehicle has operational fuel sensors in all three fuel tanks with fuel level displayed on both the driver's and vehicle commander's displays. All SDD vehicles will have this same capability.

EOA Report Comments

§8.8.8 The external fuel cells need to be completely covered by metal to prevent exposure, which might result in a perforation of the cells.
§8.9.8 The TT expressed concern about the survivability impact of having the fuel cells on the top of the vehicle. Loss of this fuel due to battle damage has the potential to reduce the range of the vehicle…

Design Improvements

Although we plan to cover the SDD external fuel tanks with 0.060-inch thick aluminum (same as the PDRR fuel tanks), the purpose of the metal covering is to reduce the AAAV IR signature and to provide a ground plane for the conformal SATCOM antennas that are mounted on the tanks. The fuel tank passed the tank bar drop test from one meter with no damage and is deemed sufficiently damage tolerant for most foreseeable events. A self-sealing ballistic liner will be incorporated into the external SDD fuel tanks for protection against small arms fire.

<u>Armor</u>

EOA Report Comments

§8.8.1 The edges of some armor panels were pulling away from their mounting. This was particularly noted directly over the track on port and starboard sides.

The damage referred to here was not to the armor panels themselves, but to the sheet metal cans which the armor is packaged in. The tracks were contacting the sheet metal and pulling it away from the armor. The armor cans in SDD have been increased in thickness from .025" thick to .040" thick aluminum and the armor panels will be bonded into the cans to provide a significantly more durable design. In addition, the exposed portion of the armor will be adjusted so as not to interfere with the track.

Ramp/Door

EOA Report Comments

§8.8.3.a The ramp is too steep, too narrow, and does not touch the ground.
§8.8.3.b …the most aft deck plate is positioned at an angle and is a trip hazard.
§8.8.4 Individuals embarking the vehicle from the ramp personnel door must be assisted by other personnel…due primarily to the location of the foothold and the height of the personnel door from the ground..

Design Improvements

The width of the ramp (33.3") is limited by the space between the waterjets. The egress of the vehicle is necessarily one at a time due to the width of the rear walkway. As shown in Figure 4, the slope of the ramp is 19° when deployed on level ground, and conforms to requirements for a ramp (acceptable for any slope equal to or less than 20°) as guidance from OSHA. In order to conform to this requirement, and in order to reduce degradation of the aluminum ramp frame, hard rubber stoppers are mounted on the outside of the ramp provide the interface between the ramp and the ground. Due to this approach, there is a resulting six inch step at the end of the ramp. This step should not present any undo trip hazard for either embarking or disembarking troops.

The flip-down step used to ease entry and exit through the personnel door does serve the intended function. However, the overall effectiveness of the step is hampered by the limited space available to mount it and the sloped nature of the rear wall. A redesign is underway to improve the effectiveness of the step.

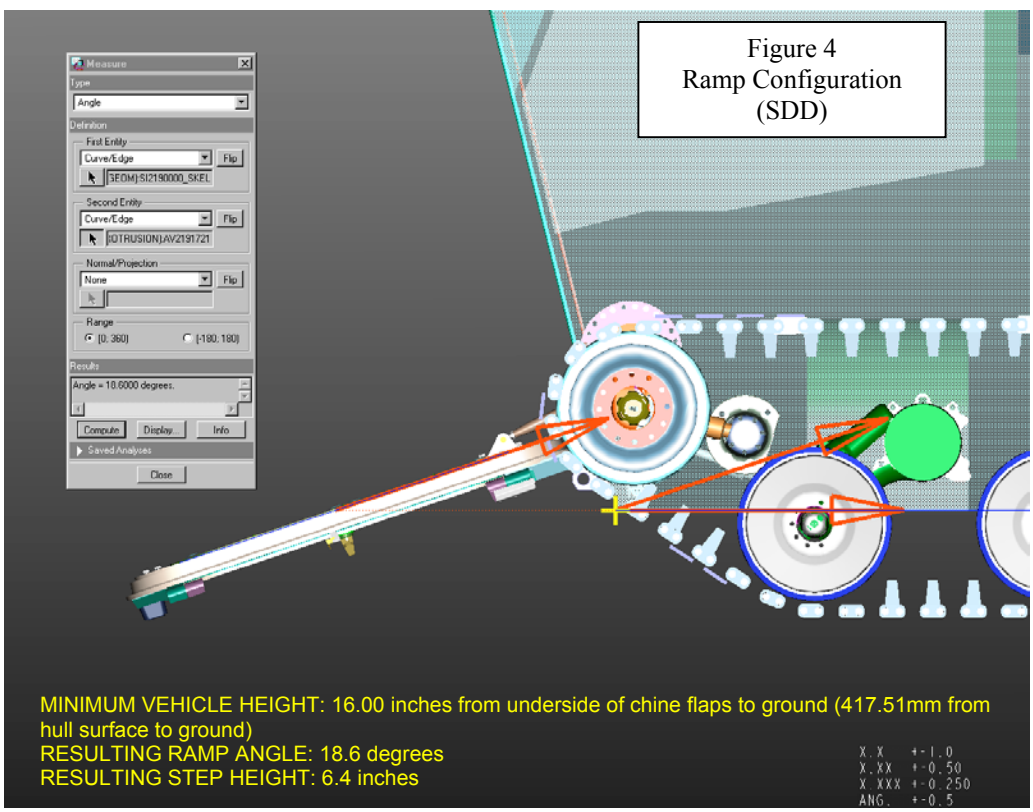


Figure 4
Ramp Configuration
(SDD)

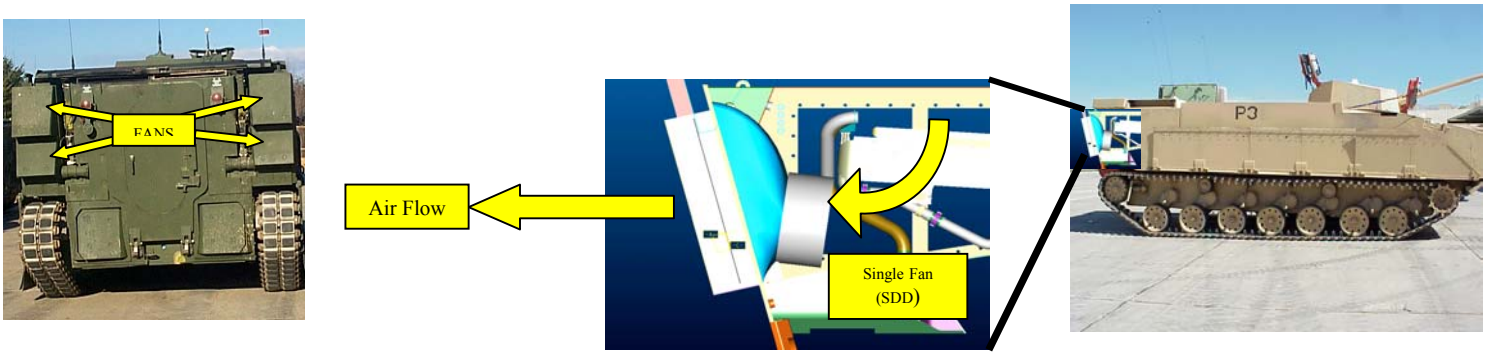
Cooling Fans

EOA Report Comments:

§8.8.5.a The rear cooling fans need to be redirected. When the vehicle is operational, the air forced from the fans creates a dust cloud behind the vehicle that creates a significant dust trail.
§8.8.5.b These [rear cooling] fans turn on automatically, causing safety concerns, when the vehicle is operational and static, such as loading infantry.

Design Improvements

In the PDRR prototypes the engine cooling fans are mounted directly to the rear of the vehicle with the airflow directed down to the ground. This design picked up dust and debris and blew it rearward. This caused a significant dust signature and would potentially blow debris into disembarked infantry or crew. Additionally, personnel could injure limbs or fingers in the event they were in contact with the fan and they turned on automatically. In the SDD design the fans will still turn on automatically, however, they are installed within the cooling compartment behind ballistic grills, making it nearly impossible for personnel's fingers or limbs to be in contact with the fan. Additionally, the airflow is directed up 5 degrees with respect to the ground, which will result in dramatically less dust and debris being blown rearward. This should reduce the AAAV's unique dust signature to match other tracked vehicles and significantly reduce any risk of debris being blown into disembarked infantry or crew.



EOA Report Comments

§7.1. Analysis of the factory training as well as lessons learned need to be analyzed by the AAAV Transition Task Force in detail. Developed curriculum should go through an Instructional System Design Process MILSTD 1379-D. The results should also be used to develop the Training and Readiness Manual. Training packages should be submitted to the AAAV Transition Task Force for review prior to any additional OT."

§7.1.1. Training packages for OT events at a minimum should be submitted for review to the AAAV Transition Task Force prior to EOA/OA Operational Test Readiness Reviews in order to provide validation of training to the OT event.

§7.2. There are currently technical manuals in existence that can support the creation of TTPs particular to the AAAV.

§7.3. Validation of what equates to a trained crewman will have to be thoroughly analyzed in the creation of a new AAAV Training and Readiness Manual. It will be incumbent upon the community [sic] to require certified annual and semi-annual qualification requirements at both the crew and individual level.

§7.4. The VSIL provided Marines a basic understanding of the complexity of this vehicle during classroom training.

§7.4.1. The potential for increased safety, effective cost [sic] training, and the production of combat ready Marines is worth the pursuit of having this system (VSIL) available at the battalion to include the AAV Schools BN.

§7.5. Unit Conduct of Fire Trainer (U-COFT) and (MCOFT) [sic] should be further developed in order to help establish and train TTPs for the AAAV at the battalion to include the AAV Schools BN.

§7.6. Embedded Training software. Development and demonstration must be proven before discounting the need of stand-alone training devices.

DRPM AAA/Log/Training Response

Observations and insights resulting from the independent assessment are consistent with the actions already under way and managed by the DRPM AAA and serve as a de-facto check list, with some exceptions, to the proposed courses of action as stated below.

Factory training is developed by the sole-source subject matter expert, General Dynamics or Prime Contractor, and it pertains to safe, technical operations and maintenance of system/sub-system vice tactics, techniques and procedures (TTP). New Equipment Training for IOT&E crews and for training to prepare initial issue to operational units will follow a similar path, pending further development under the aegis of Commanding General, Marine Corps Combat Development Command (MCCDC) and representation and coordination through the Transition Task Force (TTF).

Consistent with the aforementioned approach, doctrinal Instructional Systems Design has been initiated and Job Task Analyses (JTA) are being performed at Naval Air Warfare Training Systems Division, in cooperation with PM, Training Systems (MarCorSysCom) co-located in Orlando Florida. It is initially based on technical manual development but will eventually be expanded to include TTP related information as separation of core and core plus skills for the training continuum are determined and Training & Readiness

Manuals (T&R) are formulated. T&Rs link individual and collective training requirements with scaleable and intractable performance standards, resources, and unit readiness metrics.

As curriculum development matures it is coordinated with and validated by the Fleet Project Team, a subset of the TTF. The latter forum addresses those issues that require a holistic approach through the DOTES process and Intra-Supporting Establishment departmental and command coordination. Commanding General, Training and Education Command (TECOM) is represented in both forums, having the responsibility and lead pertaining to T&R development.

TTPs are under MCCDC lead (Doctrine) with inputs from other members of the TTF, and as with TECOM products, DRPM AAA is by necessity an interactive and responsible participant. Therefore, coordination of pertinent training packages applicable to future test events are normal courses of action. However, what cannot be overstated or overlooked are the communications required to ensure that MCOTEA and the program office have a clear understanding of the plan to evaluate pre-determined and explicitly specified training requirements during future tests.

The number, type, and application of training devices currently being planned, programmed, and budgeted for by the program office incorporate the recommendations expressed in the report for like applications both at the formal school and at Reserve units.

EOA Report Comments

§8.1. An immediate, identifiable additional Skill Set is required for crews to effectively employ the MK-46. This process will have to be developed in coordination with the Training and Readiness Manual (weapons sub-sets are listed)

§8.2. Vehicle software/hardware implementation and usage will need to be a demonstrated and evaluated skill set.

§9.1. Maintainers will need to possess the additional ability to conduct repairs on the MK-46 turret. There is not a plan to create an additional Military Occupational skill of MK-46 Turret Mechanic.

§9.2 Maintainers will need to possess the requisite skills to trouble shoot and evaluate/repair Computer Hardware and Software discrepancies.

DRPM AAA/Log/Training Response

JTAs currently underway are expected to fully provide for training to accomplish these requirements.

Deck Plates

EOA Report Comment

§8.9.5 The deck plate quick disconnects needs to be more reliable. The disconnects would break easily, causing the deck plates to become unstable, causing a trip hazard.

Design Improvements

The deck plate disconnect is a known deficiency of the PDRR prototypes. The d-ring handles pulled-out easily do to undersized fasteners, and large size of the handles resulted in large holes in the deck panels when they were removed. The hold-downs have been significantly redesigned in SDD in order to improve durability while reducing size and weight.

Turret Guard

EOA Report Comment

§8.9.6 Recommend a turret guard, such as a basket, be designed for the turret to protect the gunner and VC's appendages during turret rotation. This would also increase the safety of anyone in the general vicinity when the turret moves.

Design Improvements:

Improved turret guards are designed and will be installed in the SDD prototypes.

In addition to the above listed design improvements, the Program is incorporating thousands of other improvements in weight and cost reduction, safety, reliability, human factors, survivability, manufacturing, maintainability, and production that will appear in the 2nd generation SDD prototypes. These prototypes will begin extensive system level developmental and operational testing in FY03 to further refine the designs for the 3rd generation systems and ultimately for the full rate production units. Each of the thousands of new and modified designs in the AAAV are deliberate balances and trade offs between competing considerations. As new test information is gained, further improvements and refinements will be made in the design and incorporated at the earliest opportunity in prototypes. The program has carefully planned the build-test-analyze-fix cycle to coincide with the acquisition and fiscal timelines such that each prototype is progressively better than the last; and useful test information can be transformed into a higher quality, more cost effective, more operationally suitable and effective AAAV design.