This paper describes a reliability approach developed by the Product Assurance personnel of the Tank-Automotive Command for procuring and fielding commercial and semi-commercial systems. During prior years the Army concentrated in designing and developing unique military tactical vehicles. The extensive developmental time allowed the pursuit of comprehensive reliability programs. During recent years, however, the Army's policy has been to buy commercial tactical vehicles, since this policy reduced schedules and costs results in a fast and easy method of replacing the aging US Army fleet. This, however, creates a potential reliability problem since the commercial configuration is not specifically designed for a military environment and the time constraints may prevent detailed testing and analysis of the system's worthiness. The challenge, therefore, was to develop reliability programs which would assure success in the field without reducing the benefits of lower costs and shorter schedules. The solution was to separate the commercial buys into three categories and to structure optimum reliability programs for each of the categories. The recent Army procurements under the auspices of these categories and the lessons learned are delineated in this paper.

Introduction

A typical Army technical vehicle developmental program consumes from 10 to 15 years from initiation to vehicle deployment. These years require an extensive amount of resources in terms of manpower and test hardware. The years also represent time that the vehicle configuration control would remain with the user and, in order to expedite the procurement process and to achieve it in the most cost effective manner, the Army made a decision a decade ago to procure commercial tactical vehicles. This decision involved a number of vehicles of various sizes and capabilities. There was no question that the desired type of equipment existed in the commercial market. The nagging question was whether this equipment could, in fact, perform the required Army missions without experiencing reliability and durability problems. It was recognized that extensive testing would be prohibitive, since the time and funds required to test would negate the benefits gained through commercial buys. Additionally, it was recognized that the vehicle configuration control would remain with the commercial producer and, as such, the Army could not expect or demand major changes to the existing designs. Therefore, a decision was made to perform market surveys and to utilize information gained to establish customer satisfaction and to equate this knowledge with equipments worthiness. As time marched on and the commercial buy policies were implemented, it became apparent that the situation was not as simplistic as originally envisioned. First of all, the commercial buys were not all the same. Some of the buys consisted of vehicles experiencing extensive commercial utilization and development. Some represented vehicles that were envisioned to be used differently in the military application from that utilized in the commercial market. Others represented vehicles that did not exist as an entity in the commercial market; rather, they were systems assembled from readily available commercial components. Still some others were foreign made vehicles that were utilized by the friendly countries to satisfy their military needs. In addition to the differences in the commercial buys, it also became apparent that in most cases the commercial utilization differed from the expected military utilization. The military requirement documents are very specific in describing the stated use of the vehicles in terms of highway, secondary roads, and cross-country operations. The commercial systems either differ in the utilization from these requirements or are not designed to meet equivalent types of environments. Therefore, it soon became apparent that the reliability challenge associated with the procurements of commercial systems was greater than originally envisioned. The question facing the reliability engineers at the Tank-Automotive Command, the Army procuring agency for the tactical vehicles, was "How to proceed with the desirable benefits of commercial buys or semi-commercial buys without jeopardizing the reliability posture of the Army Fleet and without creating undue maintenance and provisioning burden on the Army?"

Reliability Categories for Commercial Vehicle Buys

The first step taken was to segregate the commercial buys into appropriate, reliability oriented, categories. This segregation was necessary in order to facilitate the construction of reliability programs within each category. It was recognized that some systems lend themselves to the original concepts of market surveys and quick buys. These type of systems represent equipment readily available in the commercial market with the expectant military utilization equivalent to the commercial utilization. These systems were identified as Category A, Forklifts, cranes, and administrative vehicles fall in this category. The systems within this category could be procured and deployed within a few years since testing is not required and the only Product Assurance is that of quality. The Army user reliability requirements are not entertained by the procuring agency since it does not have configuration control of the vehicles and, therefore, cannot influence the design of these vehicles. From the government procuring agency viewpoint the reliability posture of Category A vehicles is determined through a market survey and is deemed to be acceptable if there is sufficient proof of commercial customer satisfaction. A market survey is a systematic review of available documentation provided by the potential producers and the users of the commercial equipment. It consists of design data, laboratory test results, prototype test results and operational information provided by the users. It has been found that the information is conducive to a subjective analysis but is not adequate for a quantitative analysis, since the limitation of the data and differences in methodologies prevents a comprehensive R&M assessment. However, the market survey is sufficient to determine the cost-effectiveness of the equipment and the satisfaction of the users of the equipment. The market survey is the only proof of the system's worthiness, since a reliability program is not structured for Category A, tests are not performed, and, of course, reliability

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assessments are not conducted. Therefore, the Category A vehicles are procured based on analyses of their inherent nature and the confidence that they will continue to perform within an acceptable band. This confidence is substantiated by reliability performance data that will be gathered through post-acquisition trials of warranties similar to those provided to the commercial users. A warranty is acceptable for these type of vehicles, since they are not combat essential and their break-ins are cost oriented, rather than time mission critical. From a reliability viewpoint, the Category A systems are considered to be low risk procurements. The average procurement cycle ranges from one to two years, from initiation of the requirement to the deployment of the equipment in the field.

The second category of commercial vehicle procurements, identified as Category B, consist of items that are produced in large quantities in the commercial market and are widely utilized by the public. The only difference from Category A is that these vehicles are contemplated to be used in a different scenario or environment by the military. This difference can be reflected either by temperature extremes, soil conditions, or, most likely, through the additional cross-country operations. These cross-country operations include world-wide environments of extreme mud, parched desert, and rocky mountain terrain. Therefore, the key feature for this type of acquisition cycle is a feasibility test conducted to demonstrate the adaptability and reliability of the vehicles in the military environment. Two recent procurements for the Tank-Auto-mobile Command in this category are the Cargo and Utility Commercial Vehicle (CUCV) and the Commercial Motorcycle. For both systems extensive feasibility tests have been conducted under varying environmental conditions with a number of vehicles selected from potential producers. Then a procurement specification was prepared by identifying the weak links noted during the tests and by eliminating these weaknesses through a careful selection of the most reliable components. This specification was then used in the bidding and selection process of the producers and in this manner the vehicle reliability posture was optimized. It has to be recognized that in this case the position taken by the government procuring agency is that it cannot guarantee to the user the satisfaction of a specific reliability requirement, since it cannot influence or control the designs. However, through feasibility tests it can determine the worthiness of the existing designs and to optimize this design for a maximum reliability potential. As an example for the CUCV feasibility tests, the selected systems were the General Motors Blazer, the Ford Bronco and the Chrysler Charger. Each of the contractors provided both heavy duty and lightweight versions where the difference was reflected in the ability of the components to withstand performance and endurance limits. It was observed during the tests that the vehicles with the lightweight components experienced two times more failures than the vehicles with the heavy duty components. This was especially apparent for the subsystems of springs and shocks. For this reason, the procurement specification required heavy duty springs and shocks and a positive spring alignment. The motorcycle specification required heavy duty sealed drive chain, vibration resistant lighting equipment and adjustable heavy duty suspension. The other components, however, are inherent commercial designs which cannot be readily upgraded. These include non-weather-proofed electrical components and mud limiting transmission linkages. These limitations were identified, modifications solicited from the commercial producers and if the responses were negative, decisions were made regarding the acceptability of the limitations. Therefore, from a reliability program standpoint, the Category B systems do not have reliability requirements and do not experience reliability growth patterns. However, extensive reliability effort is performed through testing, assessment and optimization of procurement specifications geared to experience quantum reliability jump from the typical vehicle available in the commercial market. The most significant feature of Category B commercial system then is the feasibility test and specification optimization. Category B systems are the most challenging because the acceptability in the acquisition process due to the limited program time and testing.

A system procurement which is different from Category B but is treated in the same manner is the acquisition of available foreign military systems. In this case, the available foreign test data is assessed and a feasibility test is conducted to determine the systems adequacy. However, the possibility of optimizing the procurement specification is more difficult since alternatives are limited in the foreign military market. Therefore, the data analysis in conjunction with the feasibility test has to identify the adequacy of the system, since optimization is constrained. An example is a recent procurement of the Small Unit Support Vehicle (SUSV) from Sweden by the Tank-Auto-mobile Command. This vehicle has the unique features desired by the United States which cannot be found in any existing system within the USA. Therefore, a team of USA engineers, including reliability experts, was sent to Sweden to evaluate the existing data and to determine the system's potential. The results of the FAN analysis were sent to Sweden to be compared to the tests from similar equipment in the USA. Additionally, a limited number of vehicles were provided from Sweden with the objective of conducting limited performance and user evaluation tests. All of the information was assessed to determine whether SUSV can perform the required tests in a cost-effective and reliable manner. The positive results provided sufficient confidence to initiate the acquisition cycle. Overall, the Category B vehicles are considered to be of medium risk for reliability purposes with a potential of further minimizing the risk if the specifications are optimized. These systems require an average of 3.5 years from program initiation to deployment.

The Category C commercial systems, are, in fact, composed of three variations: vehicles assembled from commercially available components for the specific purpose of military use, accelerated developmental systems utilizing many commercial components, and compressed competitive development systems utilizing some commercial components. The three variations are different from the total system viewpoint in that they are treated the same for reliability because they all require reliability objectives, testing, assessment, reliability growth, and acceptability based on the success rate demonstrated during the program. The difficulty in conducting a reliability program for a Category C system exists due to the time limitations imposed on early testing and the consequent difficulty in experiencing reliability growth. During a typical military developmental process sufficient component and prototype tests exist to determine problems, to implement corrections, and to insure progress through the improvement of the configuration. This type of luxury is limited for the Category C commercial procurements because the driving force is the reduction in acquisition time and the savings of R&D costs. Therefore, the reliability program has to insure adequacy of testing and to provide safeguards against over-optimistic attitudes towards weakness. Specifically, it is critical that component qualification, prototype evaluation, and shake-down tests be conducted at appropriate times before commitments are made to procure a substantial number of vehicles. It has been observed that some of the commercial components have
difficulty surviving in the diversified military environment. Therefore, it is imperative to conduct appropriate tests and to ensure that these tests are performed at the stress levels expected during the world-wide military use.

The major systems being procured by the Tank-Automotive Command under each of the Category C variables have been the Heavy Expanded Mobility Tactical Truck, High Mobility Multi-Purpose Wheeled Vehicle, and Medium Tactical Truck.

The HEMTT is a 10 ton vehicle system consisting of five body styles with a common chassis. The body styles are: cargo w/light duty crane, petroleum tanker, truck w/military crane, ambulance, and cargo w/medium duty crane. It is assembled from available commercial components to satisfy the stated US Army need and is not available in this configuration in the commercial market. A production contractor was selected based on market surveys of components and a technical evaluation of proposals. Then a comprehensive reliability program was established to facilitate component selection and reliability management. The program culminated in a comprehensive initial Production Test with the objective of verifying the hardware to the performance specification.

The major difference of this program from a typical military developmental program is the lack of government early developmental tests and testing. The initial vehicles have been deployed in the field and have been highly praised by the troops. The lessons learned with the early shakeout tests are necessary to identify non-conforming components and that the adequacy and accuracy of test conditions are critical for limited type testing.

The HMMWV is a multi-purpose 1-1/4 ton vehicle system designed to provide cross-country and cross-road performance. Its family consists of a forward observer vehicle, communication vehicle, utility truck, ambulance, weapon station and a personnel transport. It features a low fuel consumption engine, lightweight aluminum body, commercial drive train components and a run-flat device for the tires. The program consisted of a two year developmental phase conducted with three contractors selected from initial five offerers. During the developmental phase each of the three contractors developed and built eleven prototypes each to satisfy the military specification. Then a run-off test was conducted at US Army developer and user test sites to select the most reliable, cost-effective and optimum performance system. After the selection the winner was awarded a production contract with additional funding for improvements and further testing.

The major difference of this Category C variation from a typical military developmental program is the acceleration of the developmental phase and the lack of government early developmental tests. Therefore, the reliability program has to expect that the run-off tests would demonstrate a relatively high growth achievement in order to meet the production requirements. The HMMWV production contractor has been selected and he is in the process of conducting the established R program and building prototypes for further tests. One key feature of the program is the requirement to conduct selected component qualification tests. The lessons learned with this program are again the need for complete knowledge of test scenario and the assurance that the vehicles are tested against world-wide environments.

The Medium Tactical Truck family is in the 2-1/2 ton range and consists of cargo and troop transport, shelter transport, recovery, water transport and medium evacuation vehicle. It is required to perform on off-road conditions through a world-wide environment. The HMMWV is in early phases however, it is anticipated to follow an acquisition strategy whereby R&M funds would be provided to a number of contractors to design and build test prototypes. Then a government developmental and user demonstration test would be conducted to determine the best candidate. The government at that time would obtain configuration control and the production contract would be awarded to the lowest bidder against this configuration.

The major difference between a typical military developmental program and this variation of Category C is the compressed developmental time. It differs from the HMMWV approach since the government obtains the Technical Data Package after the tests and in this manner controls the configuration. The Reliability Program structured for this variation is very similar to the ones employed for military developmental programs. The difference again is the lack of recorded R growth through the early stages of the program and the expectation that the R demonstrated reliability will be high during the government development/user test. This variation is expected to include the features found desirable from previous programs: component qualification tests, early prototype tests and careful selection of appropriate test sites.

Overall, a typical Category "C" program consumes 60-70 months from its initiation to the vehicle deployment. It is considered to be inherently medium to high risk from a reliability standpoint. However, the risk can be minimized if substantial testing is conducted and timely action is taken to experience reliability growth. The present reliability programs at the Tank-Automotive Command are structured with this in mind.

Testing Requirements for Commercial Buys

A point has been made that in order to reduce the reliability risk in procuring commercial systems sufficient testing has to be conducted throughout the program. This testing is either performed to identify military suitability and to optimize the hardware, or as for Category "C" systems, in order to experience reliability growth. It is imperative that the testing be conducted in appropriate world-wide environments. A typical military developmental program experiences numerous tests in the variety of locations. Therefore, the systems deficiencies are identified under world-wide criteria of temperature and terrain. During a typical commercial buy time is limited and, therefore a variety of testing does not exist. Therefore, it is important that the tests with commercial items be performed in an all-encompassing and grueling military environment. In order to assure that the environment is correct, the test courses have to be measured, calibrated, and compared to the known typical environmental courses used during developmental military programs. Ideally the testing environment has to stress the vehicles to a reasonable degree in order to assure success in the field. This can be accomplished by operating under a typical European and Mid-East terrain and by utilizing the vehicle velocity as a "hammer" to increase the stress. The key to success, though, is the complete understanding and control of the testing environment in order to remain within the desired and required testing envelopes. In regards to this, there is a great need to expand and develop present methodology in test course measurement and calibration. Present techniques consist mainly of either measuring the "G" forces experienced by the vehicle when traversing a given course, or by using various methods to "profile" the course. This type of measurement is one-dimensional and it is dependent on the characteristics of the vehicles. Methodology is needed to measure the potential energy forces of the terrain independent of the vehicle in both the vertical and horizontal directions; also to impact information in the form of harmonic and non-harmonic forces and torsional effects. Once this type of measuring instrumentation is developed, then the
terrain energy information could be incorporated into specifications and provided to designers to assure correct and adequate vehicle configuration. Ideally, the test courses could be constructed, calibrated, and maintained to provide accuracy and continuity. A study entitled "Energy Profile of APG, YPG, and NATC Durability Courses" was prepared by TACOM in May 1981 on this subject and future continuation on this critical matter is needed in order to identify and control the test parameters.

Conclusion

Can reliable commercial systems be procured? The answer is yes! Can this feat be accomplished without testing and conduct of reliability programs? The answer, with the exception of Category A systems, is no! Testing is required to both identify military suitability and to experience either quantum or gradual reliability growth. Reliability programs are required to logically define, develop, specify, and assure reliability. Also correct, all-encompassing, testing becomes more critical for non-developmental systems due to the curtailment of both the total test time and the variety of test locations. This highlights the need for better test course measurement techniques and incorporation of the test environment energies in the specifications.

There is no question that the benefits of cost and time saving exist in the acquisition strategy of commercial systems. This has already been demonstrated through the procurement of the CUCV, SUSV, HEMTT and HMMWV discussed in this article. However, the over-optimistic initial attitudes have resulted in unnecessary delays and increases in cost. The lessons learned and the actions taken have resulted in a more logical acquisition strategy of procurement categorization and the structuring of R programs to fit each category. With this approach it is anticipated that future commercial and semi-commercial procurements will continue to exhibit the savings in time and money with the additional feature of even earlier confirmation of a system's adequacy and field worthiness.

Biography

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Mr. Jokubaitis is the Chief of the RAM Assessment and Data Division, Tank-Automotive Command. He holds a BME degree from the University of Detroit and he has had over 20 years of experience in R&M and related areas. He has functioned as Director of Reliability for the Sheridan Armored Vehicle and the Joint USA/German Main Battle Tank Developmental Program. From 1976 through 1980 he performed as Director of the Product Assurance for the Tank-Automotive Readiness Command. He has originated techniques in projecting R growth, establishing test course parameters, defining failures and managing reliability programs. His articles on the subject of R&M have been published in the Armor, Army Logistician and National Defense magazines.