REDUCING SYSTEM COST DURING MDARS PRODUCTION

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Abstract

On the Mobile Detection Assessment Response System (MDARS) production program, General Dynamics Robotics Systems (GDRS) and International Logistics Systems (ILS), are working with the US Army's Product Manager – Force Protection Systems (PM-FPS) to reduce system costs throughout the production lifecycle. Under this process, GDRS works through an Engineering Change Proposal (ECP) process to improve the reliability and maintainability of subsystem designs with the goal of making the entire system more producible at a lower cost. In addition, GDRS recommends substitutions of Government requirements that are cost drivers with those that reduce cost impact but do not result in reduced capability for the end user. This paper describes the production lifecycle process for the MDARS system and recommends future considerations for fielding of complex autonomous robotic systems.

Introduction

MDARS provides unmanned, external security for Department of Defense (DoD) installations and storage facilities such as materiel storage yards, arsenals, petroleum storage areas, airfields, rail yards, and port facilities. Security is provided by unmanned patrol units equipped with a suite of mission specific sensors necessary to conduct supervised autonomous navigation, patrol, and specific security functions in designated exterior environments. MDARS also provides the commanders with the capability of conducting product and barrier assessments. The patrol unit (Figure 1) performs three primary functions: 1) intruder detection and assessment, 2) remote lock reading, and 3) product inventory.

Figure 1. MDARS Patrolling at Hawthorne Army Depot.

Cost reduction and product improvement, when moving from System Design and Development (SDD) through the production lifecycle, is necessary for the long term viability of robotic systems. In order to successfully reduce the systems' manufacturing cost, this effort must begin during the SDD phase by incorporating concurrent engineering principles and modern manufacturing techniques, and continue through the maintenance and sustainment phase by considering total Life Cycle Cost (LCC).

GDRS capitalizes on the use of existing manufacturing processes whenever possible. Every effort is made to reduce parts that are inherently difficult to fabricate, assemble, and test in the controlled environment of the production facility, while focusing on key producibility concepts such as modularity, tolerance control, and part number reduction. Built In Test Equipment (BITE) is extensively used to quickly isolate faults to the Line Replaceable Unit (LRU), reducing system down time and maintenance costs.

Changes From SDD to Production

During the period between the SDD program end and the Production Program contract award, GDRS implemented several efforts aimed at reducing system cost.

Concurrent Engineering

GDRS used concurrent engineering principles to implement a series of design changes that were based on results from System Development and Demonstration (SDD) testing and were applied as a Non-Recurring Engineering (NRE) effort during the first Production Delivery Order. These changes included improved Electromagnetic Interference (EMI) performance, reduced brake pad and rotor wear, decreased hydraulic and engine operating temperatures, and improved traction control on slick or loose surfaces.

Changes to improve the EMI performance focused on three areas: sensors, cables, and electronic enclosures. A review conducted by expert EMI consultants resulted in several relatively low cost improvements, including EMI Gaskets, EMI Filters and Internal Ferrites that were added to the design during the first production build. This resulted in improved performance during the EMI portion of First Article Testing.

Manufacturing Techniques

Process Focus Groups were used to define areas of producibility improvements that could be gained by implementing modern manufacturing techniques. Each group was tasked with reviewing current manufactured and purchased items to identify any possible Manufacturing Process improvements that could be made in conjunction with the NRE effort. Areas of focus were sheet metal fabrication Geometric Dimensioning and Tolerance (GD&T), machined components, and welded components. A complete review of all GD&T was applied to every manufactured item. Manufacturing engineers were assigned to specific commodities to ensure consistency and dimensional stack accuracy. The results were incorporated using the Engineering Change Proposal (ECP) process with the customer.

Tolerance stack up issues were discovered by modeling sheet metal components in place of using the paper Technical Drawing Package (TDP). This team effort afforded GDRS the opportunity to combine multiple parts that were previously assembled by hand drilling and riveting to welded subassemblies that would be installed as single piece items on to the vehicle. The reduction of parts and components improved the overall reliability of the vehicle as a result. The modeling effort supported the installation process by ensuring components fit together prior to making it to the Assembly floor. Examples include the vehicle frame, rain gutter and channel assemblies. Final installation dimensional issues were addressed and changes were captured within the Final Production Baseline TDP.

Multiple machined components were revised to single piece machined parts in many areas including the wheel spindles that were redesigned during the brake system NRE effort. Engineering, Manufacturing and Life-Cycle Support team members met to discuss the SDD issues and determined that the large number of components within some systems was driving the reliability performance of the system. Changes were made to the design that improved the maintainability and reliability by reducing the number of parts in the system from five machined parts to one. The assembly and installation time was reduced by decreasing the amount of moving parts and hardware to be installed. The performance of the braking system was improved by eliminating interferences that were discovered by the team in the GD&T review which allowed the system stopping distance in emergency situations to be reduced by more than 50%.

Team reviews of welded components were conducted to determine the value and risk associated with the processes that were employed during the SDD vehicle build phase. The team identified practices that were outdated and processes that were “risky” regarding the reliability of the drive train elements. Welded subassemblies that used dissimilar metals and heat treating processes were revised to single piece machine parts that increased the reliability of the components and reduced the cost of maintenance and production by eliminating the risk of field failure and excessive lead times.

Total Lifecycle Cost

Total life-cycle cost (TLCC) indicates whether paying higher capital costs for advanced technology with low operating and environmental costs is advantageous over paying lower capital costs for conventional technology with higher operating and environment costs, i.e. the total dollar cost of owning, operating, maintaining, and disposing of a component or material over a period of time. Life Cycle Cost Analysis (LCCA) is an economic evaluation technique that determines the total cost of owning and operating a system over period of time. The system analysis takes into account the annual operating costs such as operating and maintenance times, spares, expendables and capabilities assessments.

Through LCCA the MDARS design was improved to reduce operating and maintenance efforts. Examples of theses improvements include utilizing sensors to perform actions which an operator would normally conduct such as lane changing and intersection crossing and diagnosing component failures that would normally require maintainer action to prevent subsequent damage. Changes and improvements such as these reduced the annual operating and maintenance costs of the system.

First Production Build Enhancements

During the first production build, many additional manufacturing process improvements were realized and implemented.

Reliability and Maintainability Improvements

A Reliability and Maintainability (R&M) model was created and utilized during the production process to identify various failure points in either component reliability or design. This model identified high risk points of failure to establish target areas for improvement in design or replacement of components with excessive failure rates. Through this model and the subsequent reliability design improvement ECP processes, we were able to make improvements in areas such as:

- More design-in reliability and maintainability
- Component reliability improvements
- Better data on the lifespan of critical components
- Better use of R & M in decision-making
- Improved sensors and data acquisition
- More reliable electrical/electronic components

Our ECP process provided for approval for each suggested design change by every area affected, including Engineering, Manufacturing, Safety, Reliability, Maintainability and Human Factors in order to mitigate against unforeseen issues. The reliability improvement from SDD to production is depicted in Figure 2.

Emphasis on maintainability was not only to reduce unnecessary failures due to frequency of components needing replacement but also to provide an improved process for maintenance accessibility, thus reducing the Mean Time to Repair(MTTR) and/or Maintenance Ratio (MR). These areas of improvement included:

- Maintenance process improvements
- Standardized components on equipment
- Standardized tools for equipment repairs
- Eliminate requirements for special tools
- Standardized controls architecture
- Better use of predictive tools
- Less reactive maintenance
- More timely repairs
- Better lubrication program

- More equipment troubleshooting/diagnostics
- Better inventory/spare parts control

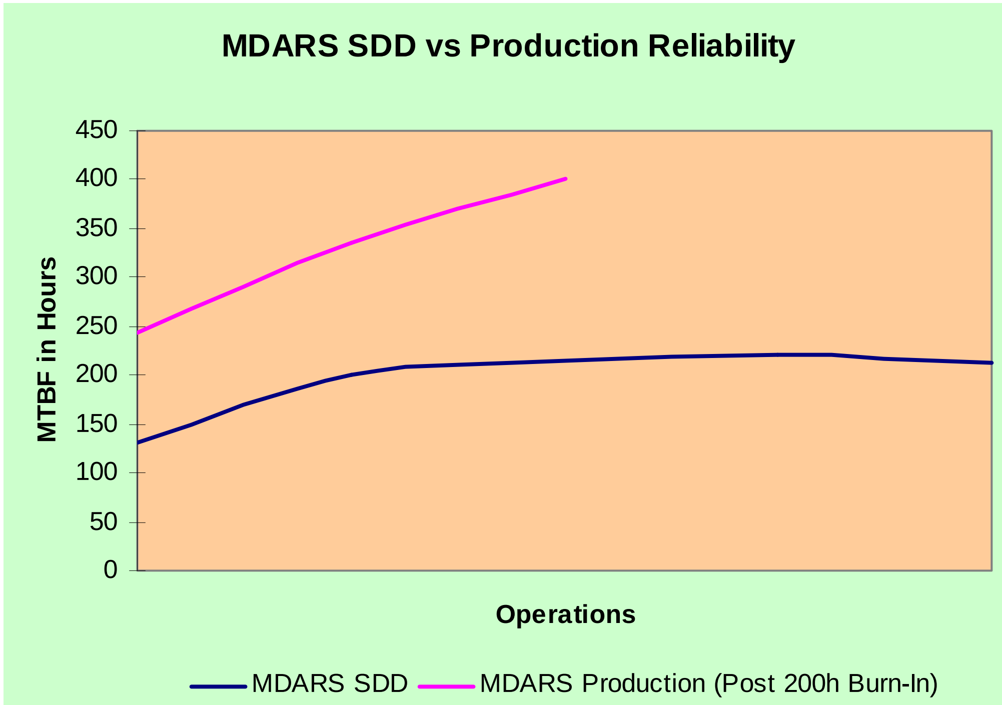

Figure 2. Reliability Improvement from SDD to Production

Existing Manufacturing Processes

GDRS applied a team based lean approach, depicted in Figure 3 that empowers individuals to identify and present Lean Initiatives to Focus Groups to be used as a base line. Lean, clean and efficient work cells were created to reduce waste in the work area. Production control and Material control personnel were assigned to each focus group to provide valuable information that may affect any plans that were created. Focus Groups were created to address individual areas of concern to minimize potential delays and Producibility concerns. These included:

- Patrol Unit Vehicle (PUV) Frame Group
- Sensor Suite Focus Group
- Suspension Group
- Console/Equipment Rack Group
- Hydraulics Group
- Electrical Group
- Final Assembly and Integration Group

Baseline initiatives were incorporated into the process plans to ensure that consistency and configuration would be controlled. Torque requirements were identified and included in the process plans. Assembly technicians were trained as certified operators to build specific assemblies and sub-assemblies. Quality Assurance was used as an audit tool to calibrate the certified operators.

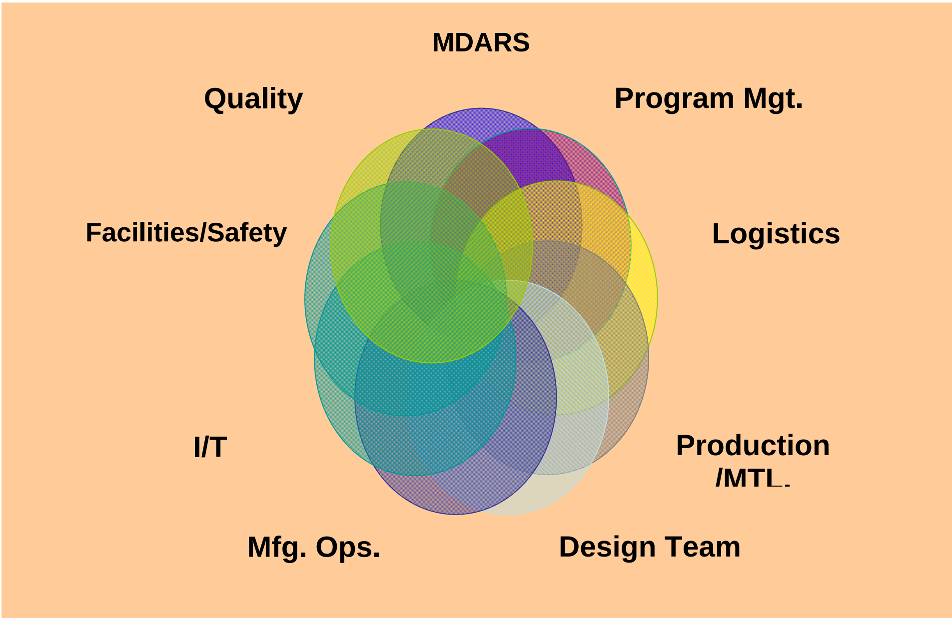

Figure 3. MDARS Manufacturing Team Based Approach

Producibility Enhancements

Several producibility enhancements were implemented during the first MDARS production build, especially in the areas of modularity and tolerance control. Several examples are given here.

Battery access was redesigned to allow full access to both upper and lower batteries for replacement and service, resulting in a reduction in installation cost, much easier trouble shooting, and a significant safety improvement.

The rain gutter assembly was reduced from a 20 piece assembly down to a two piece welded assembly. This resulted in increased ease of installation, interchangeability between vehicles due to the elimination of match drilling at assembly, and consistency when installing body panels, which greatly reduced rework costs.

The Control Station Console assembly was originally designed 15 years ago. Due to advancements in commercial availability of modular cabinet assemblies, GDRS was able to redesign this console assembly as shown if Figure 4, resulting in a lighter end product (700 lbs versus 900 lbs), newer, faster and smaller CPU's, and commercially available cable assemblies to replace custom cable assemblies. All these changes result in lower costs of assembly and maintenance.

Hydraulic Hoses and fitting were incorporated throughout the entire systems replacing stainless steel hard lines. This change resulted in improved ease of replacement, reduced installation cost, a three-year leak free warranty from the manufacturer of the O-Ring Face Seal fittings, a reduction in operating temperature from about 240ºF to about 175ºF, and a material cost reduction of the vehicle itself.

Figure 4. Modernized and Simplified Control Station Design (Shown on Right) Combines Console and Equipment Rack in a Single Unit.

Requirements Changes

Often small changes in the requirements specification of a system can result in large cost savings to the customer. GDRS works with its Army customer, Product Manager-Force Protection Systems (PM-FPS), to identify such areas for discussion. For example, by changing the flat tire requirement from having to complete a 12-hour mission on a flat tire to having to notify the operator of a flat tire condition so that another vehicle can be dispatched, we were able to change from run-flat tires with custom rims and inserts to off the shelf wheels and rims, saving over $14,000 per vehicle.

Built In Test Equipment

Built In Test Equipment (BITE) allows a system to test itself to enhance safety and reliability. The typical personal computer tests itself at start-up, so a computerized self-test was an obvious, inexpensive feature. Most modern computers, including embedded systems, have self-tests of their computer, memory and software. Unattended systems perform self-tests to discover whether they need maintenance or repair. Typical tests are for temperature, humidity, bad communications, burglars, or a bad power supply. For example, power systems or batteries are often under stress, and can easily overheat or fail, so they are often tested.

Remote systems such as MDARS have tests to loop-back the communications locally, to test transmitter and receiver, and to remotely test the communication link without using the computer or software at the remote unit. Where electronic loop-backs are absent, the software usually provides this facility. For example, IP defines a local address which is a software loopback. Many remote systems have automatic reset features to restart their remote computers. These can be triggered by lack of communications, improper software operation or other critical events. MDARS makes full use of these features in order to improve reliability and reduce down time.

Plans for Future Production Builds

Producibility analysis and enhancement will continue during subsequent equipment builds, further improving design and efficiency. In addition, online web support and updates to help improve training and support communications to facilitate improved operations, maintenance, troubleshooting and site support will be pursued. One example, Interactive Electronic Technical Manuals (IETMs) are scalable, supportable, and nonproprietary, and they have the look and feel of a Web browser. IETMs help move to an improved environment for their product support information, with publishing solutions that are process based rather than software product based, and that maximize the value and utility of their data.

IETMs provide an array of benefits as described below, but none seem more important than putting better and smarter documentation into the hands of the people who will benefit most–repair and maintenance technicians. Key IETM Benefits include:

- Increased ability to locate, comprehend, and retain information
- Decreased false removal rates of good components
- Increased effectiveness in successful fault isolation
- Reduced time in integrating maintenance actions with collateral functions (eg., with maintenance)
- Improvement in maintenance management procedures
- Improved comprehension in formal training
- Increased enthusiasm by technicians for IETMs use over paper based TMs
- Potential for significant improvement in automated on the job training
- Reduced downtime
- Reduced user time (man-hours)
- Reduced shipping costs
- Reduced printing expenses
- Reduced distribution costs
- Elimination of change pages
- Lower cost per user

Conclusion

MDARS is an example of a robotic system that has entered the production phase of its lifecycle development. In order to maximize its chances for acceptance and wide use, a continuing effort must be put forth to reduce cost and make the system more affordable. This effort began during the SDD phase, continues now in production, and will continue into the future as it continually evolves to better meet the customer's needs.