GENERAL DYNAMICS
Canada

Manufacturing for High Reliability

Optimizing Manufacturing Processes for Defence and Aerospace Products

Abstract

The manufacturing of electronic components offers defense organizations the last opportunity to ensure a product meets specified quality and operating standards. Once it leaves the manufacturing floor and moves to system integration, any defects or deficiencies will affect overall system performance, the capabilities of the platform itself and, potentially, personnel safety. But even though manufacturing is the last step in the product development process, it should be one of the first considerations. Manufacturing quality requirements should factor into product definition and should be carefully adhered to when a component moves from the engineering table to the assembly line floor. Therefore, specifications should go beyond where and how the product will be manufactured and the overall manufacturing cost. Consideration should be given to how well the manufacturing process is aligned and integrated with product development and engineering processes, and the rigor or thoroughness of the product test structure needed to meet reliability requirements.

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The Need for High Quality and Reliability

The vehicles, aircraft and naval vessels that are at the core of an active defense system are not like other manufactured products. Unlike automobiles, commercial aircraft, and industrial cargo ships, state-of-the-art defense and aerospace platforms are engineered from the ground up to work in harsh, rugged environments and under the most demanding conditions. Every nut, bolt and component is individually tested to ensure it meets stringent operating standards for safety and reliability in any situation. When all the disparate pieces can be relied upon to work together and as intended, the platform is more than the sum of its parts. It is a strategic asset for a variety of in-field operations. More importantly, it is a safe and secure environment for the personnel who operate it.

Given the nature of today's defense and aerospace operations, electronics are perhaps the most important components on any land, air or sea platform. Unlike similar products for consumer applications, these components must be engineered and manufactured to higher quality and reliability standards. They must meet more stringent performance requirements and be better able to withstand the effects of dust, heat, cold, vibration and electrostatic discharges that may affect them on the battlefield. For this reason, the costs associated with engineering and manufacturing highly reliable and sustainable electronic components can account for a significant portion of the overall budget for some platforms. Therefore, selecting the right manufacturer for these primary cost drivers requires careful consideration.

Engineering designs for the majority of electronic components are extremely complex. Once a design is approved the manufacturing process needed to produce the component cost-effectively must also meet high quality and testing standards. When custom or modified commercial off-the-shelf (COTS) components are used to reduce the cost of the integrated system, each component must be assembled and tested to stringent quality standards to meet high reliability and rugged requirements. It's not surprising, therefore, that sourcing and acquiring electronic components is challenging for defense and aerospace organizations.

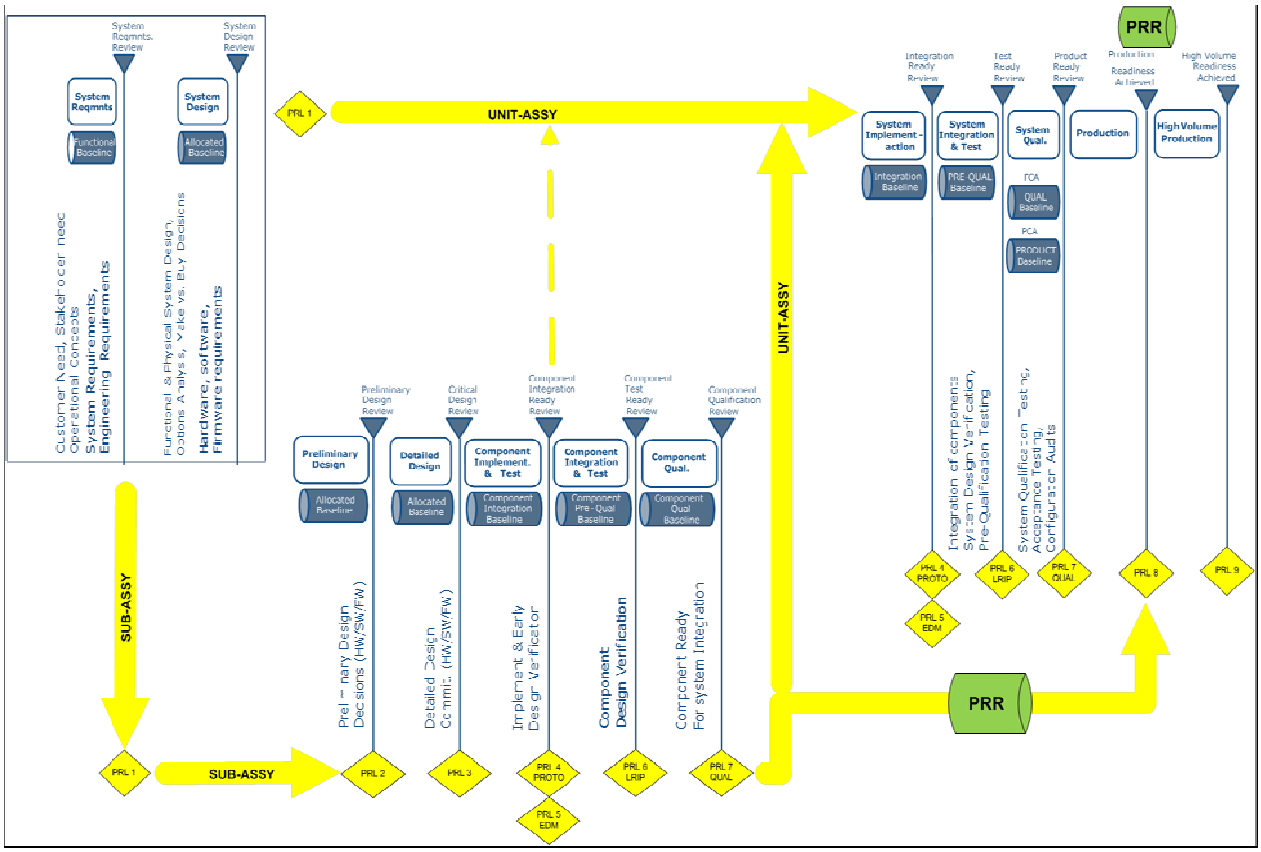
To meet quality and reliability objectives, defense and aerospace organizations need manufacturing, quality, and testing processes that are structured to screen potentially defective components from ever getting to a platform. This screening process must include a Statistical Process Control (SPC) and test strategy that eliminates parts that do not meet standards and specifications for performance and reliability. The ideal manufacturing operation will be built on a seamless integration of quality assurance, quality control and testing processes with the overall assembly process, and, where required, with the engineering process.

Choosing a Manufacturing Partner

The manufacturing of electronic components destined for defense and aerospace platforms is the critical, final step in a long process, which begins with product development and ends with the component being tested for final integration in a platform's information, communication, or control network architecture (Figure 1).

As such, it offers defense organizations the last opportunity to ensure the product meets specified quality and operating standards. Once it leaves the manufacturing floor and moves to system integration, any defects or deficiencies will affect overall system performance, the capabilities of the platform itself and, potentially, personnel safety.

Figure 1: Manufacturing is a critical, final step for electronic components destined for defense and aerospace platforms.



Given the importance of the manufacturing process, finding the right manufacturer is often a challenge. Defense organizations go to great lengths to ensure the manufacturer entrusted with producing electronic components is not only capable, but can provide value-added benefits. Usually, those benefits are based on how well the manufacturer balances its physical plant capabilities, with its knowledge and experience, and its ability to deliver within a prescribed timeframe. A supplier with an impressive physical plant and extensive experience manufacturing commercial-grade electronics may not have the same level of experience producing rugged, highly reliable components and systems. The lowest cost manufacturer may not be able to meet quality requirements. On the other hand, the highest quality manufacturer may prove to be too expensive. And the fastest manufacturer may end up cutting corners on quality, may add a premium charge for faster delivery, or may outsource part of the manufacturing to a sub-contractor, thereby losing control of the entire process.

Selection is further complicated by the simple fact that every manufacturer will claim the ability to provide some benefit in all these areas. All electronic component manufacturers will have some level of experience with rugged components. All will have some type of quality certification based on industry standards, such as ISO 9001, which ensures compliance to standards related to quality management systems, or IPC 610, which provides standards for validating various levels of workmanship. Most electronic component manufacturers will be able to point to some type of lower cost production method based on process improvement and time-saving labor practices. Finally, some electronic component manufacturers may claim to excel in all areas.

But claiming excellence in one or all of these areas is not good enough for the manufacture of highly reliable defense and aerospace electronic components and systems. World class manufacturing is not based solely on compliance to a set of industry standards, process improvements, or labor saving initiatives. These are all table stakes and prerequisites for any manufacturer in the defense and aerospace industry. What's more important is the seamless integration of all the elements that govern the manufacturing process, and the ability of those elements to produce products that work as intended the first time and every time they are called upon by the end user.

Therefore, even though manufacturing is the last step in the product development process, it should be the one of the first considerations for defense and aerospace organizations. Manufacturing quality requirements should factor into product definition and should be carefully adhered to when the electronic component moves from the engineering table to the assembly line floor. This means specifications should go beyond where and how the product will be manufactured and the overall manufacturing cost. Consideration should be given to how well the manufacturing process is aligned and integrated with product development and engineering processes, and the rigor or thoroughness of the product test structure needed to meet reliability requirements.

This requires selection of a manufacturing partner with extensive experience in rugged, high quality, reliable electronic components and systems. The ideal partner will have a thorough understanding of

manufacturing processes, as well as a high level of experience and understanding of the engineering behind each product.

Top tier manufacturers will have highly skilled and motivated employees, as well as programs to develop those employees into a customer-focused workforce. This is essential for any manufacturer wishing to align its capabilities to the needs of its customers, and to the ultimate end user of every component produced.

In addition, customer-centric manufacturers will go beyond base level certifications by continuously striving for ever higher standards. For example, these organizations will not be satisfied with an ISO 9001 quality certification when an ISO 9001:2008 certification ensures a higher quality customer product. Likewise, they will not settle for an IPC 610 Class 2 certificate when a Class 3 quality level will improve their product even more. Some will even seek out certification in segment-specific standards, such as the AS9100 certification for avionic components. More importantly, these manufacturers will have stringent programs in place to continuously gauge performance against quality standards, and these programs may include compliance audits performed by reputable external auditors.

Finally, top tier manufacturers will ensure that their cost containment efforts go beyond labor and material reduction costs associated directly with a specific product. They will examine all areas of their operation to determine where costs can be reduced to improve overall operations and thereby reduce direct and indirect costs to a customer, without risking product integrity.

Addressing Quality and Reliability Requirements

A truly integrated manufacturing process that meets the high quality and reliability requirements of defense and aerospace platforms is built on effective management of three key elements: cost, quality and schedule. How these elements are addressed and managed ultimately determines how well the electronic component being produced meets customer requirements.

Managing Cost

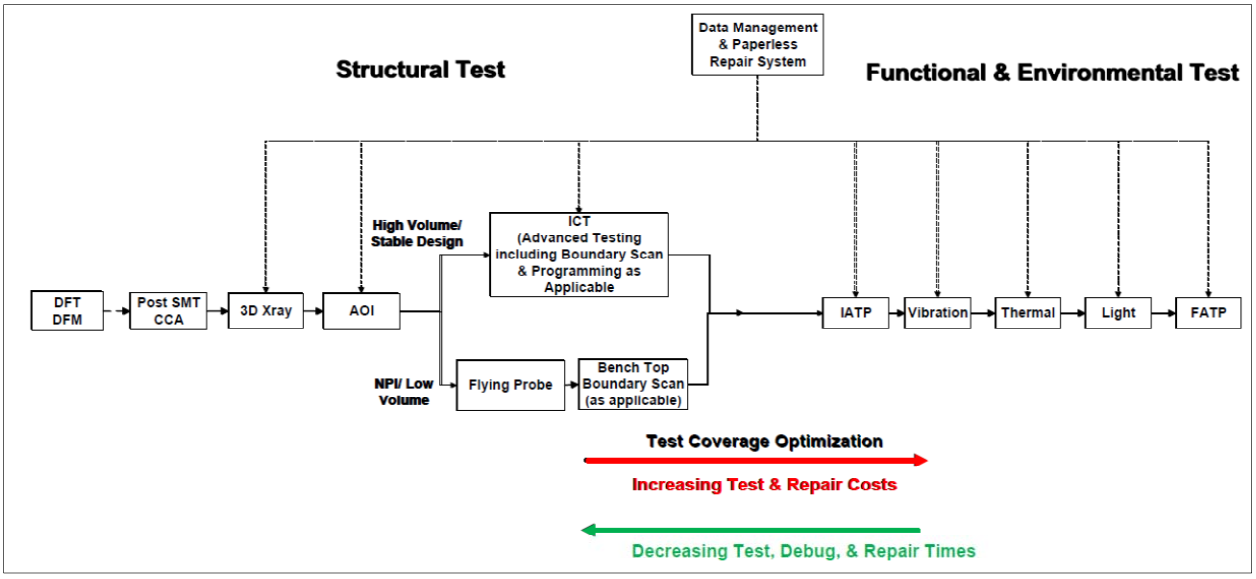
Traditionally, defense and aerospace manufacturing was done on a cost plus basis. Customers would get an estimate of the cost to produce a specific component and would also be responsible for any costs above and beyond the original estimate. Today, this model is no longer viable. Manufacturers provide firm fixed pricing and must avoid incremental charges and hold to the estimated cost of producing a specific component.

One of the most effective ways for a manufacturer to do this is to integrate an optimized quality control test strategy into key steps of the manufacturing process. Integrated properly, this ensures outgoing end product quality is high and minimizes the effect of the quality control/test process on the overall cost of the product. Obviously, this requires the manufacturer to ensure that the cost of testing is low, and that

this cost is continuously monitored and reduced. At the same time, the manufacturer must maintain the level of test coverage and, where possible, enhance it to improve quality.

Manufacturers can achieve this balance by tailoring the quality test process to fit product requirements and integrating tests earlier in the manufacturing chain (Figure 2). For example, quality tests or inspections can be introduced early in the assembly or sub-assembly process. With this approach, manufacturers producing a product that has multiple components, of which one is a video display unit (VDU), can test the VDU before it is integrated. This avoids the need to incur the cost of testing the VDU after integration and eliminates the potential cost impact that may arise from the discovery that the VDU is not operating to specifications further in the assembly process.

Figure 2: Quality tests should fit product requirements and be integrated earlier in the manufacturing process



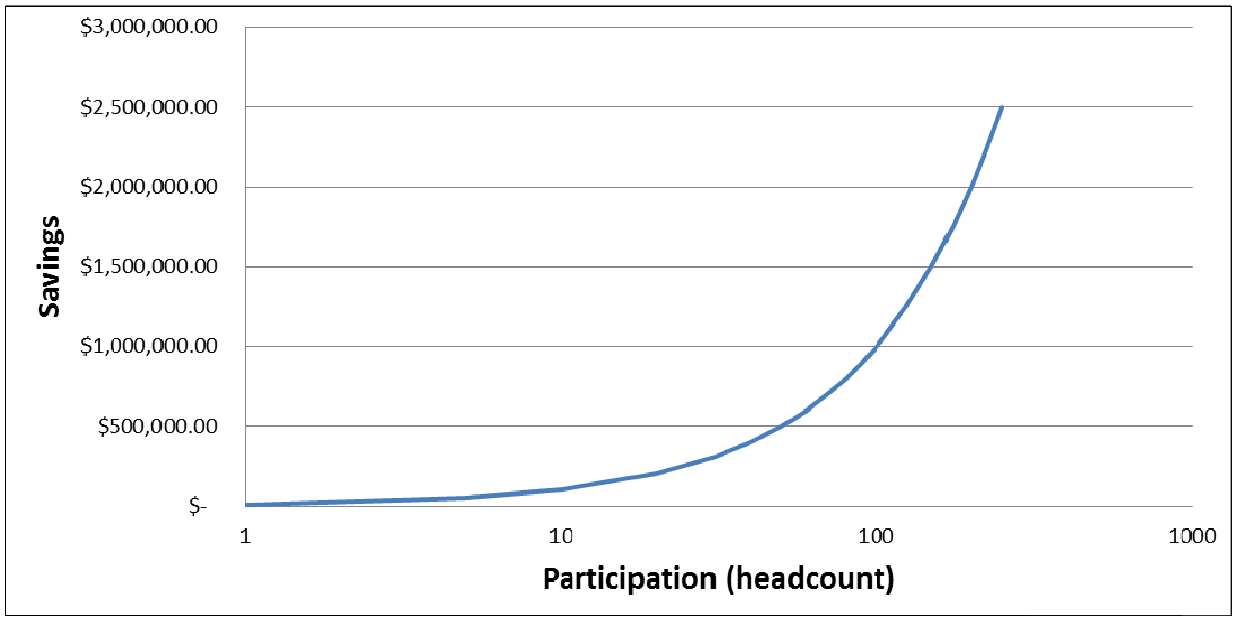
Another way for manufacturers to maintain an optimal balance between quality control and cost is to reduce process costs. A top tier manufacturer must have initiatives in place to reduce the number of steps required to manufacture a product. In most cases this is achieved through the use of continuous improvement processes on the factory floor or on the assembly line. But there are other ways to enhance these efforts.

Ensuring Quality

One approach is to take responsibility for improvement out of the hands of a small centralized group tasked with overseeing corporate efforts and extend it beyond the factory floor to all employees. This is important because it empowers everyone associated with production to contribute to making the product better for the customer. More importantly, it is extremely effective because humans are

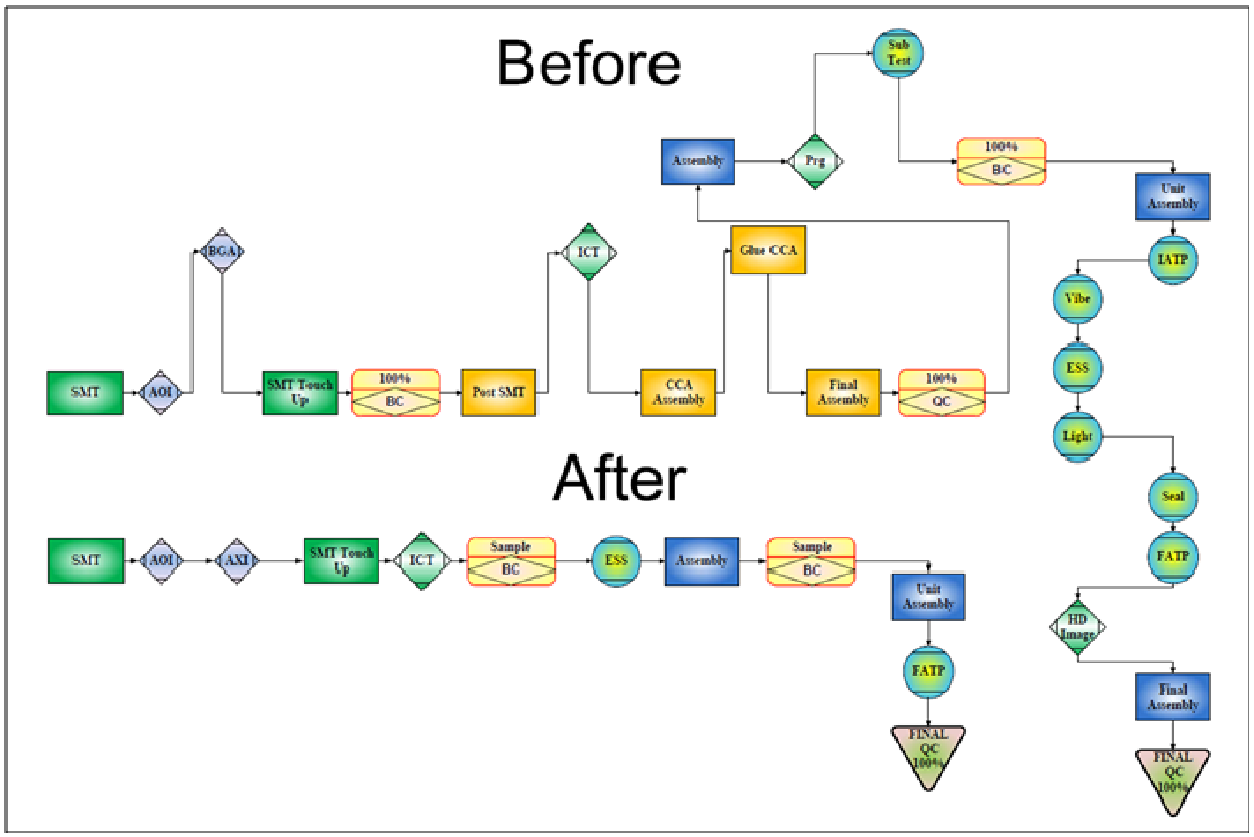
naturally inclined to always look for improvement opportunities (Figure 3). By tapping into this natural tendency, manufacturers can ensure the process is more aligned with the way people work and reap the benefits of a total team effort versus that of a few individuals.

Figure 3: Continuous improvement savings versus participation



This same inclination can also be leveraged to better integrate lean methodology practices into every employee's daily routine and eliminate wasteful work. By using the lean value stream mapping process, manufacturers can seamlessly integrate test stages into the manufacturing process while at the same time reducing the number and duration of the stages (Figure 4). This ensures a better product and reduces overall costs.

Figure 4: Lean value stream mapping enables test stages to be integrated into the manufacturing process

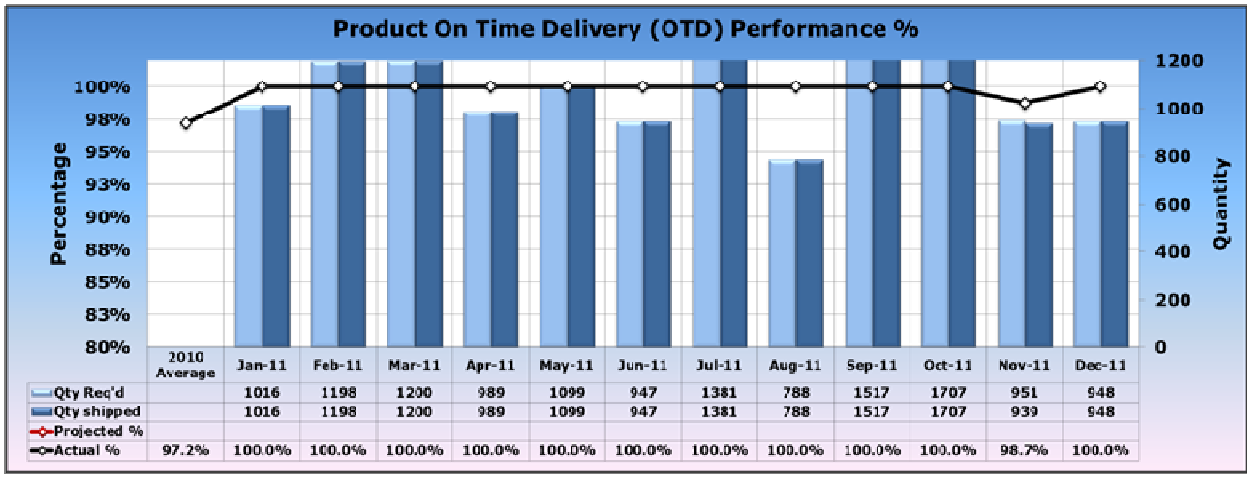


Ultimately, this approach improves the identification of potential problems in the process itself, and the detection of any quality issues in a component. It introduces quality process rigor by making individuals accountable for self-verifying and ensuring the quality of their work. And it ties individual quality and accountability directly to customer requirements.

Improving Schedule

Finally, a truly integrated manufacturing process that meets the high quality and reliability requirements of defense and aerospace platforms must also have a mechanism in place to improve the ability of the organization to deliver quality products on time, every time (Figure 5). This is best achieved by ensuring individuals and teams involved in the manufacturing process are aligned with each other, product quality requirements, and the overall quality objectives of the organization.

Figure 5: A truly integrated manufacturing process delivers quality products on time, every time.



One of the best ways to make this happen is to have everyone involved agree and adhere to specific metrics associated with the delivery of every component, sub-system and top-level product. Once true alignment is achieved and has been verified, and each team member takes ownership of overall goals, the organization can work as a truly integrated unit to ensure customers get the quality and reliability they expect from every component produced.

Manufacturing for High Reliability at General Dynamics Canada

General Dynamics Canada has developed an integrated manufacturing capability that meets the high quality and reliability requirements of defense and aerospace customers around the world. This has been achieved by balancing the capabilities of a state-of-the-art physical plant, with extensive knowledge and experience gained from multiple programs, and a proven ability to meet stringent delivery schedules. The company's quality manufacturing process is based on a company-wide commitment to deliver defect free products that are cost competitive and meet customer performance and reliability requirements. This commitment is shared by all employees at all levels, from production program management, through business resource planning, to manufacturing engineering, test engineering and product support.

To ensure customers continue to receive high quality, reliable components from its team of 230 manufacturing employees, General Dynamics Canada has adopted a Lean Six Sigma production philosophy at its 103,000 square foot facility. Manufacturing capabilities are focused on electronic and mechanical assembly, integrated with a complete test strategy that includes:

- Radio Frequency (RF) testing
- Environmental Stress Screening (ESS)
- Structural and functional testing:

- X-Ray Inspection
- Automated Optical Inspection
- Boundary Scan Test
- Flying Probe
- In-Circuit Test (ICT)

Quality control in this low volume, high mix manufacturing process is maintained by highly trained and skilled employees organized into product line cells and integrated product development teams. All employees and teams are empowered with responsibility for quality, cost and schedule, as well as lean manufacturing techniques. In addition, the entire operation is supported by the latest integrated information, quality tracking, and cascade project management systems.

The overall structure of the manufacturing process is based on the philosophy that extraordinary thinking delivers extraordinary action and results by all employees. As a result, employees are empowered to apply breakthrough thinking to meet and exceed customer quality and reliability expectations. Plus, employee empowerment is enabled by core values that provide a customer-focused, quality-centric framework for all decisions.

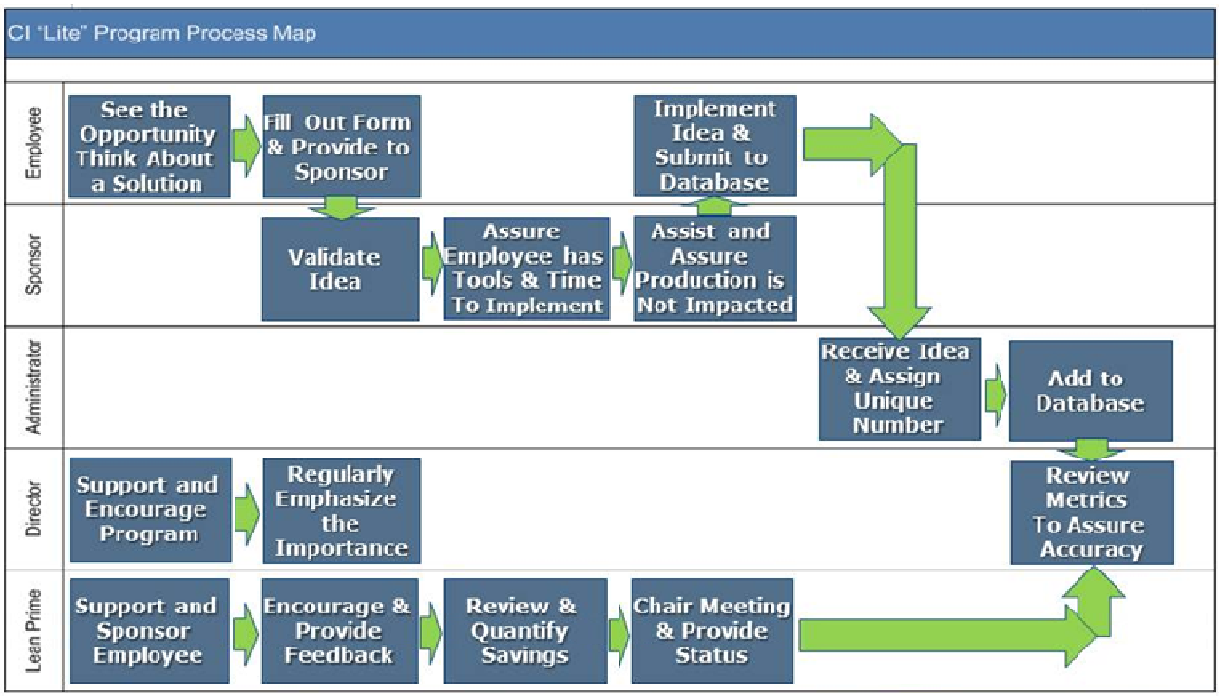
This approach to quality permeates the entire manufacturing process and is evident in the organization's commitment to:

- Rapid turnaround, which is enabled by the integration of manufacturing operations into the product development cycle, and by the fact that manufacturing owns the new product introduction and release process
- Higher standards, which is backed by the organization's certification in IPC 610 Class 3, IPC 620 Class 3, AS9100, and ESD Class 0
- Zero product failures, which is supported by:
  - Integrated Design for Manufacturability, Design for Testability
  - Programs that enable employee ownership of quality work, self-verification and buddy checks
  - A seamless integration of test and verification methodologies, as well as improvement through continuous review and analysis of quality in-house and field data to drive improvements in process, design and materials
- Twenty-year product service life, which is facilitated by:
  - Lean Six Sigma build practices that validate product quality and reliability throughout the assembly cycle
  - An unrivalled test and ESS process that ensures world-class final product reliability

An integrated repair and overhaul facility, with co-dependent systems for products still in production and independent systems for products out of production.

Finally, to ensure all employees have the opportunity to contribute to overall business objectives, General Dynamics Canada has adopted its own brand of continuous improvement. Known as “CI Lite”, this program is designed to engage all employees in improvement efforts by capturing small improvements that affect overall quality and providing a path to change the manufacturing environment wherever it will benefit the customer. With this effort, General Dynamics Canada has moved the responsibility for quality and continuous improvement out of the hands of a centralized group and empowered everyone in the manufacturing process with the knowledge that they can make a difference (Figure 6).

Figure 6: General Dynamics “CI Lite” Continuous Improvement Program



Conclusion

Unlike components for consumer applications, electronic components destined for defense and aerospace platforms must be engineered and manufactured to higher quality and reliability standards. They must meet stringent performance requirements and be better able to withstand the effects of dust, heat, cold, vibration and electrostatic discharges that may affect them on the battlefield. Therefore, finding the right manufacturer is the key to a program’s success.

The ideal manufacturing partner will have a thorough understanding of manufacturing processes, as well as a high level of experience and understanding of the engineering behind each product. The right partner will also have highly skilled and motivated employees, as well as programs to develop those employees into a customer-focused workforce aligned to the needs of each customer, and to the

ultimate end user of every component produced. In addition, a customer-centric manufacturer will go beyond base level certifications by continuously striving for ever higher standards.

A truly integrated manufacturing process that meets the high quality and reliability requirements of defense and aerospace platforms is built on effective management of cost, quality and schedule. To manage costs, the manufacturer must integrate an optimized quality control test strategy into key steps in the manufacturing process. Integrated properly, this ensures outgoing end product quality is high and minimizes the effect of the quality control/test process on the overall cost of the product. To improve quality, the manufacturer must take responsibility for improvement out of the hands of a small centralized group tasked with overseeing corporate efforts and extend it beyond the factory floor to all employees. Finally, a truly integrated manufacturing process must also have mechanisms in place to improve the ability of the organization to deliver quality products on time, every time. This is best achieved by ensuring individuals and teams involved in the manufacturing process are aligned with each other, product quality requirements, and the overall corporate objectives.

For more than 60 years, General Dynamics Canada has delivered high quality, highly reliable products to defense and aerospace organizations worldwide. Its integrated manufacturing capability has been achieved by balancing the capabilities of a state-of-the-art physical plant, with extensive knowledge and experience gained from multiple programs, and a proven ability to meet stringent delivery schedules. Quality control in its low-medr volume, high mix manufacturing process is maintained by highly trained and skilled employees empowered with responsibility for quality, cost and schedule, and it is supported by customized implementations of lean manufacturing and continuous improvement techniques.

In addition, General Dynamics Canada is part of General Dynamics C4S, a division of General Dynamics Corporation, which procures material at a rate ten times greater than that of General Dynamics Canada alone. By leveraging this purchasing strength, General Dynamics Canada provides defense and aerospace organizations with all the benefits of integrated quality manufacturing backed by the power of a large supply chain.

Acronyms

Term	Definition
COTS	Commercial off-the-shelf
ICT	In-Circuit Test
ESS	Environmental Stress Screening
RF	Radio Frequency
SPC	Statistical Process Control
VDU	Video Display Unit

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