U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Primer on Lean Six Sigma

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Contact/Author

Latif Hamdan, Business Process Improvement Specialist
Communications and Performance Improvement
Office of Executive Director for Operations
(301) 415-6639
Latif.Hamdan@nrc.gov

Contact/Business Process Improvement Program

John Harrison, Program Manager, Business Process Improvement
Communications and Performance Improvement
Office of Executive Director for Operations
(301) 415-0151
John.Harrison@nrc.gov

Contact/ Communications and Performance Improvement

Mindy Landau, Deputy Assistant for Operations
Communications and Performance Improvement
Office of Executive Director for Operations
(301) 415-8703
Mindy.Landau@nrc.gov

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In 2007, the U.S. Nuclear Regulatory Commission (NRC) launched an initiative to develop Lean Six Sigma capability at the NRC. The agency deployed a Lean Six Sigma program to improve the quality and timeliness of products and services, increase efficiency, and improve operational effectiveness.

This primer is part of an effort to communicate Lean Six Sigma knowledge throughout the NRC. It provides readers with basic information about Lean Six Sigma and the Lean Six Sigma program activities at the agency. The primer is organized into the following three parts:

Part 1 presents an overview of Lean Six Sigma, including its benefits and implementation difficulties.

Part 2 provides a general practice guide for Lean Six Sigma.

Part 3 describes the Lean Six Sigma infrastructure, internal resources, and potential applications at the NRC.

Part 1: Lean Six Sigma Overview

Lean Six Sigma is a proven business model centered on process improvement. It is used to improve performance and increase effectiveness and has been successfully applied to improve performance in both the private sector and the Government.

All organizations want to run effective businesses that improve the quality and timeliness of their products and services, increase efficiency, and reduce cost. Lean Six Sigma is implemented specifically to meet all of these goals. Private businesses use Lean Six Sigma to stay competitive and improve the bottom line—to maximize profits and return on shareholder investment. It helps businesses accomplish this goal both by increasing sales, revenues, market share, and growth rates and by increasing efficiency and reducing cost—all at the same time. Many success stories recount the benefits private companies have realized from Lean Six Sigma applications. As an example, Toyota Motor Company has reportedly been able to achieve the following results by applying a production system rooted in Lean Six Sigma (Arthur, 2007):

- The annual profits by Toyota in 2003 exceeded the profits of General Motors, Ford, and Chrysler combined.

- Toyota's market capitalization in 2006 was $181 billion compared to General Motors's $15 billion and Ford's $12 billion.

Other examples of private companies that have benefited from Lean Six Sigma applications include Motorola, General Electric, Allied Signal, IBM, and Texas Instruments (Arthur, 2007; Brussee, 2006; Brue, 2002).

Government agencies can use Lean Six Sigma to improve performance, deliver high quality services, increase efficiency, meet strategic and operational goals, and increase stakeholder satisfaction inside and outside the Government. A publication by Maleyeff (2007) highlights the need and cites examples of successful Lean Six Sigma projects and programs that have been completed at the Federal, State, and local government levels. Cited examples include activities by the U.S. Department of Defense (Army, Navy, Air Force, and Office of the Secretary of Defense); National Nuclear Security Administration in the Department of Energy; Washington State Department of Licensing; Florida Department of Revenue; Lane County, OR; the city of Hartford, CT; and the city of Fort Wayne, IN.

Graham (2008) discusses and provides excellent examples of how Lean Six Sigma was used to turn city government in Fort Wayne, IN into a customer-driven and efficient enterprise.

Lean Six Sigma organizations achieve their goals through the following strategies:

- following a disciplined results-driven approach that relies on data and measurements to improve processes and business effectiveness

- defining quality by what the customer wants and is willing to pay for

- setting an extremely high quality standard that aims at eliminating virtually all errors, defects, and variation and achieving a near-perfect production process

- improving efficiency by increasing process speed and eliminating delays and other time traps

- eliminating waste and reducing production cost

- promoting teamwork and building effective working and business relationships between the senior management, workforce, suppliers, and customers

- instituting and supporting a policy for continuous process improvement and maintaining the flexibility to implement improvements in response to evolving conditions and opportunities inside and outside the business

The decision to apply Lean Six Sigma is strictly a business decision. In both the private and public sectors, Lean Six Sigma projects and programs are expected to pay for themselves. If the projected long-term benefits from a Lean Six Sigma project do not exceed the anticipated cost, the project will not be approved. In general, when properly applied, Lean Six Sigma can result in high returns on investment because the benefits from process improvement are usually repetitive and continue to accrue over time. In addition, Lean Six Sigma can also effect important less tangible and intangible benefits. Examples include improved communication at all levels in the organizational hierarchy, increased employee morale and job satisfaction, energized and empowered workforce, improved productivity, and improved overall work and business environment.

Origins of Lean Six Sigma

Lean Six Sigma integrates two proven process improvement methodologies: Lean and Six Sigma. Both methodologies share a common commitment to improving performance and maximizing results and outcomes; they focus on the process and not on personnel; they aim at making products that fully meet or exceed customer needs and expectations; and they rely on quantitative data and measurements to make informed and objective decisions. However, the two methodologies have some different, albeit complementary, emphases.

Modern concepts of Lean are rooted in a process improvement methodology developed by W. Edward Deming in the middle of the

20th century (Deming, 1952; Deming, 1986; see also The W. Edwards Deming Institute at http://deming.org/). Deming determined that 85 percent or more of production problems result from process deficiencies and that workers are responsible for only 15 percent (or less) of business problems. Deming argued that, rather than blaming and relying on workers to improve operational and organizational effectiveness, organizations ought to focus on improving the processes instead. These concepts, adopted by Toyota Motor Company, form the basis for the famed and highly efficient Toyota Production System (Womack, et al., 1991).

Lean emphasizes the importance of defining and fully satisfying customer needs, improving process efficiency, and reducing cost. Lean achieves these goals and improves business effectiveness through the following:

- defining customer needs and producing products that fully meet or exceed customer specifications and expectations

- reducing process cycle time by increasing process speed and flexibility, eliminating work overload, unnecessary steps, delays, and other time traps that can slow the process

- eliminating or vastly reducing waste that results from variation, errors, and defects, large inventory, overproduction, and other unnecessary activities

- maintaining flexibility to continue process improvement in response to evolving opportunities and/or changing internal and/or external conditions

Motorola developed and successfully implemented Six Sigma in the 1980s. The methodology aims at building quality into the start of every process, thereby eliminating the need for rework to fix variation, errors, and defects.

Six Sigma is rooted in the premise that traditional operations result in costly variation, errors, and defects and that significant savings and other benefits can be realized by eliminating or vastly reducing them. Six Sigma aims at perfecting the production process so that the product (and/or service) is virtually free of variation, errors, and defects through the following actions:

- setting an extremely high quality standard that aims at eliminating virtually all errors, defects, and variation and achieving a near-perfect production process

- providing the concepts, methods, tools, and guidance for developing Lean Six Sigma infrastructure, improving the production process, and achieving and sustaining high performance goals

Six Sigma raised the benchmark for acceptable defects from the number of defects per 100, or per 1,000, to the number of defects per 1 million.

In Six Sigma, sigma is a quality level that characterizes process variation and the number of defects or errors. A low sigma process results in a large number of defects and large variation. A high sigma process results in a small number of defects and small variation. The following table provides the quantitative relationship between the quality level and the number of defects per 1 million opportunities (dpmo):

- 1-sigma level: 691,400 dpmo
- 2-sigma level: 308,700 dpmo
- 3-sigma level: 66,810 dpmo
- 4-sigma level: 6,210 dpmo
- 5-sigma level: 233 dpmo
- 6-sigma level: 3.4 dpmo

Traditional non-Six Sigma operations run at about a 3-sigma level, while Six Sigma organizations adopt the 6-sigma level. The number of defects differs significantly between the two levels. Traditional organizations are satisfied with 66,810 dpmo; Six Sigma companies aim at having no more than 3.4 dpmo.

The 6-sigma level is a goal that may not be attained in practice. This is because Lean Six Sigma projects are approved only if they are economical and cost effective (Brussee, 2006), and achieving a 6-sigma level may not be cost effective on some projects. Still, by seeking to reach the 6-sigma level, these companies operate at a higher level than their non-Lean Six Sigma competitors and achieve far better results and outcomes. Fewer defects and errors lead to important cost reductions and corresponding increases in earnings and profits. Even though the 6-sigma level may not be within reach, Lean Six Sigma can still go a long way in helping companies attain

their business goals and serve the interests of their shareholders.

Pizdeck (1999) notes that the need for performance at a high 6-sigma level is not limited to the manufacturing processes. He cites the following examples of failures that can be expected to take place in nonmanufacturing businesses operating at a low 3-sigma level in today's society:

- Virtually no modern computer would function.
- 10,800,000 healthcare claims would be mishandled each year.
- 18,900 U.S. Savings Bonds would be lost each month.
- 54,000 checks would be lost each night by a single large bank.
- 4,050 invoices would be sent out incorrectly each month by a modest-sized telecommunications company.
- 540,000 erroneous call details would be recorded each day from a regional telecommunications company.
- 270 million erroneous credit card transactions would be recorded each year in the United States.

Brue (2002) makes a similar point. Noting that the 6-sigma level of no more than 3.4 dpmo corresponds to a highly effective process and results in a nondefective output rate of 99.9997 percent, he asserts that such a high performance level is needed in the modern world. He points out that accepting a lower quality level, such as a 99-percent nondefective rate, would result in the following undesirable outcomes:

- The postal service would lose 20,000 pieces of mail every hour.
- Drinking water would be unsafe for almost 15 minutes of every day.
- 5,000 surgical operations would go wrong in some way every week.
- Electricity would be unavailable for almost 7 hours of every month.

Brue (2002) also provides an insightful example from the package-

handling capability of the airlines. He indicates that many airlines are operating at a 3-sigma level, leading to about 66,000 mishandled bags (or defective services) for every 1 million luggage transactions. This translates to about a 94-percent probability that travelers will get their luggage without incident. He argues that operating at the 3-sigma level represents a large cost for the airlines, both in terms of handling misplaced luggage and dealing with unhappy customers. If the airlines were to achieve a 6-sigma level, the number of service defects would be cut to a very manageable 3.4 misplaced bags per 1 million luggage transactions.

Approach and Methodology

Lean Six Sigma is commonly used to improve existing processes. However, in some cases, it can also be used for process design. This is known as "Design for Lean Six Sigma," and it is used when there is a breakdown in an existing process, or when designing a new process that can best meet business goals. The discussion in this primer is limited to the use of Lean Six Sigma to improve existing processes.

Process improvement in Lean Six Sigma is accomplished in practice by executing Lean Six Sigma projects. Team launch is the first formal step in the execution of any Lean Six Sigma project.

Lean Six Sigma projects have sponsors and are executed by project teams following a method known as "DMAIC." This is an acronym for five systematic steps or phases: define, measure, analyze, improve, and control. At the end of each phase, the project team conducts a "gate review" to brief the project sponsor about the team findings and recommendations and to solicit the project sponsor's feedback. The gate review is an important feature of Lean Six Sigma. It affords the project sponsor the opportunity to instruct the project team to proceed with the project as may be recommended by the team, proceed with modification, or stop the project.

In some cases, a discovery phase may also be implemented upfront to collect information about the process, customer and stakeholder needs, and business goals. This information is used to prepare a preliminary project charter.

In a nutshell, the DMAIC method follows five systematic steps or phases that aim at collecting information about the process, customer and stakeholder needs, and business goals; defining the

current process including problems, opportunities, and critical customer and stakeholder requirements; conducting measurements and establishing performance metrics, baseline conditions, and performance goals; analyzing problems and identifying their root causes; developing, demonstrating, and implementing a solution; and establishing monitoring and control measures to sustain the improvements long term. The following is a brief discussion of the five phases of the DMAIC method.

(1) ***Define Phase***. The purpose of the define phase is to validate project viability including the business impacts, and to finalize the project charter and execution plan.

This phase involves the following main activities: (1) collecting information about the process, the customers, and the business, (2) defining process steps and developing a high-level process map (flow chart), (3) defining process suppliers, input, output, and customers, (4) identifying critical requirements of customers and stakeholders, (5) updating the project charter, (6) assessing project risk, (7) evaluating business impacts and validating project viability, and (8) presenting team findings and recommendations to the project sponsor in the gate review.

(2) ***Measure Phase***. The purpose of the measure phase is to develop quantitative performance metrics and establish performance baseline and goals.

This phase involves the following main activities: (1) collecting process records and establishing a process database, (2) deciding the need for and feasibility of additional measurements including data collection methods and measurement systems to support the project, (3) preparing a detailed value stream map (VSM) of the process showing process steps and flow including quantitative data (e.g., cycle times, time traps, inefficiencies, and waste), (4) developing performance metrics and establishing performance baseline and performance goals, (5) revising the project charter as necessary consistent with the measure phase findings, and (6) presenting team findings and recommendations to the project sponsor in the gate review.

(3) ***Analyze Phase***. The purpose of the analyze phase is to identify and rank process problems and their root causes.

This phase involves the following main activities: (1) analyzing process data and identifying process performance issues and problems (e.g., constraints, bottlenecks, and quality issues), (2) identifying and ranking root causes, (3) identifying critical-to-quality inputs, and (4) presenting team findings and recommendations to the project sponsor in the gate review.

(4) ***Improve Phase***. The purpose of the improve phase is to recommend process improvements and implement a pilot to demonstrate benefits, and to prepare a plan for full-scale implementation of recommended improvements.

This phase involves the following main activities: (1) identifying and ranking of process improvement measures based on benefits and risks, (2) recommending a best solution, (3) implementing a pilot solution and demonstrating benefits, (4) developing a plan for a full-scale implementation of improvements, and (5) presenting team findings and recommendations to the project sponsor in the gate review.

(5) ***Control Phase***. The purpose of the control phase is to document the results of the project, and to develop monitoring and control measures to be used for self-assessment and sustaining improvements long term.

This phase involves the following main activities: (1) documenting the project including the improved process, (2) developing and instituting monitoring and control measures to sustain improvements long term, and (3) handing off project documentation to the process owner.

The execution of a Lean Six Sigma project can vary depending on project scope and complexity. Typically, the DMAIC phases are executed in 3–6 months. However, under certain conditions they are executed in just one week. This latter approach is called a "Kaizen," which means "change for the better" in Japanese and involves an expedited execution of the DMAIC phases, typically one phase per day. The Kaizen may not include implementation of a pilot or a full-

scale solution.

In general, the Kaizen approach is usually used in the following situations (George, et al., 2005):

- Obvious waste sources have been identified.
- The scope and boundaries of a problem are clearly defined and understood.
- Risk is minimal.
- Results are needed immediately.
- It is important to gain momentum and build credibility in the early stages of deployment.
- Opportunities to improve a process have been identified.

Other considerations for executing a Kaizen event may include those listed below:

- The process is not complex.
- The effort is directed more toward tactical operations.
- The effort is at low levels of the organization.
- The process is within one organizational unit or crosses no more than one organizational boundary.
- The effort is directed more toward internal customers and stakeholders.
- The results are needed immediately.

This primer focuses on the traditional DMAIC process. Additional information about the Kaizen approach is available in many of the references and on the Lean Six Sigma page on the NRC internal Web site (http://nrcweb:8600/oedo/LEAN SIX SIGMAP/index.html).

Finally, Lean Six Sigma uses quantitative analysis and analytical and graphic tools. Part 2 briefly discusses some of the more commonly used Lean Six Sigma tools. A detailed discussion of Lean Six Sigma tools is beyond the scope of this primer, but this information is readily available from many sources, including some of the references and bibliography in this primer.

Lean Six Sigma versus Traditional Approach

Lean Six Sigma is not complicated or difficult, but it differs from the traditional business approach such as the mass production system in manufacturing in some important respects. Lean Six Sigma follows

different concepts, philosophy, and mindset and uses a different approach and methods. These are some of the differences as they apply to private businesses

- Traditional businesses design their products and make decisions based on their expertise; Lean Six Sigma organizations design their products to their customers' specifications, and data and results drive their decisions.

- Traditional businesses spend an inordinate amount of time on rework and fixing defective products and services; Lean Six Sigma organizations consider defects and rework as waste and strive to identify and eliminate the root causes of defects. The threshold for acceptable defects for Lean Six Sigma organizations is significantly lower than in traditional businesses, which means less time spent on rework and fixing defects.

- Traditional businesses learn to accept their performance gaps and rely on temporary fixes; Lean Six Sigma organizations think long term and institute long-term solutions.

- Traditional businesses rely on large inventories to satisfy projected demand; Lean Six Sigma organizations consider inventory to be unnecessary and rely on flexibility and speed to make and deliver products on time and thereby eliminate the inventory cost.

- Traditional companies focus on the outside business and the need to increase sales, revenues, and market share; Lean Six Sigma companies focus on two equally important businesses—the outside business and the internal operations, particularly in terms of eliminating waste, improving efficiency, and reducing cost.

- Traditional businesses are likely to blame employees and workers for performance problems; Lean Six Sigma organizations believe the process is responsible for the great majority of problems.

The following example illustrates some of these differences relating to process improvement. Consider the performance gaps between expectations and actual performance, which is a common problem for organizations and businesses. Performance gaps result from

variations in performance over time, and they surface when products do not meet specifications or standards (quality gaps), or when tasks cannot be completed on time (timeliness gaps), or both.

Traditional non-Lean Six Sigma organizations handle performance gaps by applying temporary measures to fix problems, usually without giving much attention to making any significant changes in the underlying process. Performance gaps related to quality are mitigated by applying quality control measures that involve rework and fixing of errors. Performance gaps related to timeliness are resolved by asking employees to step up, work harder, or work overtime. Additional resources are sometimes allocated to ensure that deadlines are met. Management in these organizations relies on temporary fixes to close performance gaps without taking the time or effort needed to make fundamental changes to permanently improve process capability. The end result is that non-Lean Six Sigma organizations are unable to control product variation over time, they accept the process performance gaps, and they continue to run incapable processes and inefficient operations.

Lean Six Sigma organizations rarely resort to temporary measures to improve performance, and they do not address all performance gaps in the same way. They routinely monitor their processes and, when a performance gap is discovered, they proceed to investigate it and identify its root cause. Based on the investigation findings, they may decide to do nothing (e.g., if the underlying problem represents a normal occurrence in the process or if it is related to a special one-time cause or event that may or may not require fixing). However, if the performance gap results from a common cause or an inherent deficiency in the process, Lean Six Sigma organizations will take the time to implement long-lasting measures to improve overall process capability. They do so because they know that investment in such improvements will pay off many times over in the long run.

Attributes and Benefits

The following are some of the attributes and benefits that may be unique, at least in some respects, to Lean Six Sigma:

- *Focus on Process*

  Lean Six Sigma aims at improving business operations by focusing on improving business processes. It is rooted in the

premise that organizations can eliminate 85 percent or more of operational problems by fixing business processes.

- *Customer Driven*

  Lean Six Sigma focuses on increasing the value to business customers and stakeholders and delivering products and services that fully meet customer specifications in terms of quality and timeliness. Customer input, from both external and internal customers and stakeholders, is vital to achieving good results.

- *Results Driven*

  Lean Six Sigma is driven by results. Lean Six Sigma projects are not approved unless they are economical and cost effective. To be successful, a Lean Six Sigma project must demonstrate a positive and measurable outcome and show that project benefits exceed project cost.

- *Measurements-Based Decisionmaking*
  Lean Six Sigma is an objective approach; decisions are primarily based on data and measurements. Lean Six Sigma uses existing data and new information about the process (Voice of the Process), the customer (Voice of the Customer), and the business (Voice of the Business) to establish baseline conditions and goals and relies on quantitative performance metrics to quantify and demonstrate the results.

- *Value Focus*

  Lean Six Sigma organizations achieve efficiency by focusing on improving value-added activities and eliminating nonvalue-added work. In general, value-added activities are defined as activities that customers are willing to "pay for" and add value to the product the first time they are implemented. Rework is not a value-added activity in Lean Six Sigma. Some of the basic business requirements may also be considered as value-added activities.

- *Team Approach*

  Lean Six Sigma projects are not executed by individuals

working in isolation. They are executed by project teams, and every Lean Sigma project begins with a formal team launch. The project team is ultimately responsible for verifying the problem and goal statements, analyzing process steps and workflow and identifying root causes of problems, identifying solutions and evaluating improvement benefits and risks, and making recommendations to the process owner. Every member of a Lean Six Sigma project team is responsible, and receives credit, for project success.

- *Flexibility*

  Flexibility is an important attribute of Lean Six Sigma. It allows businesses to make improvements in response to opportunities identified during operational monitoring. It also allows organizations to respond promptly to outside change and support continuous improvement. The flexibility in Lean Six Sigma extends to project execution as well. During the gate reviews, the project team recommends to the process owner whether the project should proceed to the next phase or whether it should be stopped. Thus, the process owner can stop the project at the end of any phase of the DMAIC process.

- *Empowerment of Employees and Workforce*

  Lean Six Sigma will improve employee morale and workforce productivity and effectiveness by encouraging workers to participate in the decisionmaking process as members of Lean Six Sigma project teams and offering them the opportunity to take pride in the quality and timeliness of their products and services.

- *Lean Six Sigma Is a Philosophy and a Mindset*

  Lean Six Sigma is not merely a method or a set of tools, and merely learning the method and tools may well achieve very little. To reap outstanding results, Lean Six Sigma ought to be viewed as a continuous improvement process and become part of the business culture, philosophy, and mindset.

- *Turnkey/Wall to Wall/Beginning to End*

  Lean Six Sigma is a turnkey process improvement approach.

It validates the need, identifies the problems and their root causes, identifies and implements a pilot solution and demonstrates benefits, and develops a plan for instituting a solution, including performance metrics and control measures to sustain the gains long term.

- *Managing the Outside and the Inside of the Business*

  Lean Six Sigma addresses problems on the outside and the inside of the business. On the outside, it improves product and service quality and increases business effectiveness with external customers and stakeholders, which, in the case of private companies, results in increased sales, market share, revenues, and growth. On the inside, it improves process efficiency, which, for private companies, results in reduced cost. By focusing on both the outside and the inside, private businesses realize significant improvements in the bottom line in terms of profits and net return on their shareholders' investments.

Limitations and Difficulties

Companies and organizations implementing Lean Six Sigma initiatives for the first time usually face programmatic and other difficulties that they will need to understand and overcome to ensure success. The following are some of the more common difficulties:

- *Demonstrating Benefits*

  Success of Lean Six Sigma depends entirely on results and outcomes. Lean Six Sigma initiatives, programs, and projects must demonstrate tangible benefits to the organization or business. Although execution of Lean Six Sigma can result in many intangible benefits, success depends on and is ultimately measured by tangible and quantitative results and outcomes. Realizing real and tangible benefits is essential for gaining acceptance and for creating the enthusiasm and energy to propel the program forward.

- *Defining a Pressing Business Need*

  Lean Six Sigma initiatives, programs, and projects must address real and pressing business needs. Identifying

a pressing business need (sometimes called a "burning platform") is key to realizing and demonstrating large benefits.

- *Project Selection*

  Projects ought to be carefully identified, ranked, and selected to ensure that they are beneficial and that the most pressing needs receive the most effort. Doing many process improvement projects instead of focusing on mission-critical or high-value processes may not produce the desired outcome or results. Executing poorly selected projects without the use of discriminating project selection criteria can kill the program.

- *Reliance on Data and Quantitative Analysis*

  Lean Six Sigma relies on objective and data-driven decisionmaking. Decisions about problems and solutions are based not on someone's opinion, but rather on data and analysis. Objectivity comes at a price: data must be acquired or collected and then analyzed to support decisionmaking.

- *Upfront and Sustained Commitment and Sustained Support for Continuous Improvement*

  Lean Six Sigma requires upfront investment, preparation, and planning. Perhaps even more important, Lean Six Sigma ought to be considered as a journey not a destination. To reap full benefits, Lean Six Sigma requires sustained support for a culture and a mindset of continuous improvement.

- *Commitment To Implementing Recommended Improvements*

  Success requires commitment to following through with and implementing recommended improvements and instituting monitoring and control measures to sustain the improvements over the long term.

- *Planning and Managing Change*

  Lean Six Sigma entails change that may bring about uncertainty and even fear. Change generates resistance.

Implementation of Lean Six Sigma programs and initiatives will need to include a strategy and a plan to manage change and mitigate resistance to change in all of its forms.

- *Understanding the Limitations*

  A limited general knowledge of Lean Six Sigma methodology and a limited appreciation of its many benefits may hamper Lean Six Sigma applications. In this regard, it is important that businesses and organizations applying Lean Six Sigma understand what Lean Six Sigma is and what it is not.

  - Lean Six Sigma is not an external audit or inspection; it is an internal self-assessment by the process owner who solely has the authority to initiate a Lean Six Sigma process improvement project and implement recommended improvements.
  - Lean Six Sigma is not a panacea; it is a methodology and an approach for process improvement.
  - Formal training is necessary but not enough; Lean Six Sigma requires learning by doing.
  - Knowledge of Lean Six Sigma methods and tools is useful, but understanding Lean Six Sigma philosophy, mindset, and culture is crucial.
  - Too much focus on activity and application of methods and tools and not enough focus on the results do not bode well for new Lean Six Sigma deployments.

- *Managing the Critics and Skeptics*

  Lean Six Sigma has its critics. Some feel that Lean Six Sigma is about complicated statistics, or that it may not apply to Government work. Others are concerned about the price tag. However, as previously discussed, Lean Six Sigma is about results and outcomes, and Lean Six Sigma activities pay for themselves many times over in the end.

Part 2: General Practice Guide for Lean Six Sigma

Properly deployed and implemented Lean Six Sigma initiatives and programs can result in a major payoff, including significant long-term process and business improvements. The success rate for Lean Six Sigma initiatives by commonly used approaches is reportedly 50 percent (Arthur, 2007). Poorly deployed or implemented initiatives and programs that do not meet expectations are abandoned.

The success or failure of Lean Six Sigma initiatives depends on programmatic factors, as well as project execution. The following is a general practice guide for both program deployment and execution of individual projects. The guide is based on a limited literature review and firsthand experience with Lean Six Sigma project execution at the NRC.

2A—Program Deployment Guide

Investment in infrastructure and staff training to develop certified professionals are needed for successful deployment of Lean Six Sigma initiatives and programs. Sustained commitment and support for continuous process improvement by senior management is also important, but above all else, successful deployment of Lean Six Sigma ultimately depends on successful execution of individual projects and demonstrating the benefits of Lean Six Sigma.

Organizational Orientation

The initial stage of Lean Six Sigma deployment necessarily involves organizational and staff orientation. This effort is critical for general knowledge and program support and for support of specific projects. The target audience could include senior managers, prospective process owners, and key program support staff, particularly those involved in key business processes and who may be prospective team members for Lean Six Sigma projects. This effort could involve short-term training sessions conducted by outside contractors, involvement in process improvement projects, and effective communication.

Lean Six Sigma Training

Training of Lean Six Sigma analysts includes both formal and on-the-job training (i.e., training by doing Lean Six Sigma projects). Lean Six Sigma analysts are certified at one or more of the following levels:

- White Belt: Attains basic knowledge in Lean Six Sigma
- Green Belt: Works part time as a Lean Six Sigma professional or analyst on noncomplex Lean Six Sigma improvement projects
- Black Belt: Works full time as a Lean Six Sigma professional leading, facilitating, and coaching Lean Six Sigma project teams
- Master Black Belt: Oversees multiple Lean Six Sigma improvement projects
- Champion: Active sponsor, advocate, and leader for a Lean Six Sigma program

Black belts support large projects; green belts support smaller projects. Green belts are also good prospects to become future black belts. Candidates for black belt and green belt training should be selected based on clearly defined criteria, including both technical and business skills, and their ability to advocate for agency policy change when necessary.

Black belt training is incomplete without hands-on experience. In-house black belts involved in project execution may have to be supported initially by a master black belt or a highly experienced black belt provided by outside contractors.

Management Support

Sustained management support is a prerequisite for successful deployment and implementation of Lean Six Sigma initiatives and programs. Management support is needed for providing financial and other resources, identifying processes requiring improvements, and implementing and institutionalizing recommended improvements. Even more than that, management support is needed to make an organizational commitment to continuous process improvement so that the organization remains flexible and open to change in response to new and evolving developments inside or outside the organization.

Demonstrating Benefits

All Lean Six Sigma efforts will likely result in important intangible and indirect organizational benefits. Nevertheless, in both the public

and private sectors, process improvement projects are initiated and executed on the expectation and subsequent demonstration that project benefits exceed project cost. The success of Lean Six Sigma initiatives and programs ultimately depends on demonstrating that Lean Six Sigma process improvement projects achieve tangible and measurable benefits that exceed the initial investment. If the expected benefits do not exceed the initial investment, the program will not be sustained.

Planning and Implementation

The concepts, methods, and tools of Lean Six Sigma are straightforward and are generally well understood. All Lean Six Sigma projects are executed following a standardized process. So why do some Lean Six Sigma initiatives and programs succeed while others fail?

Success of Lean Six Sigma ultimately depends on successful implementation measured by results and outcomes. Success requires organizational commitment and proper planning and implementation. This requires organizational commitment; understanding and appreciation of Lean Six Sigma benefits at the organizational, program, and project levels; proper selection and execution of projects; and proper planning to overcome implementation difficulties.

The following is a general guide for Lean Six Sigma deployments and projects at the organizational, program, and project levels.

At the Organization Level

- Use Lean Six Sigma under the following circumstances:
  - You have a business challenge.
  - You have a specific business process that has problems.
  - The challenge and problems have persisted over a long time.
  - The solution is not known.
- Do not use Lean Six Sigma if:
  - You do not have a specific challenge.
  - You do not have a process to improve.
  - You already have a solution.

- Identify and rank pressing business needs that can benefit from process improvement.
- Emphasize results and outcomes, not activity or the number of projects.
- Emphasize proper project selection.
- Develop own black belts and master black belts.
- Emphasize learning by doing.
- Anticipate and prepare for change and resistance to change.
- Implement recommended improvements.
- Recognize and reward progress.
- Commit to continuous process improvement.
- Commit necessary budget and resources.

At the Program Level

- Emphasize results and outcomes, not activity or the number of projects.
- Select projects carefully.
- Execute projects to improve clearly defined processes.
- Ensure that projects have sufficient resources and are properly executed.
- Communicate well.
- Encourage internal networking and advocacy.
- Emphasize learning by doing.
- Be flexible and be prepared to make adjustments when needed.
- Recognize opportunities and risks.
- Anticipate and prepare for change and resistance to change.
- Select outside contractors carefully.
- Beware of skeptics and naysayers.

At the Project Level

- Choose the project team carefully (Lean Six Sigma may be easy; team work is hard.)

- Emphasize results and outcomes, not activity.

- Rely on data to verify and validate project and to support decisionmaking throughout the project.

- Evaluate the available data and determine how data collection and acquisition will impact the project positively or

negatively.

- Do not confuse symptoms with root causes.
- Implement quick wins and demonstrate results at every opportunity.
- Secure commitment from the process owner to implement improvements.
- Implement pilot solutions and demonstrate improvements on every project.
- Prepare plans and institute controls to sustain gains over the long term.
- Communicate results and lessons learned.
- Beware of excuses and naysayers.
- Beware of scope creep during project execution.

2B—Project Execution Guide

Successful Lean Six Sigma applications typically involve properly selecting and executing projects, implementing improvements and demonstrating business benefits, and instituting improvements and sustaining gains long term.

Project Selection

Proper selection of Lean Six Sigma projects is critical, especially during the initial stage of a Lean Six Sigma program. The importance of this activity cannot be overemphasized. Poor project selection is the surest path to project failure. Likewise, selecting and successfully executing the right project in the early stages of Lean Six Sigma deployment may be the most important single factor in propelling the program forward.

First and foremost, Lean Six Sigma projects should be executed in response to real and pressing business needs, and they should be ranked on the basis of their estimated payoff in terms of business impact and benefits. However, other factors must be considered, such as the prospects for successful results and the process owner's

commitment to implementing improvements at the conclusion of the project. The following are some of the criteria that may be used in the selection and ranking of projects:

- *What are the business benefits*? Projects are executed only if it is determined that the expected business benefits will exceed the project cost.

- *Is there a pressing business need for process improvement*? Lean Six Sigma projects should not be undertaken if there is no real or pressing need for process improvement, because the project benefits will likely be small.

- *Is the process stable and repetitive*? Organizations can expect large benefits from Lean Six Sigma projects involving stable and repetitive processes, because the benefits accrue every time the process is used, over a long period of time. If the process is not stable and repetitive, the benefits may not be sufficient to justify the project.

- *What are the prospects for success*? Is the project scope realistic? Is senior management supportive and willing to provide sufficient budget and resources to execute the project? Is there a record of process performance? If sufficient resources cannot be committed or if there are no data and the data cannot be acquired in a reasonable time, Lean Six Sigma projects should not be approved.

- *Is the process owner committed to implementing improvements once they have been identified*? If the improvements will not be implemented, there is no point in doing a Lean Six Sigma project.

- *Do we know the solution*? Do we know of specific actions that will improve the process without Lean Six Sigma? Lean Six Sigma projects ought not to be approved if solutions to improve the process are already known.

Project Execution

Preliminary Steps. Once a Lean Six Sigma project is approved, the project is assigned a Lean Six Sigma analyst (usually a black belt, although a green belt may be assigned to smaller projects). The project sponsor, who is usually the process owner, and the black belt collaborate on the following preliminary activities before the formal team launch:

- Define the process, including the problem statement, goal statement, and business impact.
- Determine the project scope and a tentative execution schedule.
- Estimate project costs and benefits and verify that the estimated benefits exceed the estimated costs.
- Select members of the project team.
- Prepare a draft project charter (a draft project plan).
- Schedule and conduct a team launch to formally start the project.

As previously stated, a discovery phase may be implemented upfront to collect information about the process, customer and stakeholders needs, and business goals. This information is used to prepare a preliminary project charter.

Project Charter Development. Before the team launch, the project black belt collaborates with the process sponsor to prepare a draft project charter. The project team can revise the project charter during the project execution based on process information. All revisions are subject to the sponsor's approval. The project charter will address the following standard items:

- *Problem Statement*: This is also called the "opportunity statement." The problem statement identifies the pressing business need that requires a solution. This statement must be quantitative. If the required data are not readily available, the team can use placeholders until the data are acquired during the define phase from existing records, or collected

during the measure phase from direct measurements. The importance of the problem statement cannot be overstated; a problem that is well defined is more than half solved.

- *Goal Statement*: The goal statement is the opposite of the problem statement. It provides a quantitative performance goal. If data are not readily available, the team can use placeholders until the data are acquired during the define phase from existing records, or collected during the measure phase from direct measurements.

- *Business Impact*: The business impact defines the expected impacts on the business once the project goals are achieved. This too is an important part of the project charter. To be approved, the business impact from a Lean Six Sigma project has to be tangible and measurable, and the expected benefits must be shown to exceed the expected project cost.

- *Project Scope*: The project charter must clearly define in-scope and out-of-scope items, and it must also guard against "scope creep" during project execution.

- *Project Schedule*: The project charter should include a project schedule with the expected start and completion dates, and interim dates for completing each phase of the DMAIC process.

- *Project Team*: The project charter should include a list of the project team members. The project charter will typically list the names of the project sponsor or process owner, Lean Six Sigma champion, Lean Six Sigma analyst, and individual members of the team and their roles and responsibilities.

Selecting Members of the Project Team. The project team is typically limited to no more than seven or eight members. Most of the project team members are selected, in part, because of their knowledge of the underlying process. Other team members include product users, a Lean Six Sigma analyst, and a professional with project management expertise and skills. Product users include not only the final user, but also other people who come in touch with the product.

Lean Six Sigma is not difficult, but team work is. Apart from the specific expertise individuals bring to the project, selection of team members should consider the following factors:

- Availability: Team members should be available to participate fully in project meetings and deliver on project assignments for the entire duration of the project.

- Teamwork Experience: Team members should ideally have previous teamwork experience.

- Motivation: Team members should have a desire to fix the process and help the business.

- Objectivity and Independence: To the extent possible, team members should be independent and objective free thinkers so that analyses and recommendations are based on relevant data and information.

Every project must have a Lean Six Sigma black belt, although green belts are sometimes used on small projects. Larger or more complex projects may also benefit from a master black belt.

The process owner or project sponsor assigns a team leader to every team. The team leader has ultimate responsibility and accountability for the execution and timely completion of the project and communicating the results to the process owner. The team leader is typically a Lean Six Sigma black belt or green belt, depending on the project size. In some cases, the team leaders are not Lean Six Sigma analysts, and they are selected for their team leadership and project management skills or other qualifications.

Team Launch. As previously stated, project teams execute the Lean Six Sigma projects, and the team launch is the first formal step in the execution of any Lean Six Sigma project.

The team launch is used to present the project to the team members, to introduce the team members to each other and to the project sponsor, to answer team member questions, and to develop a project plan and schedule.

The project team has complete responsibility for the project. It follows the DMAIC process to implement all of the project activities from beginning to end. These include validating the project charter, particularly including the problem and goal statement and the business impact; establishing performance metrics and developing quantitative baseline and performance goals; analyzing problems and identifying their root causes; selecting a solution and implementing a pilot to demonstrate benefits; and finding a full-scale solution, including an implementation plan and performance metrics to monitor and control the process and sustain improvements long term.

Project Management. Like any other project, a Lean Six Sigma project will need to be managed to ensure that the project milestones, goals, and products are completed on time and within budget. Additional project management may also include, for example, the following activities:

- preparation of project meeting including schedules and logistics
- preparation of meeting summaries including agreements reached and takeaway items
- follow-up on action items
- preparation of a project communication plan
- effective and timely communication of project progress and status to concerned stakeholders
- evaluating risk including the risk of executing a project or a particular activity, as well as the risk of implementing alternative recommendations

DMAIC Process Guide. Table 1 provides a general guide for implementing the standardized DMAIC process, including a discovery or preparatory phase that may be implemented before the team launch.

Table 1 General Guide for the DMAIC Process

Phase	Purpose	Main Activities	Main Deliverables	Typical Duration (Weeks)
Discovery Phase (optional)	To reach understanding with the process owner and to prepare a draft project charter	– Discuss project with process owner, including problem and expectations – Identify members of the project team – Prepare a draft project charter, including problem and goal statements, business impact, scope, timeline, and project team	– Draft project charter – List of team members	2–4
Define Phase	To validate project viability including the business impacts, verify the project charter, define and map process, and identify critical customer and stakeholder requirements	– Collect information about the process, the customers and stakeholders, and the business – Define process steps and develop a high-level process map (flow chart) – Define suppliers, input, output, and customers – Identify critical customer and stakeholder requirements – Evaluate business impacts and validate project viability – Review and revise the project charter based on the define phase findings – Assess project risk – Develop a project plan – Present team findings and recommendations to the project sponsor in the gate review	– Validated project charter – Critical customer and stakeholder requirements – "SIPOC" chart; this chart defines the process and process related elements: S—Suppliers I—Input P—Process O—Output C—Customers – High-level process map – "RACI" chart; this chart defines the roles and responsibilities of project personnel with regard to specific tasks: R—Responsible A—Accountable C—Provides consultation I—Receives information – Project management plan – Gate review—Team recommendations for path forward	3–4

Table 1 General Guide for the DMAIC Process *(continued)*

Phase	Purpose	Main Activities	Main Deliverables	Typical Duration
Measure Phase	To develop a quantitative database and quantitative performance metrics, and establish performance baseline and performance goals	– Collect process records and establish a process database – Decide on the need for additional measurements including measurement systems and data collection methods – Prepare a VSM of the process; this is a detailed process map showing process steps and flow including quantitative data (e.g., cycle times, time traps, inefficiencies, and waste) – Develop performance metrics and establish performance baseline and performance goals – Update the project charter as necessary – Present team findings and recommendations to the project sponsor in the gate review	– A VSM of the process – Quantitative validation of problem, goal, and business impact statements – Measurement system, including operational definitions and performance metrics – Baseline process capability and performance – Updated project charter – Possible quick wins – Gate review—Team recommendations for path forward	4–6
Analyze Phase	To identify and rank process problems and their root causes	– Analyze process data and identify process issues and performance problems – Identify critical-to-quality inputs – Identify, screen, and rank root causes – Present team findings and recommendations to the project sponsor in the gate review	– Root cause(s) of process issues and performance problems – Critical-to-quality inputs – Possible quick wins – Gate review—Team recommendations for path forward	3–4

Table 1 General Guide for the DMAIC Process *(continued)*

Phase	Purpose	Main Activities	Main Deliverables	Typical Duration
Improve Phase	To identify process improvement measures, implement a pilot to demonstrate improvements, and prepare and execute a plan for full-scale implementation of the improved process .	– Identify, screen, and rank process improvement measures based on benefits and risks – Select and recommend a best solution – Implement a pilot and demonstrate improvements – Develop a plan for a full-scale implementation of the solution – Present team findings and recommendations to the project sponsor in the gate review	– Tested solution to the problem – Plan for full-scale implementation of the solution – Before and after performance metrics – Gate review—Team recommendations for path forward	2–3
Control Phase	To document the project, including demonstrated improvements, and to develop monitoring and control measures to sustain improvements long term	– Document the project, including recommended improvements – Develop monitoring and control measures to sustain improvements long term – Hand off the project documentation to the process owner	– New process map and documentation of improved process and an implementation plan for long-term solution – Process control plan, including process monitoring and control measures – Project documentation	2–3

Guide to Lean Six Sigma Tools. A detailed presentation of Lean Six Sigma tools is beyond the scope of this report, but the reader can learn about these tools in many of the listed references (e.g., Juran & Godfrey, 2000), as well as the internal NRC Lean Six Sigma Web page: http://nrcweb:8600/oedo/LEAN SIX SIGMAP/index.html.

Table 2 provides a list of some of the more commonly used Lean Six Sigma tools and their uses.

Table 2 Selected Lean Six Sigma Tools

Tool	Description, Function and Uses	DMAIC Phase
Project charter	The project charter is a one-page project summary that covers: Business Impact Opportunity/Problem Statement Goal Statement Project Scope Project Plan Project Personnel Including Roles and Responsibilities	Discovery, Define, Measure
SIPOC chart	This chart defines the process and process related elements defined in Table 1	Define
Process map	A process flow chart showing process steps and flow	Define, Measure
Value stream map	A detailed process map showing process steps and flow including quantitative process data (e.g., cycle times, time traps, inefficiencies, and waste)	Measure
Fishbone diagram	A cause-and-effect diagram used to uncover the root causes of problems	Analyze, Improve
5 whys	A method used with the cause-and-effect diagram and the Pareto chart to critically examine the causes of problems and identify the root causes	Analyze
Pareto chart	A bar chart used to rank problems, causes, inputs, and solutions in terms of their effects and impact on process output and results	Define, Analyze, Improve
Cause-and-effect matrix	Not to be confused with the cause-and-effect diagram, this is a matrix used to correlate process inputs and outputs and identify and rank input variables that significantly impact process output (critical to quality requirements and inputs)	Define
Kano diagram	A data collection tool used to understand what product or service features are valued by customers and develop critical-to-quality requirements	Define, Measure
Gage R&R (Repeatability and Reproducibility)	A measurement system analysis tool used to determine the repeatability and reproducibility of measurements and measurement system reliability to consistently produce accurate measurements	Measure

Table 2 Selected Lean Six Sigma Tools (continued)

Tool	Description, Function and Uses	DMAIC Phase
Statistical tools: Histograms, box plots, mean, median, mode, range, variance, and standard deviation Time series, run charts, control charts Scatter plots, correlation, and regression analysis Hypothesis tests (e.g., t-test, analysis of variance)	Statistical tools used to characterize and analyze process data sets Statistical tools used to display and analyze process data and illustrate how the process is changing over time Statistical tools used to determine whether relationships exist between process input and output variables and to develop quantitative equations for relationships Statistical tests used to make judgments about process samples and their underlying populations to ultimately determine whether there are statistically significant changes in the process at different times (or places)	Measure, Analyze

Part 3: Lean Six Sigma Infrastructure and Internal Resources at the U.S. Nuclear Regulatory Commission

The NRC launched a Lean Six Sigma initiative in 2007. The agency wanted to develop a Lean Six Sigma capability to improve quality, timeliness, and efficiency and increase the overall effectiveness of its operations. Much progress has been made. The agency established a Lean Six Sigma program and created a Lean Six Sigma infrastructure, provided Lean Six Sigma training to staff members and managers, and executed several Lean Six Sigma projects.

Potential Applications and Benefits at the NRC

Lean Six Sigma applications can increase the NRC's "business" effectiveness by improving individual processes throughout the agency. It will also support the agency's operational planning, as well as strategic objectives (effectiveness, operational excellence, and openness) and strategic goals (safety and security) as provided in the current (fiscal year 2008–2013) strategic plan. In addition, Lean Six Sigma will result in some important intangible benefits to the NRC. Examples include improved communication and transparency, increased staff empowerment at all levels, and increased stakeholder satisfaction and confidence.

Process Improvement. Lean Six Sigma could potentially improve hundreds of NRC processes. Examples include licensing reviews, rulemaking activities, contract review and award, document development and concurrence, budget development, resource allocation, and operational planning. Specific benefits from individual process improvement projects include the following:

- improved product and service quality by reducing variability, defects, and errors
- improved timeliness and efficiency by eliminating delays, waiting times, and unnecessary activities and tasks including rework
- freed full-time equivalents and increased productivity by improving efficiency
- reduced cost by eliminating or significantly reducing waste

- reduced gap between expectations and actual performance

Strategic Plan Support. Successful execution of a Lean Six Sigma program and the improvement of different NRC processes will lend significant support to the implementation of the agency's strategic planning, including the current strategic plan.

The current NRC strategic plan for fiscal years 2008–2013 can be found on the agency's Web site at http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1614/v4/sr1614v4.pdf. This plan describes the NRC's mission, values, and strategic safety and security goals, including the strategic outcomes, issues, and resources needed to support these goals. The strategic plan also describes three organizational excellence objectives (openness, effectiveness, and operational excellence) that will also support the strategic goals and attributes the safe use of radioactive materials to the agency's adherence to the "principles of good regulations," which include efficiency, independence, clarity, and reliability. The strategic plan indicates efficiency can be improved without compromising safety. Finally, the strategic plan states that the effectiveness concepts apply to all levels of the agency and identifies a number of effectiveness strategies, including the use of state-of-the-art techniques.

Lean Six Sigma can support all three organizational excellence objectives in the NRC strategic plan and thereby can support the agency's strategic safety and security goals. The use of Lean Six Sigma can improve the accuracy and timeliness of regulatory products and licensing actions, reduce the variability in the agency's products and actions, increase process efficiencies, stabilize and improve the reliability of agency processes, improve process flexibility to handle change, and increase confidence in the regulatory process.

Support for Operational Planning. Lean Six Sigma can also support improved business operations and process monitoring and control activities, such as data collection, project management, staff development and training, and staff empowerment. Examples include improved budgeting and resource allocation and disbursement processes and operational plans, and reducing performance gaps.

Increased Stakeholder Satisfaction. Lean Six Sigma can improve the agency's effectiveness with its stakeholders both inside the agency (Commission, senior management, and NRC staff) and outside

the agency (Congress, the public, licensees, and others). Increased satisfaction is a direct result of improved product and service quality and timeliness, increased efficiency, and reduced cost.

Other Benefits. Successful implementation of Lean Six Sigma can have other benefits, including improved communication and coordination throughout the agency, increased staff empowerment, improved employee morale and self-esteem, improved transparency, and a greater ability to respond to outside change.

Infrastructure and Internal Resources

The Lean Six Sigma program at the NRC resides in the Office of the Executive Director for Operations and consists of a Lean Six Sigma Program Manager, a core group of black belts, and rotating black belt trainees. The program is responsible for developing and maintaining a Lean Six Sigma capability, supporting internal Lean Six Sigma training, supporting Lean Six Sigma project execution, and supporting other Lean Six Sigma planning and operation activities throughout the agency.

The Lean Six Sigma program maintains an internal NRC Web page, which can be accessed at http://nrcweb:8600/oedo/lean six sigmap/index.html. This Web page provides information about the Lean Six Sigma program, including program capability, Lean Six Sigma projects, forms for new project submittals, criteria for project selection, training opportunities, and some of the commonly used Lean Six Sigma tools.

The Lean Six Sigma program supports the execution of Lean Six Sigma projects in response to requests by management and staff throughout the agency. For additional information or questions about the Lean Six Sigma program, please contact the Lean Six Sigma Program Manager, John Harrison (301-415-0151; John.Harrison@nrc.gov) or Mindy Landau, Deputy Assistant for Operations, Communications and performance Improvement (301-415-8703; Mindy.Landau@nrc.gov) in the Office of the Executive Director for Operations.

Staff Development

Many NRC managers and staff members have received formal training in Lean Six Sigma. Eleven staff members have received Lean Six Sigma training as black belts, and many managers have also received training as white belts. In addition, all of the black belt trainees and many other staff members have been involved in Lean Six Sigma projects, as either team members or project sponsors. Both formal and on-the-job training are continuing at a rapid pace.

Sample Lean Six Sigma Projects

The NRC has executed several Lean Six Sigma process improvement projects. Readers can find an updated list and descriptions of completed and ongoing Lean Six Sigma projects at http://nrcweb:8600/oedo/lean six sigmap/index.html.

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Lean Six Sigma Academy Web site: http://Lean Six Sigmaacademy.com/

The W. Edwards Deming Institute Web site: http://deming.org/

U.S. Nuclear Regulatory Commission Lean Six Sigma internal Web page:
http://nrcweb:8600/oedo/lean six sigmap/index.html

U.S. Nuclear Regulatory Commission Strategic Plan for Fiscal Years 2008–2013:
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