STATISTICAL PROCESS CONTROL DESIGN OF EXPERIMENTS MEASUREMENT SYSTEMS ANALYSIS ADVANCED STATISTICS EXCEL PRIMER

MiC Quality

COURSE REFERENCE

MiC Quality Online Courses

SIX SIGMA PRIMER

SHORT SUMMARY

with Expected Black Belt Knowledge

SIX SIGMA PRIMER

ONLINE COURSE WITH FULL REFERENCE

"SIX SIGMA PRIMER"

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SIX SIGMA PRIMER

This publication belongs to a series of **Course Reference** booklets that accompany our online courses. This booklet contains a **short summary** of the material covered in our **Six Sigma Primer** online course.

For information about all our courses and **free Six Sigma resources** visit our Web site at **www.micquality.com**:

- σ **Free Online Module** "**Introduction to Statistics**"
- σ **Free Glossary** with 300+ Six Sigma and statistical terms
- σ **Free Online Excel Primer**
- σ **Reference tables**, **Six Sigma and Normal Distribution calculators**

Glen Netherwood, ***MiC Quality***

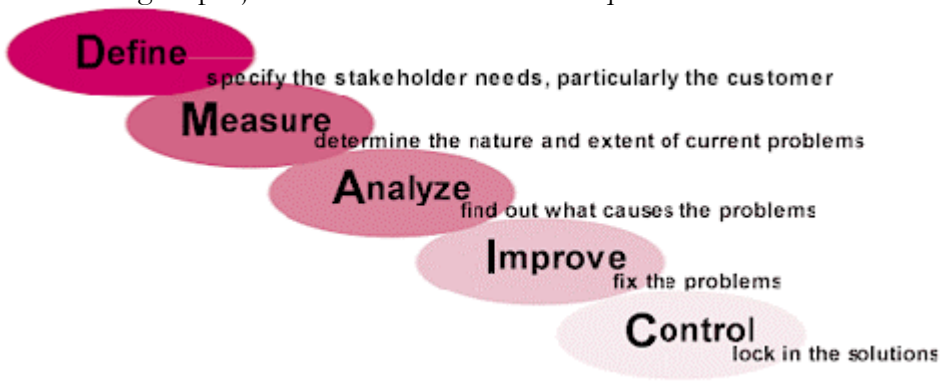
CONTENTS

APPENDICES

OUR STUDENTS SAY: Jennifer McClare, Engineer, Canada

"Very practical, lots of examples, easy to understand. Rather than just a review of math, the course was very applied with a number of very practical real-world examples. It showed me that I already knew enough to be making improvements in processes, but just didn't know how to apply it. The email support was very thorough and contained personal responses, not "canned" answers; individual attention was at least as good as in a classroom setting, if not better."

DMAIC

The DMAIC Sequence	
DEPLOYMENT	Deployment refers to the overall organization of Six Sigma within the company and the initiation of the projects. There are four main aspects: • preparing the organization for Six Sigma organizationally and culturally • maintaining and developing the benefits of Six Sigma over time • selecting individual projects and forming the project team • spreading knowledge and experience to other projects and activities
DMAIC	Each Six Sigma project follows the 'DMAIC' sequence: 
DEFINE	• identify the main steps in the process that is to be improved, particularly where it starts and ends, and the customers and suppliers • investigate the needs and expectations of the customers and other stakeholders and translate them into specific measures • firm up the project objectives and timescales
MEASURE	Collect information on how well the existing process achieves the measures that were selected in the define stage. Gather information on the nature and extent of the issues identified.
ANALYZE	Identify the factors that affect the process, and that contribute to the problems that were identified in the measure stage. Carry out testing and analysis as necessary to achieve this.
IMPROVE	Use the understanding of the factors identified in the analyze stage to come up with possible improvements and solutions. Use systematic testing to decide between alternative approaches and confirm that the proposed solutions work as expected.
CONTROL	Put in place monitoring and control systems to lock in the improvements and make sure that the process performance will not slip back. Hand the process back to the process owner.

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Six Sigma Roles

Six Sigma Roles	
EXECUTIVES	Management support is essential to the success of Six Sigma. A large organization should have a Six Sigma council or equivalent body to oversight and represent Six Sigma. The executive will be concerned with corporate level goals and targets
CHAMPION	Can be used to describe anybody who 'champions' Six Sigma, but usually refers to a senior executive who takes responsibility for Six Sigma projects and oversees, supports, finds resources, and monitors progress.
MASTER BLACK BELT	An expert in Six Sigma responsible for Six Sigma mentoring and training and for the technical and professional standards of Six Sigma. In a Six Sigma company there is roughly one Master Black Belt for every thousand employees. They will have been Black Belts on a number of Six Sigma projects and have excellent knowledge of statistical methods. They will have ASQ Six Sigma Black Belt certification or equivalent qualifications.
BLACK BELT	Black Belts are experts in Six Sigma who manage Six Sigma projects. In a Six Sigma company there is roughly one Black Belt for every hundred employees. Black Belts will have completed a Black Belt course offered by a reputable organization. These normally involve about 16 days training over four to six months and concurrent completion of a Six Sigma project. The Black Belt courses should be regarded as an introductory qualification, the Black Belt should continue to develop their knowledge and skill under the guidance of a Master Black Belt. They should be working towards ASQ Six Sigma Black Belt certification.
GREEN BELT	Green Belts are similar to Black Belts, but less highly qualified, particularly in statistical methods. They can lead smaller projects under the supervision of a Black Belt, or work with a Black Belt on larger projects. A Green Belt course usually involves about 10 days training. Green Belts should also have, or be working towards, the ASQ Six Sigma Green Belt Certification.
PROCESS OWNER	The manager or supervisor of the section most concerned with the project. They will be responsible for the process after the Six Sigma project is complete.
SIX SIGMA TEAM	The people who work on the Six Sigma project under the guidance of the Black Belt. Six Sigma teams are best kept small, six people or fewer, and the members are selected for their process knowledge, their ability to contribute to the project and to work as part of the team.

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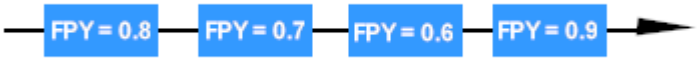
DPMO, DPU & YIELD

Six Sigma Metrics	
INTRODUCTION	Various metrics are used in Six Sigma. These include the concept of 'defect opportunities' and the use of 'sigma' to measure process performance.
EXAMPLE	Attaching a cover plate involves tightening five screws. 2000 plates were fitted and two screws were missed.
DPMO	'Defects Per Million Opportunities'. An activity or product may have several 'opportunities' for a defect. If each screw is defined as an opportunity: $$\text{DPMO} = \frac{2}{5 \times 2{,}000} \times 1{,}000{,}000 = 200$$
SIGMA LEVELS	The number of DPMO can be converted to a 'sigma level'. 200 DPMO converts to slightly better than a 5 sigma process.
DPU	Defects Per Unit: $$\text{DPU} = \frac{2}{2000} = 0.001$$
YIELD	The yield is calculated from: $\text{yield} = e^{-\text{DPU}}$ $\text{yield} = e^{-0.001} = 0.999$ NOTE: The correct formula is not: $$\text{yield} = 1 - \text{DPU}$$ This formula ignores the possibility that one unit may have several defects.
FPY	First Pass Yield. The yield before any defects have been corrected.
FINAL YIELD	The yield after defects have been corrected.
HIDDEN FACTORY	The rework and 'waste' that is hidden if only the final yield is considered.
ROLLED THROUGHPUT YIELD	In a multi-step process the overall yield from each step based on the First Pass Yield:  $$\text{RTY} = 0.8 \times 0.7 \times 0.6 \times 0.9 = 0.302$$

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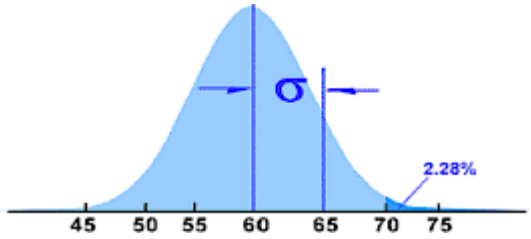
SIGMA LEVEL & PROCESS CAPABILITY

The Sigma Level

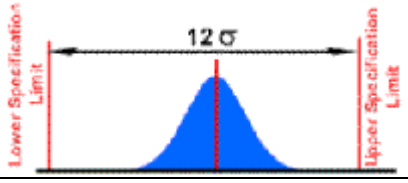
Continuous data often conform to a normal distribution:



The area of the curve maps to the proportion of the process output. In the example 2.28% of the output will be greater than 70

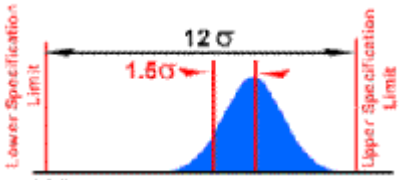
SIX SIGMA

In a Six Sigma process there should be at least six standard deviations between the target and each specification limit:



SIGMA LEVEL & DPMO

It is difficult to keep a process dead on target and when the sigma level is converted to the number of DPMO it is usual to assume the actual process mean is 1½ standard deviations from the target:

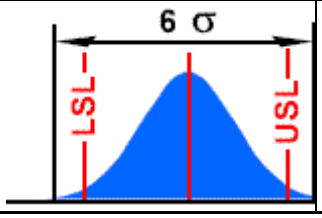
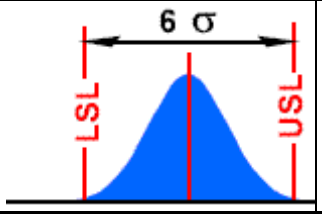
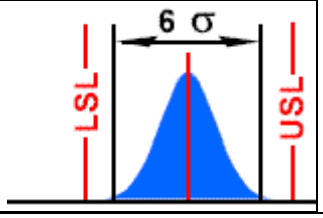


PROCESS CAPABILITY

The Process Capability is another measure of the number of defects. The formula is:

$$C_p = \frac{USL - LSL}{6\sigma}$$

NOTE: 'σ' must be calculated using the 'range' method, see the MiC Quality course in Statistical Process Control.

$C_p < 1$ Not Capable	$C_p = 1$ Just Capable	$C_p > 1$ Capable
		

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LEAN SYSTEMS

Lean Systems

INTRODUCTION

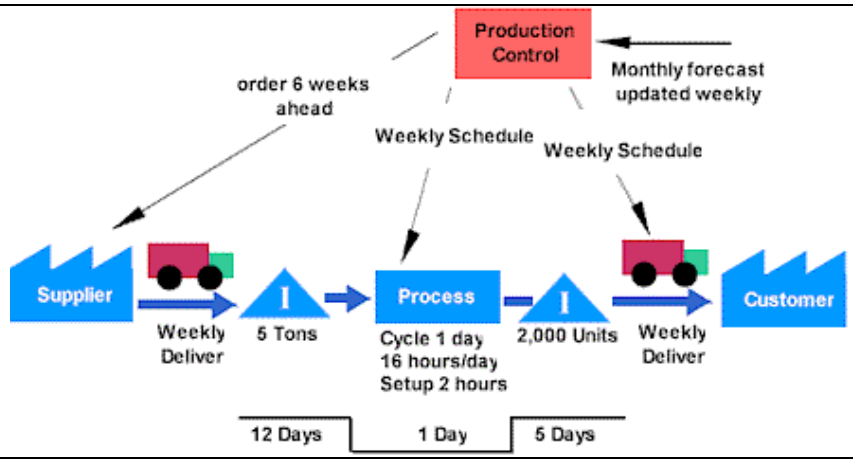
Six Sigma is about reducing process variation, whilst Lean is about eliminating waste, often known as 'muda'.

5S

A five-step method for eliminating waste and making the workplace more efficient:

Seiri (Sort)	get rid of unused, or rarely used material, tools etc.
Seiton (Set in Order)	make a place for everything, it should be clear where everything should go and if anything is missing (e.g. by using a shadow board)
Seiso (Shine)	carry out a thorough clean and tidy
Seiketsu (Standardize)	implement standard ways of carrying out tasks
Shitsuke (Sustain)	keep up with the improvements, every day

Value Stream



Kanban

A method used to control production in a 'Pull' system:

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DESIGN FOR SIX SIGMA

Design for Six Sigma

INTRODUCTION

Design for Six Sigma is used where the process is totally new, rather than improving an existing process.
The DMAIC sequence is replaced by a DMADV (Define, Measure, Analyze, Design and Validate).

DMADV

Define	Decide on the goals of the activity. Make sure the goals meet the customer expectations and are in line with the strategy of the organization. This is similar to the 'D' in DMAIC.
Measure	Use the feedback from the customers, and other stakeholders, to decide on the metrics that the project must achieve. The Voice of the Customer can be translated into specific features of the product or service using Quality Function Deployment (QFD), often known as the 'House of Quality'.
Analyze	Develop several options for the design, and choose between them. Developing the options may involve using strategic-level analytical tools, such as Porter's Five Factor Analysis or Benchmarking. Deciding between the options may involve using a method such as Pugh Analysis.
Design	Carry out the design. The design should make use of the appropriate 'Design for X' (DFX) methods. Available methods include Design for Quality, Design for Manufacture and Design for Assembly. Where the design is a physical product, rather than a service, robust design principles (the Taguchi method) may be used.
Validate	Put the design into practice and make sure it works. This will involve prototype trials. It will also involve collecting detailed feedback from customers and stakeholders.

DMADOV is an alternative to DMADV. The additional 'O' stands for optimize, this where experimental design would be used.

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APPENDIX

EXPECTED BLACK BELT KNOWLEDGE

NOTE: The terms are defined in the MiC Quality free Six Sigma Glossary:
http://www.micquality.com/six_sigma_glossary/index.htm

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Deployment	
MANAGING UPWARDS	Ensure that the project will meet the business needs of the organization. This requires a broad background knowledge of Six Sigma & Lean, business imperatives, key financial measures, and the organizational structure to put the project into the strategic context.
TEAM MANAGEMENT	• select an effective team and organize and run meetings • use various methods to forestall and resolve conflicts between team members • use techniques to encourage individual contributions and get the best out of each individual and the team
PROCESS IMPROVEMENT TOOLS	• use a selection of methods that promote creative decision making e.g. brainstorming, nominal group technique and multivoting • use a range of graphical tools that help with creative problem solving e.g. affinity diagrams, tree diagrams, process decision program charts, matrix diagrams, interrelationship digraphs, prioritization matrices, activity network diagrams

Define	
PROJECT CHARTER	Develop the Project Charter, including the problem statement, business case, project scope, objectives and performance measures
PROJECT TRACKING	Be able to plan and maintain the project schedule using project management tools such as Gantt Charts and toll-gate reviews
SIPOC	Create a SIPOC Diagram.
VOICE OF CUSTOMER	• Be able to gather information about the Voice of the Customer using a variety of methods, including surveys, focus groups, interviews and observations • Convert the VOC information to customer requirements using Quality Function Deployment and the Kano model
CTQ FLOWDOWN	Create specific metrics using CTQ flow-down.

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Measure	
PROCESS ANALYSIS	Define the process using various types of chart e.g. value stream maps, process maps, flowcharts and spaghetti diagrams.
COLLECT DATA	Collect data from the process and use check sheets.
SAMPLING	Develop a sampling plan using an appropriate method including random, convenience, stratified or systematic sampling.
MSA	Carry out measurement systems analysis. This includes gage R& R studies and bias and linearity studies for continuous variables. It also includes using the analytic method for attributes.
SUMMARIZE DATA	Summarize the data using analytical & descriptive statistics and probability. Use graphical methods including Pareto charts, control charts, run charts, box & whisker plots, scatter diagrams and normal probability plots.
PROCESS CAPABILITY	Carry out a process capability study and calculate Process Capability and Process Performance using the appropriate measures, selecting from C_p, C_{pk}, P_p, P_{pk}, C_{pm}. This includes dealing with non-normal data using a Box-Cox transform.
SIX SIGMA METRICS	Calculate Six Sigma Metrics, Parts Per Million (PPM), DPMO, DPU, RTY and the sigma level.
Lean Measure	
PROCESS FLOW METRICS	Evaluate process flow and utilization by analyzing Work in Progress (WIP), Work in Queue (WIQ), touch time, 'takt' time, cycle time and throughput.

Analyze	
STATISTICAL ANALYSIS	Use advanced statistical methods to explore the relationships between factors in the process: • use regression, correlation and multivariate analysis to find the relationship between the factors that affect the process and the process outcomes • use various types of hypothesis tests to test for significant differences in results (t, F, chi-square tests, contingency tables, nonparametric tests)
FMEA	Conduct a Failure Mode and Effects Analysis study (DFMEA or PFMEA).
PRODUCTION SYSTEM ANALYSIS	Analyze a production system using e.g. Gap Analysis, Root Cause Analysis and/or Waste analysis

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Improve	
EXPERIMENTAL DESIGN	Design and carry out Full and Fractional Factorial experiments, including Plackett Burman designs. Ideally Black Belts should be able to use more advanced methods including Central Composite, Response Surface and Box Behnken designs, Hill Climbing and Taguchi designs. Black Belts concerned with chemicals or other mixtures should be familiar with mixture designs.
RISK ANALYSIS	Evaluate risk from an organizational (macro) perspective. Useful methods include SWOT (Strength, Weakness, Opportunities, Threats) analysis or PEST (Political, Environmental, Social and Technological) analysis.
Lean Improve	
WASTE ANALYSIS	Analyze a production system and identify the 'seven classic wastes'. Introduce methods to reduce waste including pull systems, kanban, 5S, standard work and poka-yoke.
CYCLE TIME REDUCTION	Reduce cycle time by introducing continuous flow methods and Single Minute Exchange of Die (SMED).
KAIZEN	Be able to recognize opportunities for, and apply, Kaizen and Kaizen Blitz.

Control	
STATISTICAL PROCESS CONTROL	Be able to design and apply Statistical Process Control to a process using the appropriate type of control chart (Xbar & R, Xbar & s, ImR, p, np, c, u, moving average, short run SPC). This includes carrying out the process capability study.
TPM	Be familiar with the principles of Total Productive Maintenance.
VISUAL FACTORY	Be familiar with the methods used in a 'Visual Factory'
DOCUMENTATION	Develop documentation used in control including Control Plans, Standard Operating Procedures and Training Plans

Design for Six Sigma	
DESIGN FOR X	Be familiar with the use of DFX where 'X' stands for cost, manufacturability, test, maintainability, quality or other key criteria.
ROBUST DESIGN	Be able to apply the principles of robust design, tolerance design and statistical tolerancing.
DESIGN TOOLS	Be able to use Porters five forces analysis, Portfolio analysis, the Theory of Inventive Problem Solving (TRIZ) and Pugh analysis.

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MiC Quality Online Courses

Six Sigma Primer

This course provides an in-depth introduction to Six Sigma. It takes you through each stage of the DMAIC sequence using case studies to show you how, and when, to use the most important methods and tools.

Topics: Deployment, Six Sigma metrics, the DMAIC sequence, Lean methods, Design For Six Sigma (DFSS).

Recommended for everyone implementing Six Sigma or studying for a Black Belt.

Statistical Process Control (SPC)

You will learn how to carry out process capability studies, use control charts effectively, and use the results to improve your processes.

Topics: Variation; process capability Cp, Cpk; process performance Pp, Ppk; X-Bar and R control charts; attribute control charts p, np, c, u.

A must for everyone involved in quality management, ISO9000, Six Sigma.

Advanced Statistical Process Control

Covers 10 types of control charts for a variety of process situations, including short and high volume, as well as supporting process improvement and Six Sigma initiatives.

Topics: Given Standard, X-bar & s, Median, Demerits Per Unit (U), Individual and Moving Range (XmR), Moving Average & EWMA, CuSum; Short Run SPC; PRE-control.

Recommended for everyone involved in quality management, ISO9000 and Six Sigma.

Primer in Statistics

An introduction to statistics and process improvement tools.

Topics: Mean, Median, Mode, Range, Variance, Standard Deviation, Normal Distribution, Testing for Normality, Grouped Data, Percentiles, Histograms, Pareto Charts, Box Plots, Stem & Leaf Plots, Multi-Vari Charts, Scatter Graphs, Correlation, Confidence Intervals, Hypothesis Testing, p-Values, Power, Calculating the Sample Size.

A must for everyone involved in Quality Management, Process Improvement and Data Analysis.

Advanced Statistics

Comprehensive coverage of the statistical methods for engineers and scientists. An excellent preparation for the American Society for Quality Six Sigma Black Belt (ASQ SSBB) exam.

Topics: Confidence Intervals; t-distribution; Hypothesis Testing; t-tests; Type I and II errors and Power; Chi-Square Distribution; Contingency Tables; Regression Analysis; Correlation; ANOVA; Probability; Binomial, Poisson & Hypergeometric Distributions

Recommended for scientists, engineers, Six Sigma Black Belts and Master Black Belts.

Design of Experiments (DOE)

A practical guide for people who need to improve their processes using experimental design.

Topics: Full and Fractional Factorial Designs; Design Resolution; Hypothesis Testing; ANOVA; Analysis of Residuals; Screening Designs; Plackett-Burman Designs

A must for Six Sigma Black Belts and Master Black Belts; recommended for engineers.

Advanced Design of Experiments

The course shows how to analyze the advanced methods of experimental design using Minitab.

Topics: Taguchi Signal to Noise Ratio and Taguchi designs, Response Surface Designs, “Hill climbing” approach for process optimum, Mixture Designs

A must for Six Sigma Black Belts; recommended for engineers and researchers.

Measurement Systems Analysis (MSA/Gage R&R)

SPC and DOE rely on the integrity of the measurement systems. This course provides a thorough treatment on how to evaluate and improve measurement systems.

Topics: Control Chart Methods; Repeatability & Reproducibility; Gage R & R Studies; Evaluating the Results; Using Minitab; ANOVA Methods; Capability, Bias, Linearity & Stability; Attribute Studies - long and short methods.

Recommended for quality managers, Six Sigma Black Belts and Master Black Belts.

"The fundamentals of statistics have been explained in a beautiful manner which makes them easy to understand."
"I really appreciate your clear and practical explanations and the simulations! I've never really understood statistics very well. Your Primer was VERY helpful. I think I'm starting to understand this stuff!"

About MiC Quality

MiC Quality is a global provider of e-learning solutions. We provide online courses in the statistical methods used in quality assurance, process improvement, research and development, and **Six Sigma** programs. The courses are ideal for quality professionals, engineers, scientists, managers and supervisors who need to use statistics in their work. Our customers come from many industries including healthcare, manufacturing, biotechnology, electronics, IT, research and pharmaceuticals.

Benefits of MiC Quality online courses:
:: **interactive** with exercises, simulations and case studies
:: **extensive support** with individual coaching and feedback
:: **comprehensive** with about 30 hours of in-depth study per course
:: **flexible** self-paced learning available anywhere, anytime
:: **effective** in developing practical knowledge and hands-on skills

MiC Quality online courses include:
:: Six Sigma Primer
:: Statistical Process Control (SPC)
:: Advanced Statistical Process Control (SPC)
:: Primer in Statistics
:: Advanced Statistics
:: Design of Experiments (DOE)
:: Advanced Design of Experiments (DOE)
:: Measurement Systems Analysis (MSA)/ Gage R&R

(see previous page for more information)

Solutions for Organizations and Individuals

Six Sigma, Process Improvement Programs

Use MiC Quality self-paced e-learning for the statistical component of Six Sigma methodology and reduce the need for expensive class-based courses.

Quality Management Systems

Provide training for group and individual staff members in statistical quality assurance methods to support **ISO9000, TS16949** and supplier accreditation requirements.

Professional Development for Associations

Form partnerships to provide members with professional development at discounted prices.

Career Development for Individuals

Support your professional career development, including the American Society for Quality qualifications of **Certified Quality Engineer (CQE), Six Sigma Black Belt (SSBB) and Green Belt (SSGB)**.

Licenses and Partnerships

Site and group licenses are available. We welcome opportunities for new partnerships. Please **contact** us for more information.

Dragos Gabriel Marin
Analyst, Pratt & Whitney
"When I started the course my experience in statistics was a very traumatizing course at the university plus a number of unsuccessful attempts of studying SPC from books. Now, at the end of the course, I can say that yes, I understand the concepts, and I will apply them. It is very well designed, the e-mail support is excellent, and it is affordable."

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