DESIGN FOR SIX SIGMA
DFSS

Messias Borges Silva
2025

DFSS

- A metodologia DFSS surgiu com o intuito de projetar um novo produto desde sua fase inicial até ser construído.

DFSS

- O Design For Six Sigma (DFSS) é uma metodologia cujo objetivo principal é compreender todas as fases existentes dentro de um projeto.
- Isso vai permitir que os retrabalhos, que geralmente acontecem para que correções futuras aconteçam, não se torne mais necessário.

Objetivo do DFSS

- O principal objetivo do Design for Six Sigma (DFSS) é projetar um novo produto ou serviço ou até mesmo redesenhá-lo desde o início.
- Design for Six Sigma busca compreender completamente as necessidades dos clientes e atender suas expectativas.
- Tudo isso é feito antes do projeto chegar à fase de conclusão e sua consequente implementação.

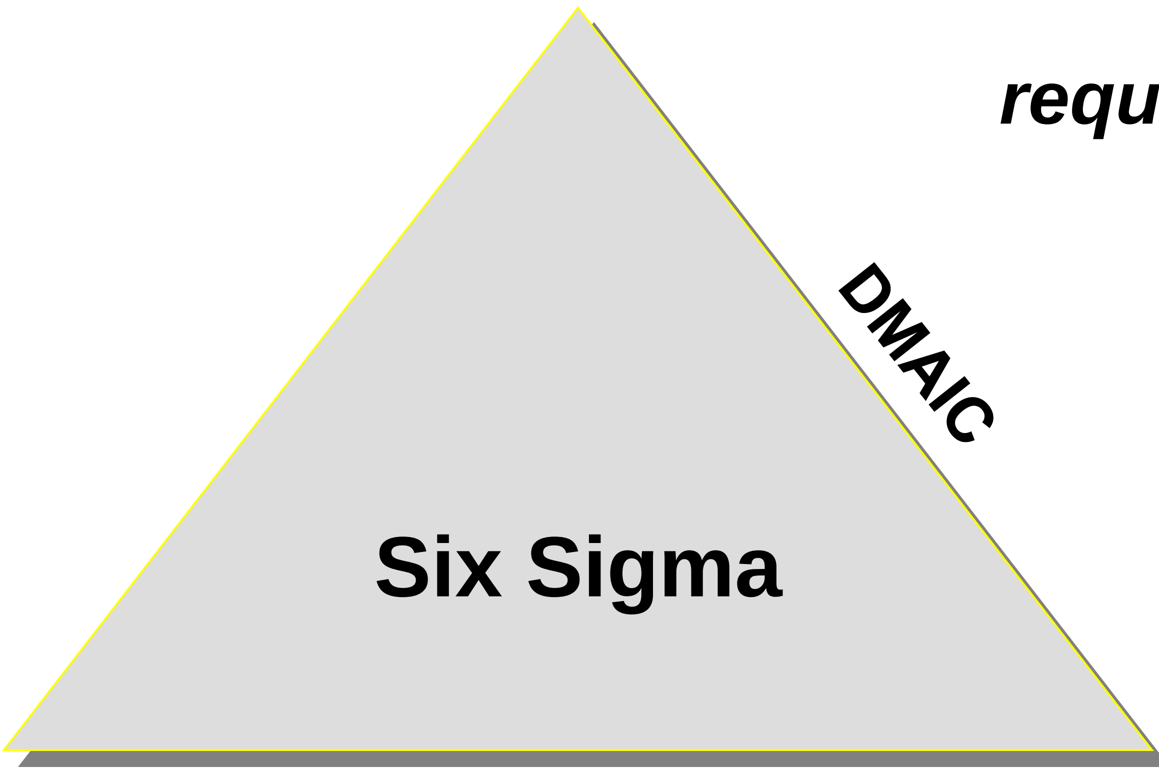
Quando o DFSS deve ser utilizado?

- 1 – A empresa tem a intenção de iniciar um projeto ou pretende dar início a um processo.
- 2 – O novo processo já foi iniciado e chegou em um nível de performance que não tem mais o que fazer, está no máximo. Mas a empresa deseja que essa produção aumente e para isso um processo mais eficiente deve ser empregado para substituir o antigo.

- 3 – Por meio da utilização do projeto DMAIC um processo ou melhoria em produto não consegue mais suprir com as exigências do consumidor. Nesse caso, é preciso executar um novo projeto.

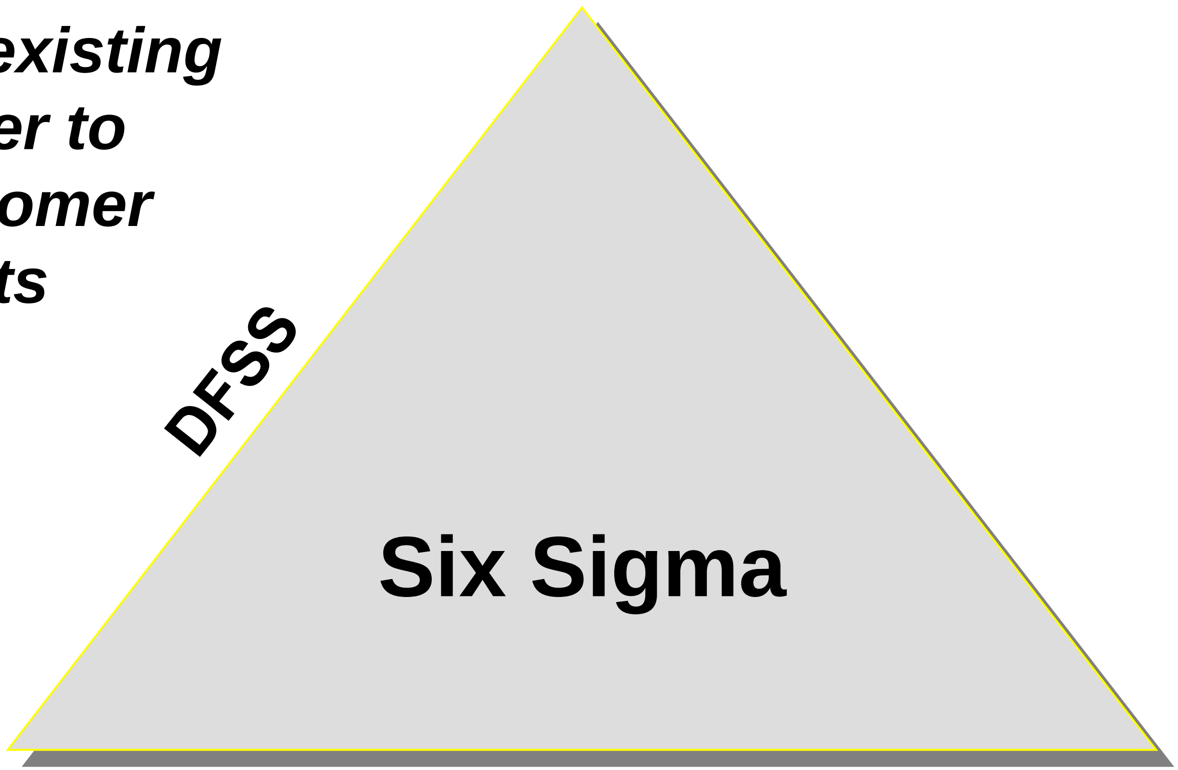
DFSS – DMAIC

To improve the existing processes in order to satisfy customer requirements.

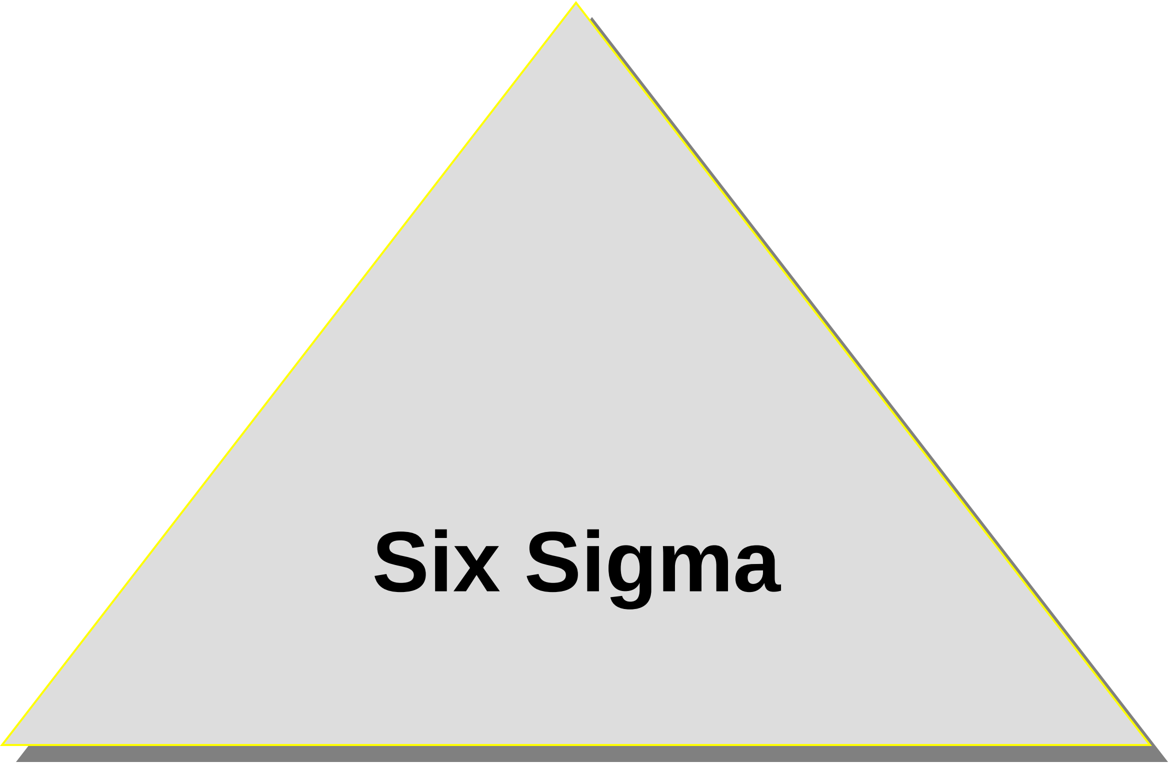


DFSS – DMAIC

To design new products or processes, or to improve the designs of existing ones in order to satisfy customer requirements



DFSS – DMAIC



Process Management

To achieve the business results, managing the processes efficiently.

DFSS – DMAIC

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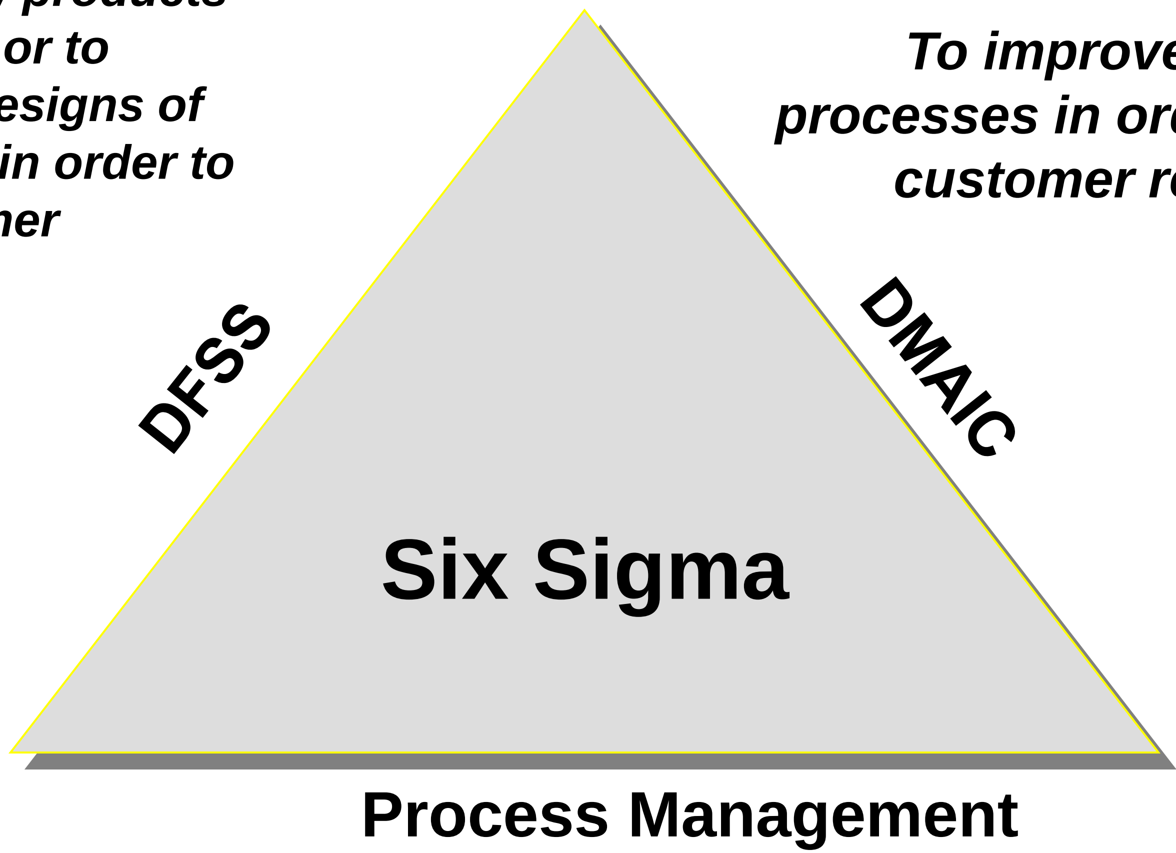


To achieve the business results, managing the processes efficiently.

DMAIC

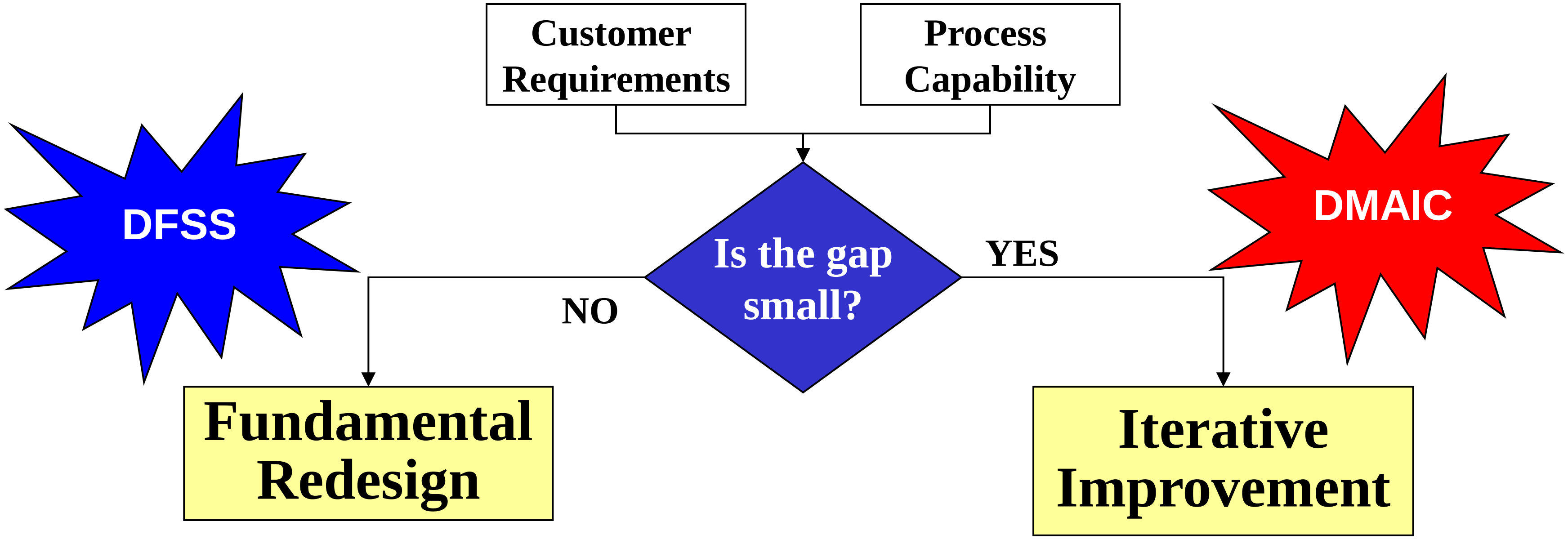
Characterization

- **Define** — *Define the problem with outputs and potential inputs*
- **Measure** — *Analyze the existing process: Is the process measured correctly? If so, what is the capability of the process?*
- **Analyze** — *Analyze and identify the important factors that cause the variation of the process: Where and when do the defects occur?*

Optimization

- **Improve** — *Optimize the output by optimizing the inputs: To reach at the six sigma process, what should be the levels of each factor?*
- **Control** — *Which controls should be done in order to continue process at six sigma?*

Improvement Strategies



- Design a new product / process
- Broad approach
- Blank sheet of paper approach
- High risk
- Longer time span
- Addressing many CTQs
- Goal: Quantum Leap

- Fix an existing process
- Narrow Focus
- Use current process model
- Low risk
- Shorter Time Span
- Addressing few CTQs
- Goal: Improvement

The Impact of DFSS

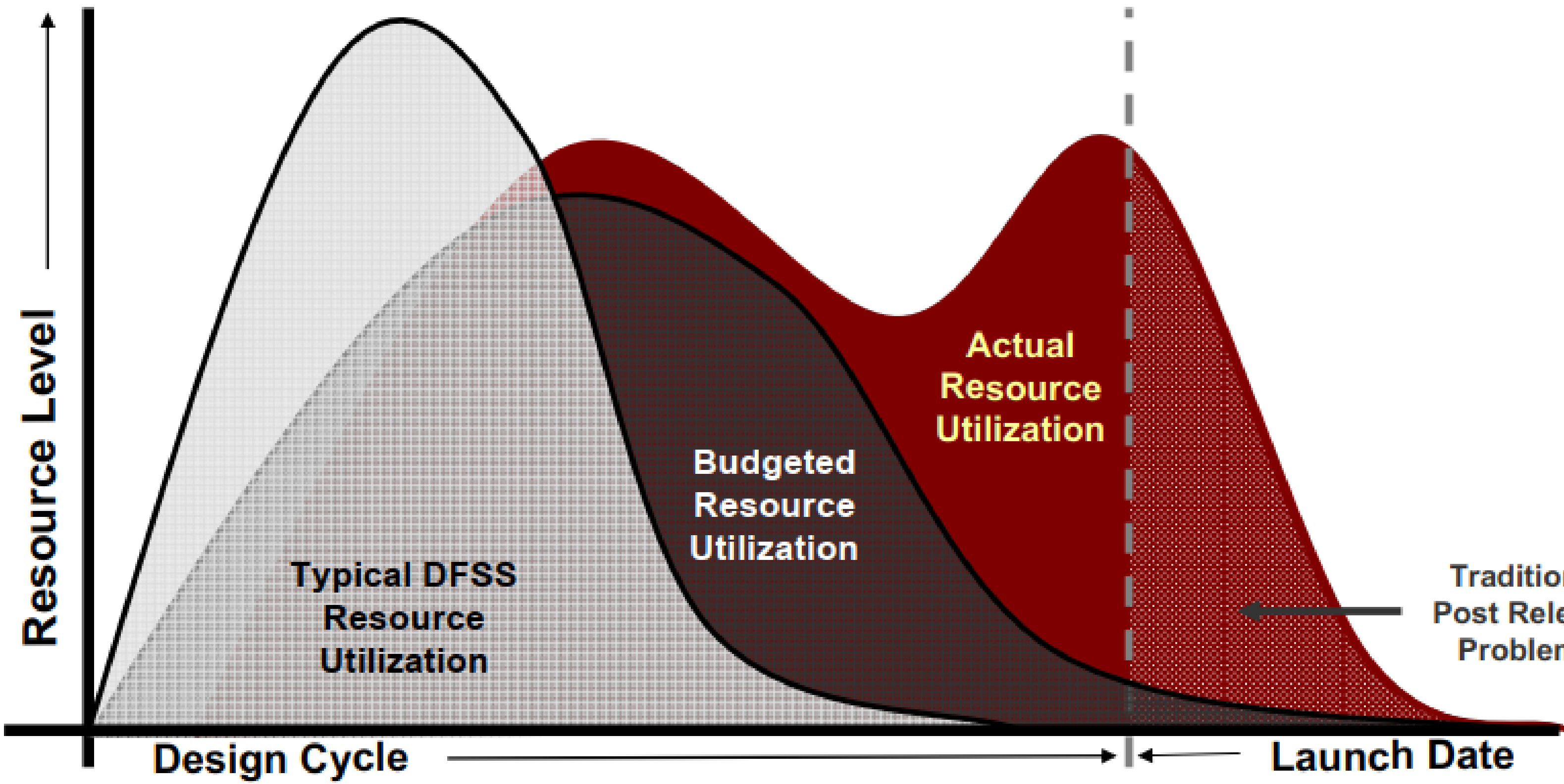
SSA
SIX SIGMA ACADEMY

- By integrating DFSS methods and tools within their design organizations, companies have experienced the following benefits:
  - Shorter development cycles from idea-to-sale
  - Reduction is design process complexity
  - Reduced warranty cost after launch
  - Reduced early-life failures
  - Increase initial customer satisfaction
  - Greater efficiency in design resource utilization
  - Less post-pilot design changes
  - Easier integration of geographically separated design groups

How The Impact of DFSS Is Seen

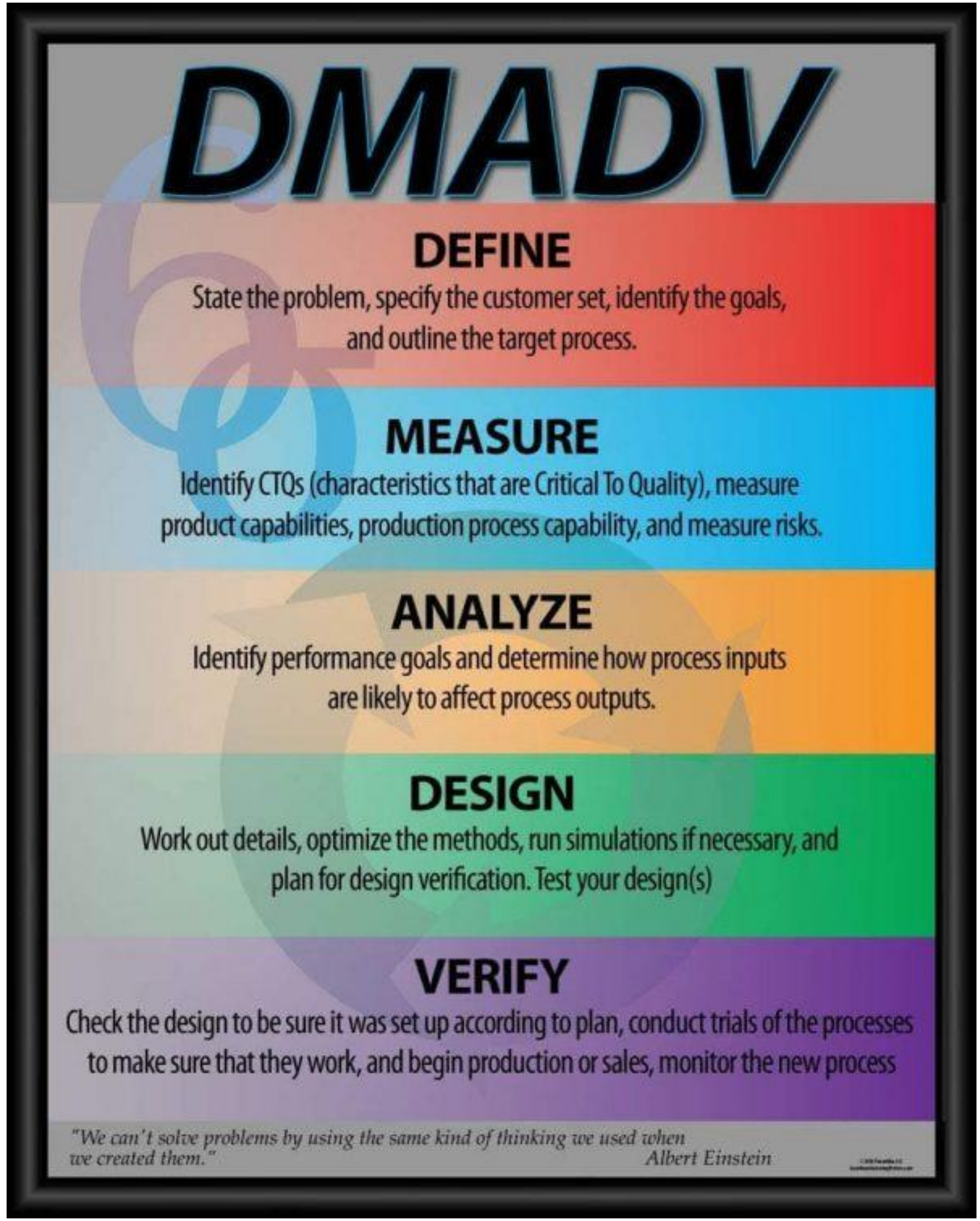
SSA
SIX SIGMA ACADEMY

DFSS requires more resources early, but offers more effective utilization and less overall resource use during the design cycle.



Tipos de metodologia do DFSS

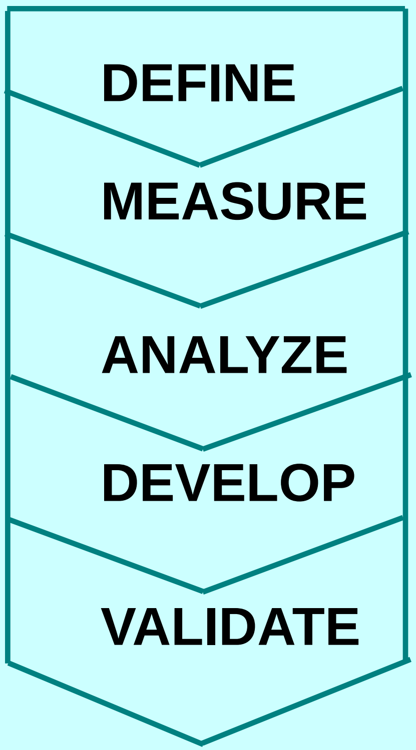
DMADV


DMADV
DEFINE
State the problem, specify the customer set, identify the goals, and outline the target process.
MEASURE
Identify CTQs (characteristics that are Critical To Quality), measure product capabilities, production process capability, and measure risks.
ANALYZE
Identify performance goals and determine how process inputs are likely to affect process outputs.
DESIGN
Work out details, optimize the methods, run simulations if necessary, and plan for design verification. Test your design(s)
VERIFY
Check the design to be sure it was set up according to plan, conduct trials of the processes to make sure that they work, and begin production or sales, monitor the new process
"We can't solve problems by using the same kind of thinking we used when we created them."
Albert Einstein

DFSS Methodology: DMADV

- ***Define*** **the project goals and customer requirements.**
- ***Measure*** **and determine customer needs and specifications; benchmark competitors and industry.**
- ***Analyze*** **the process options to meet the customer needs.**
- ***Design*** **(detailed) the process to meet the customer needs.**
- ***Verify*** **the design performance and ability to meet customer needs.**

DFSS Methodology: DMADV



TOOLS
Project management
QFD
Benchmarking
Value analysis
Financial analysis
SIPOC
IPDS - Integrated Product Development System
FMEA
TRIZ
Design scorecards
MSA
Basic statistical techniques
DOE
Optimization
Simulation
Robust design
Tolerance design
Reliability engineering
Design for manufacture and assembly

IDOV

IDOV
Identificar
(Identify)
Desenvolver
(Design)
Otimizar
(Optimize)
Validar
(Validate)

DFSS Methodology: IDOV

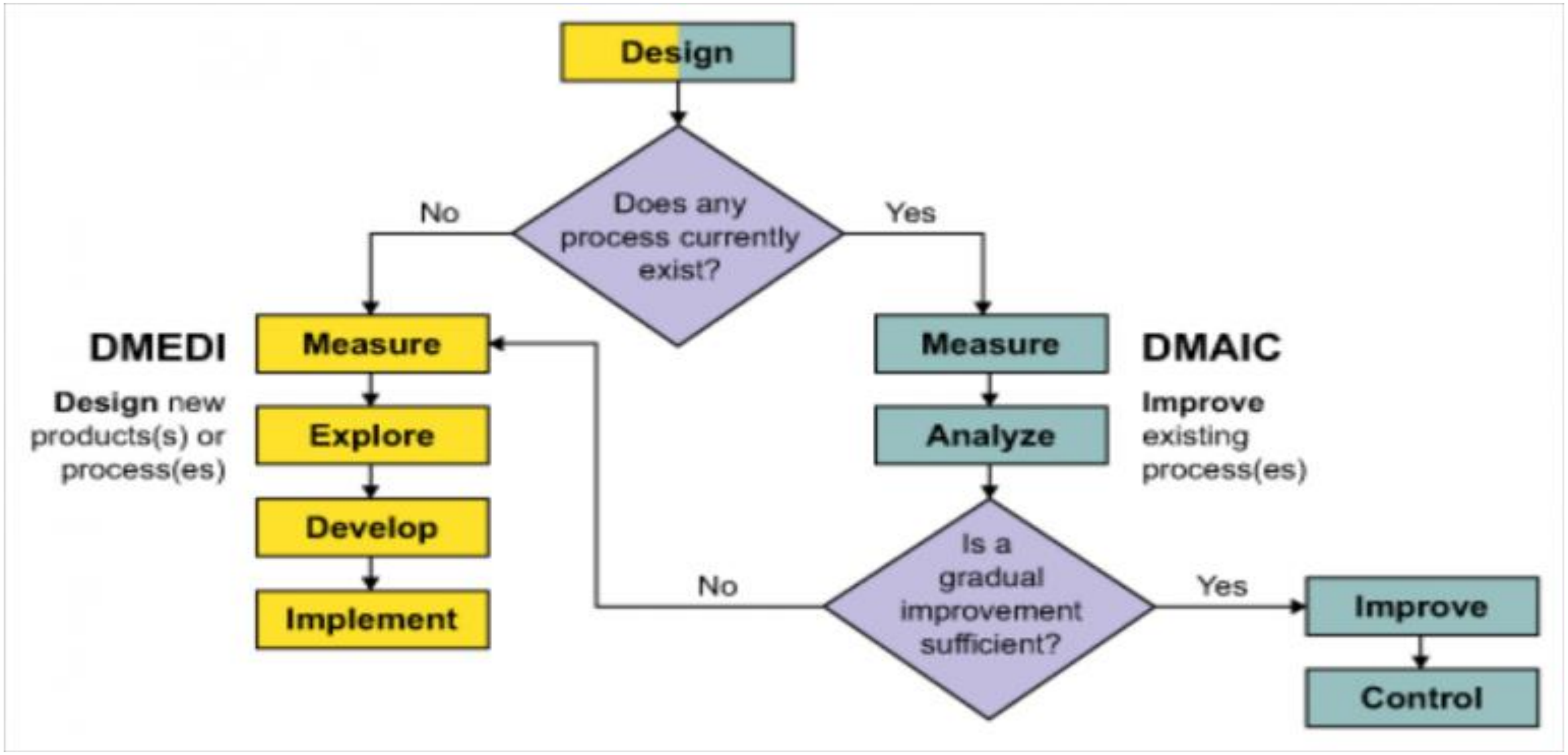
Identify the customer and specifications (CTQs).

Design translates the customer CTQs into functional requirements and into solution alternatives.

Optimize uses advanced statistical tools and modeling to predict and optimize the design and performance.

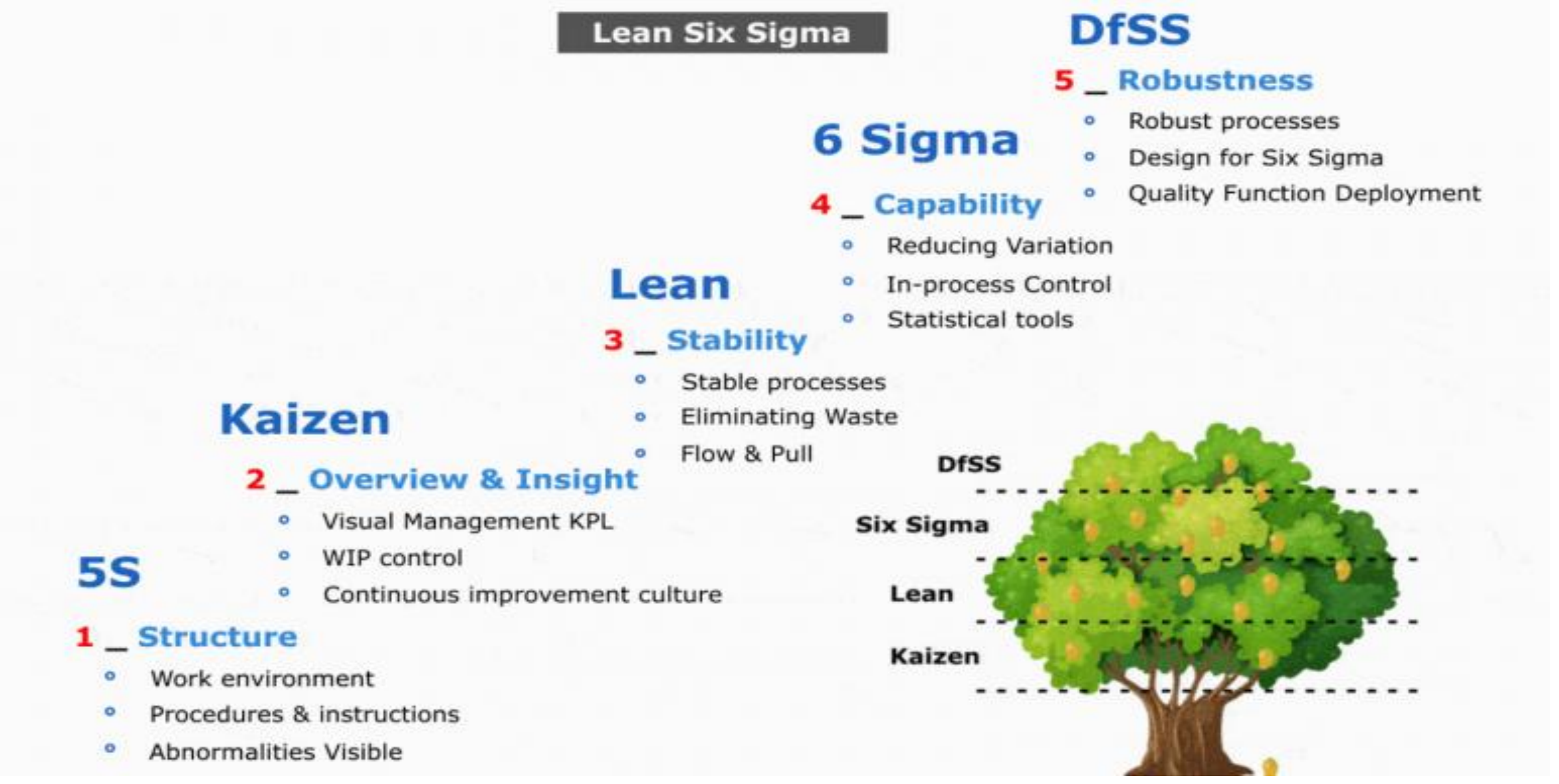
Validate makes sure that the design developed will meet the customer CTQs.

DMEDI



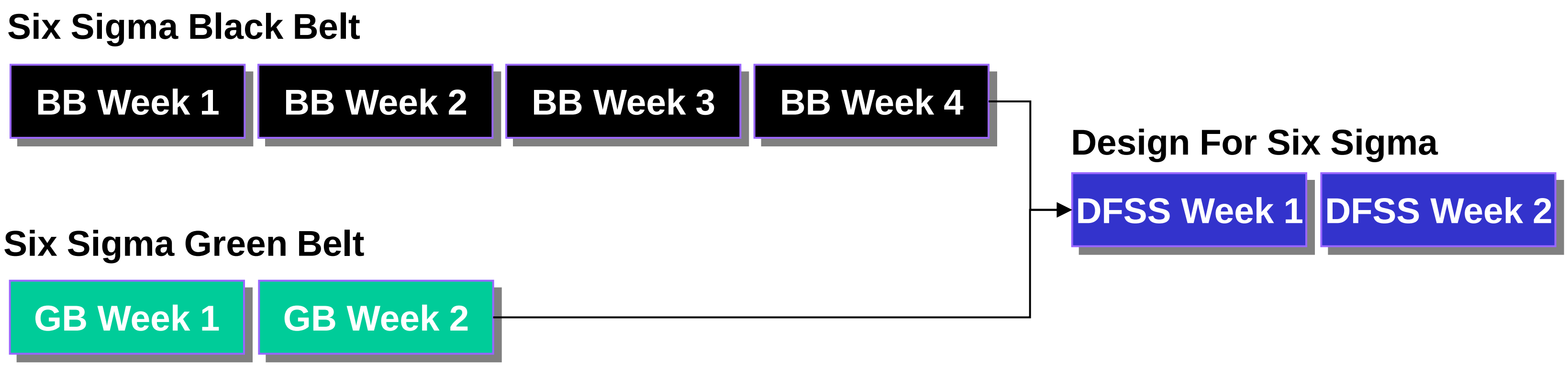
Design
Does any process currently exist?
No
Yes
DMEDI
Design new products(s) or process(es)
Measure
Explore
Develop
Implement
Measure
Analyze
DMAIC
Improve existing process(es)
Is a gradual improvement sufficient?
No
Yes
Improve
Control

Realmente é importante adotar o DFSS?



How is it implemented?

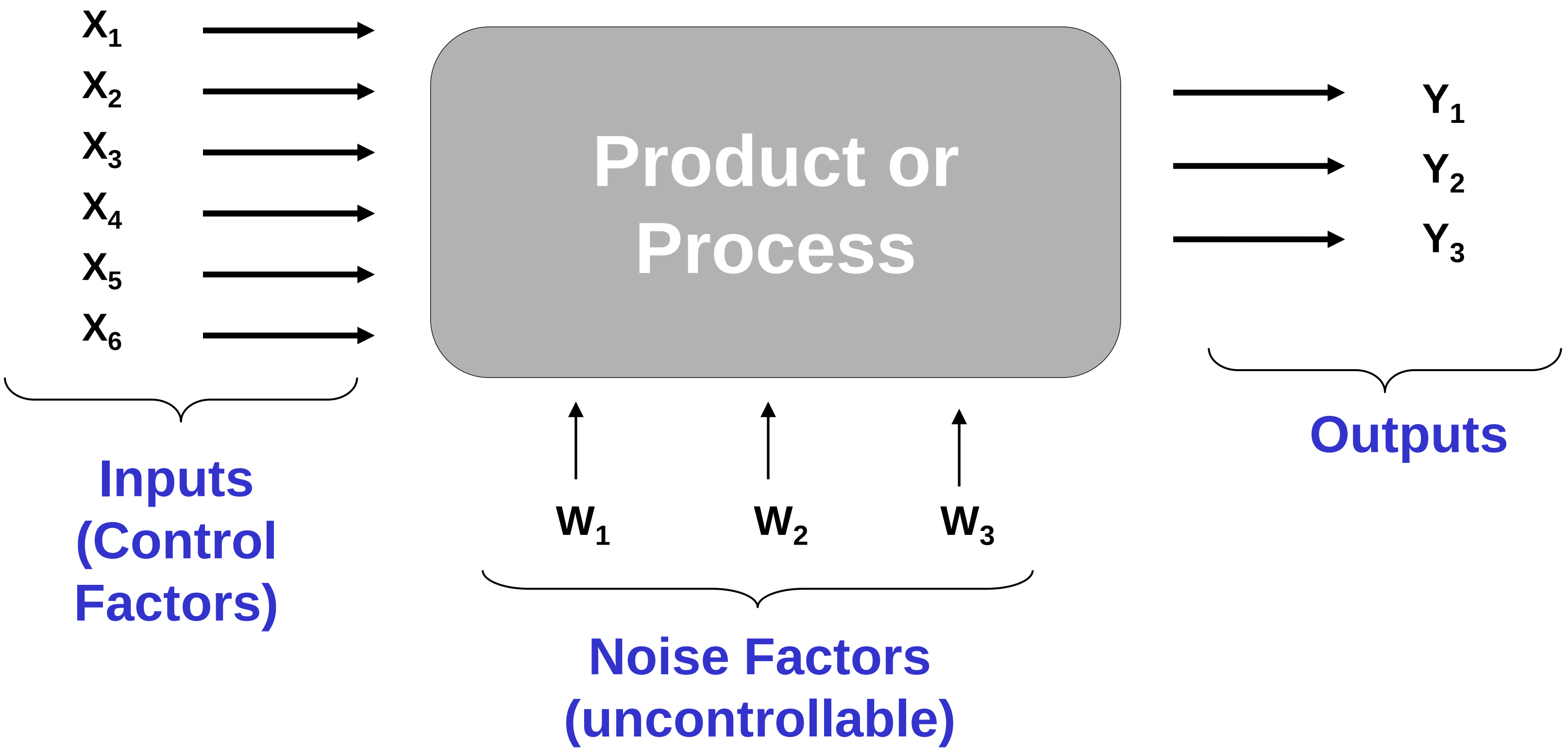
- 2 weeks of DFSS training
  - Six Sigma BB or GB knowledge required for participation
  - 2 project groups and 1 project per group
  - In between training and after training there are a lot of MBB coachings (2-3 days/project-month)



- Or combined Six Sigma / DFSS Black Belt training program
  - Totally 5 weeks of training
  - Black Belts work on the design project
  - Team members may participate on a common project

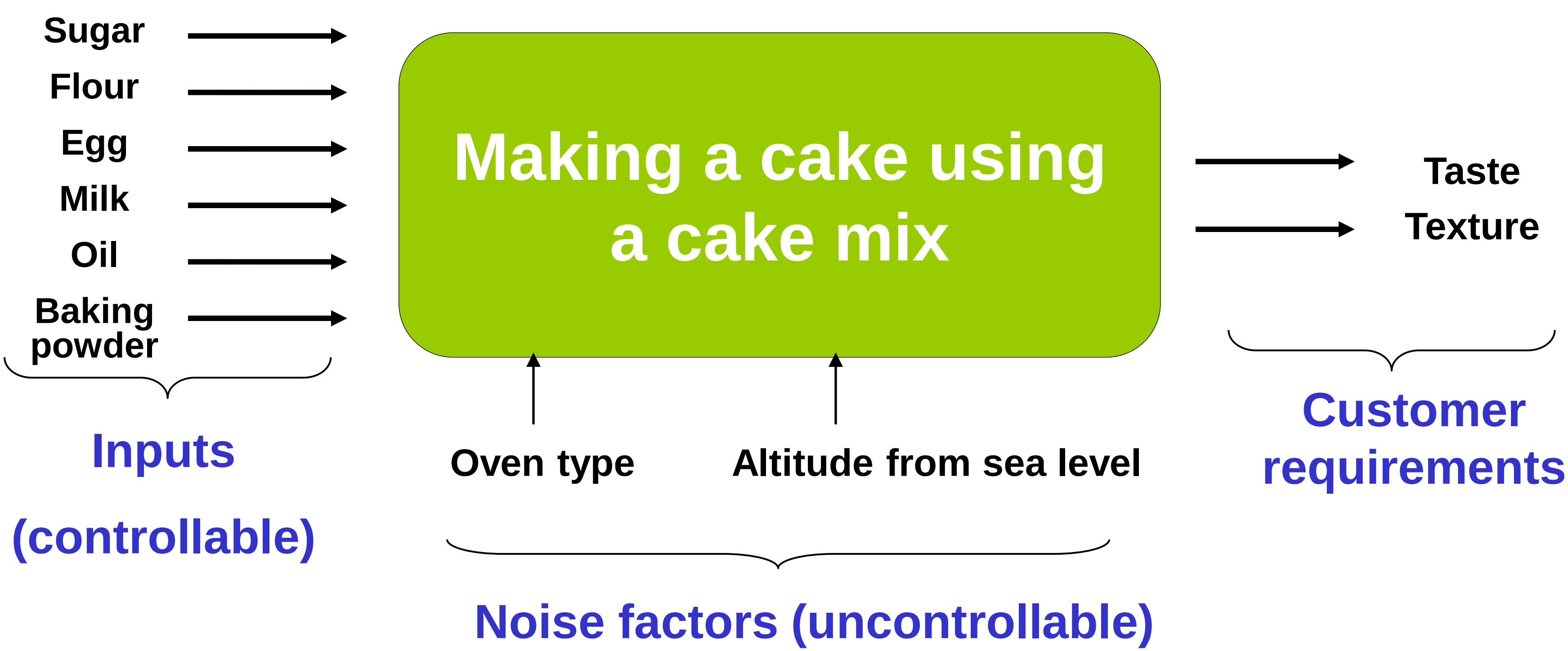
Robust Design Problem

To make system outputs insensitive to variation in inputs, process and environmental factors.



Robust Product Design Example

Making system output robust to environmental usage conditions



A robust cake mix recipe reduces variability in taste and texture.

Guidelines for Robust Design through Statistical Experimentation

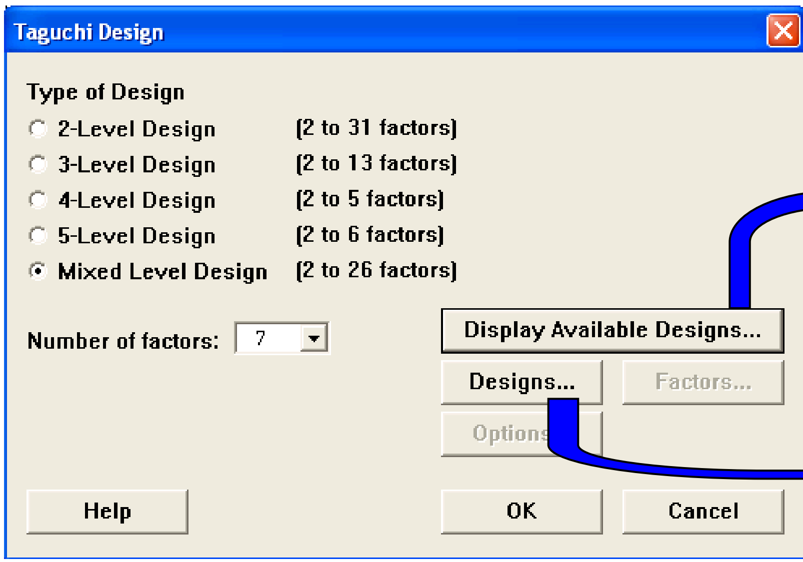
1. Choose control factors and their levels
2. Identify uncontrollable (noise) factors and decide on how they will be simulated
3. Select the response variable(s) and determine the performance measures (mean, standard deviation, SNR, etc.)
4. Setup the experimental layout (choose appropriate design array(s))
5. Conduct the experiments and collect data
6. Analyze the data (effects, ANOVA, regression)
7. Choose optimal control factor levels and predict the performance measure at these levels
8. Confirm the optimal levels by experimentation

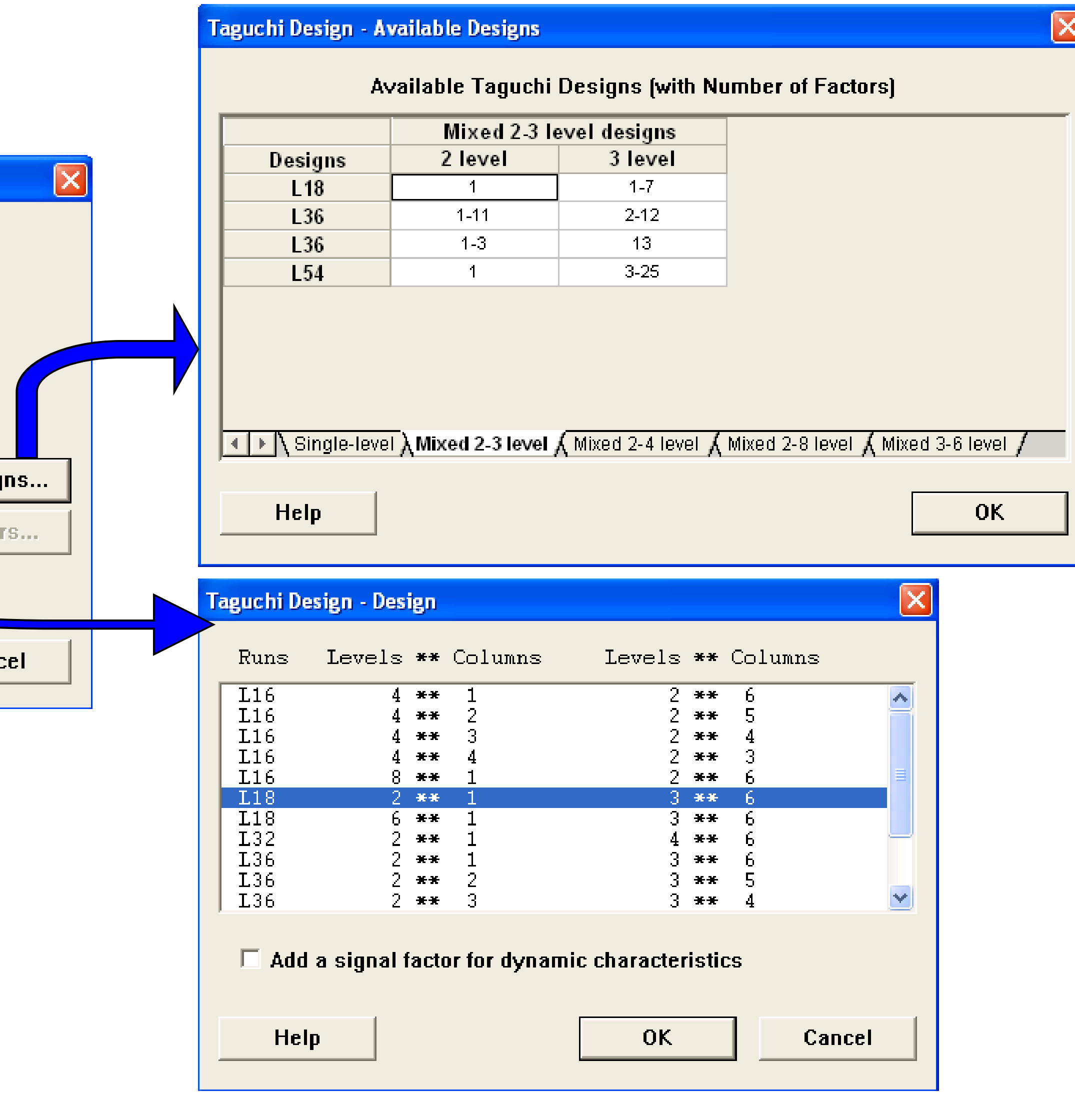
Orthogonal Arrays

Ortogonal Array	No. of rows	Max. no. of factors	Max. no. of factors at these levels			
			2	3	4	5
L_4	4	3	3	-	-	-
L_8	8	7	7	-	-	-
L_9	9	4	-	4	-	-
L_{12}	12	11	11	-	-	-
L_{16}	16	15	15	-	-	-
L_{16}	16	5	-	-	5	-
L_{18}	18	8	1	7	-	-
L_{25}	25	6	-	-	-	6
L_{27}	27	13	-	13	-	-
L_{32}	32	31	31	-	-	-
L_{32}	32	10	1	-	9	-
L_{36}	36	23	11	12	-	-
L_{36}	36	16	3	13	-	-
L_{50}	50	12	1	-	-	11
L_{54}	54	26	1	25	-	-
L_{64}	64	63	63	-	-	-
L_{64}	64	21	-	-	21	-
L_{81}	81	40	-	40	-	-

Ortogonal Array Construction Example

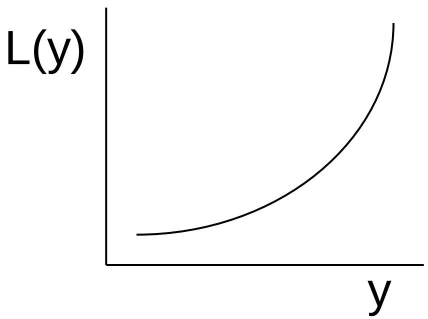
One factor with 2 levels,
6 factors with 3 levels





Smaller-the-Better Response

- **Loss Function L(Y)**



$$L(y) = \frac{A}{\Delta^2} y^2$$

$$\overline{L} = \frac{A}{\Delta^2}(\overline{y}^2 + s^2)$$

Examples:

- Gas, Energy etc. consumption
- Noise
- Radiation

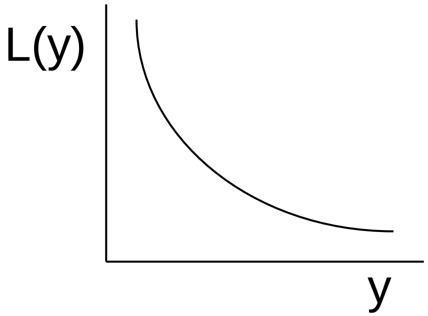
- **Signal to Noise Ratio:**

$$SNR = -10\,log(\frac{1}{n}\sum_{i=1}^{n} y_i^2)$$

$$= -10\,log(\,\overline{y}^2 + s^2\,)$$

Larger-the-Better Response

- **Loss Function L(Y)**



$$L(y) = A\Delta^2 \frac{1}{y^2}$$

$$\overline{L} = A\Delta^2 \frac{1}{\overline{y}^2}(1+3\frac{s^2}{\overline{y}^2})$$

Examples:

- Mechanical power
- Strength
- Wearout resistance

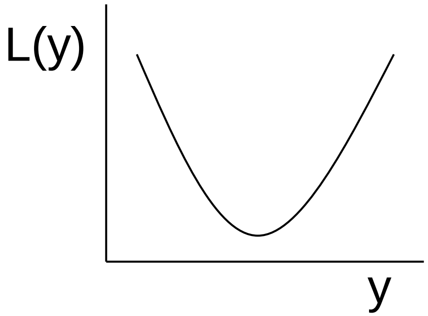
- **Signal to Noise Ratio:**

$$SNR = -10\log(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2})$$

$$= -10\log(\frac{1}{\overline{y}^2}(1+3\frac{s^2}{\overline{y}^2}))$$

Nominal-the-Best Response

- **Loss Function L(Y)**



$$L(y) = \frac{A}{\Delta^2}(y - T)^2$$

$$\overline{L} = \frac{A}{\Delta^2}(s^2 + (\overline{y} - T)^2)$$

Examples:

- Dimension (mm)
- Strength
- Voltage (V)

- **Signal to Noise Ratio:**

1. Minimize variance

$$SNR = -10 \log s^2$$

2. Bring the mean to the target

$$SNR = 10 \log(n\overline{y}^2)$$

A Robust Design Experiment Layout

	Control Factors				Noise Factors				Performance Measures
					1	2	....	1	
					1	1	....	2	
					1	2	....	2	
i				j	1	2	....	n	
1	1	1	1	1	y_{11}	y_{12}	....	y_{1n}	$\bar{y}_1, s_1^2, SNR_1$
2	1	2	2	2	y_{21}	y_{22}	....	y_{2n}	$\bar{y}_2, s_2^2, SNR_2$
3	1	3	3	3	y_{31}	y_{32}	....	y_{3n}	
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	
m	3	3	2	1	y_{m1}	y_{m2}	....	y_{mn}	$\bar{y}_m, s_m^2, SNR_m$

Cookie Recipe Robust Design (A larger-the-better robust design problem)

Objective: To find the control factor levels that maximize cookie chewiness under uncontrollable effects of the noise factors.

Control Factors:	**Levels:**
A: Cooking temperature	Low, high
B: Syrup content	Low, high
C: cooking time	Short, long
D: cooking pan	Solid, mesh
E: Shortening type	Corn, coconut

Noise Factors:	**Levels:**
Z1: Cookie position	Side, middle
Z2: Temperature at test	Low, high

(Source: W.J. Kolarik, 1995, Creating Quality, McGraw-Hill)

The experimental design layout, and data collected

↓	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
	a	b	e	c	d	y1	y2	y3	y4	SNRA1	LSTD1	STDE1	MEAN1
1	1	1	1	1	1	2	6	4	8	10,5073	0,94856	2,58199	5
2	1	1	1	2	2	7	12	6	15	18,2700	1,44519	4,24264	10
3	1	2	2	1	2	23	35	27	39	29,2666	1,98828	7,30297	31
4	1	2	2	2	1	29	41	34	36	30,6796	1,60273	4,96655	35
5	2	1	2	1	2	3	12	2	11	10,2650	1,65405	5,22813	7
6	2	1	2	2	1	2	23	8	19	11,7024	2,27165	9,69536	13
7	2	2	1	1	1	3	18	5	22	14,0820	2,24244	9,41630	12
8	2	2	1	2	2	16	28	21	31	26,7316	1,91432	6,78233	24

Chewiness measurements

	y1	y2	y3	y4
Z1:	side	side	middle	middle
Z2:	low	high	low	high

$\bar{y}$

$$s = \sqrt{\frac{1}{3}\sum_{i=1}^{4} (y_i - \bar{y})^2}$$

$\log_e s$

$$SNR = -10\log\left(\frac{1}{4}\sum_{i=1}^{4}\frac{1}{y_i^2}\right)$$

Response Tables

Taguchi Analysis: y1; y2; y3; y4 versus A; B; C; D; E

The following terms cannot be estimated, and were removed.

A*B

A*C

A*E

B*C

B*D

B*E

C*D

C*E

D*E

Response Table for Signal to Noise Ratios

Larger is better

Level	A	B	C	D	E
1	22,18	12,69	17,40	16,03	16,74
2	15,70	25,19	20,48	21,85	21,13
Delta	6,49	12,50	3,08	5,82	4,39
Rank	2	1	5	3	4

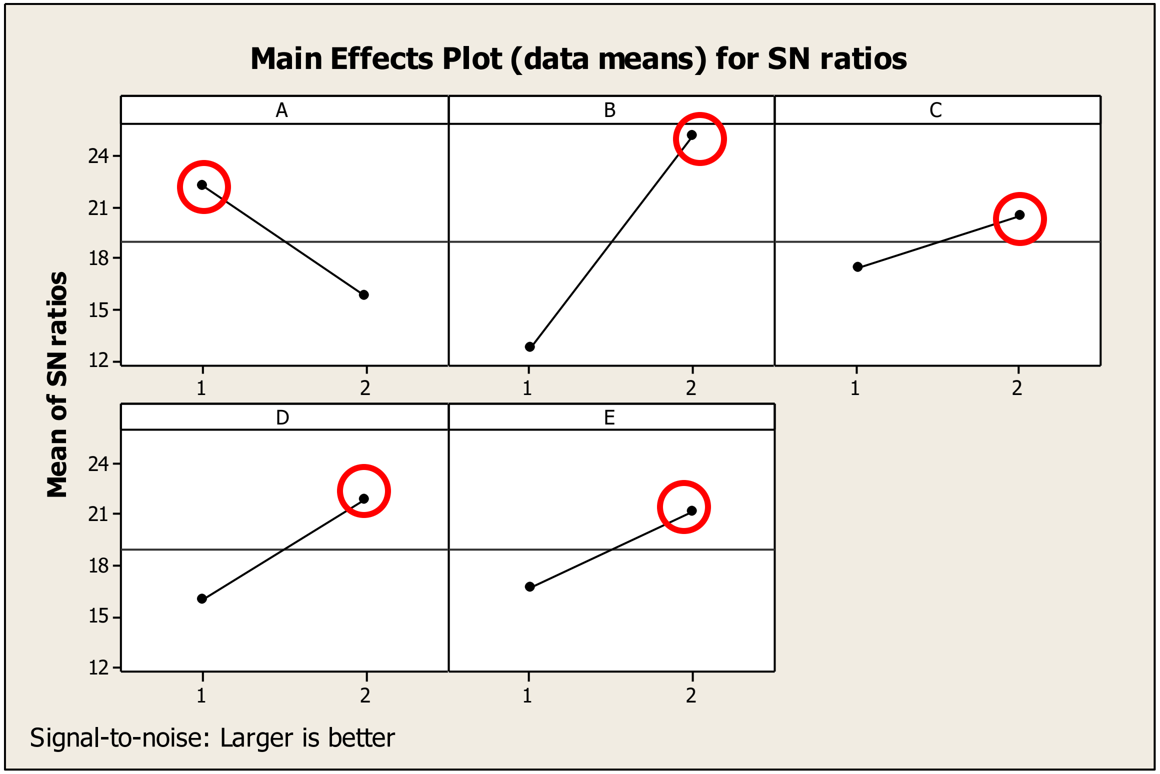
Response Table for Means

Level	A	B	C	D	E
1	20,250	8,750	12,750	13,750	16,250
2	14,000	25,500	21,500	20,500	18,000
Delta	6,250	16,750	8,750	6,750	1,750
Rank	4	1	2	3	5

Response Table for Standard Deviations

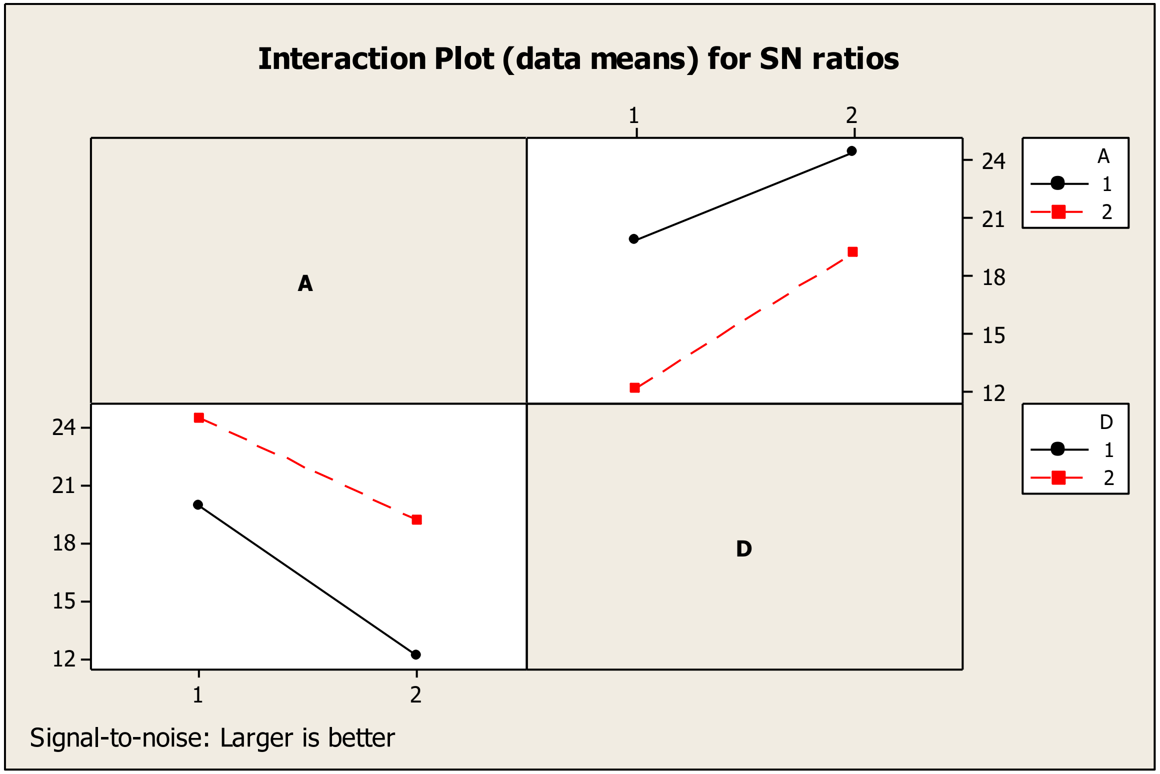
Level	A	B	C	D	E
1	4,774	5,437	5,756	6,132	6,665
2	7,781	7,117	6,798	6,422	5,889
Delta	3,007	1,680	1,042	0,289	0,776
Rank	1	2	3	5	4

Marginal Average (Main Effect) Plots



Variables A, B, D and E have significant effects on SNR. C does not seem to be significant. But let us check this with ANOVA as well.

Interaction Plots



Only AD interaction could be estimated and it seems to be insignificant.

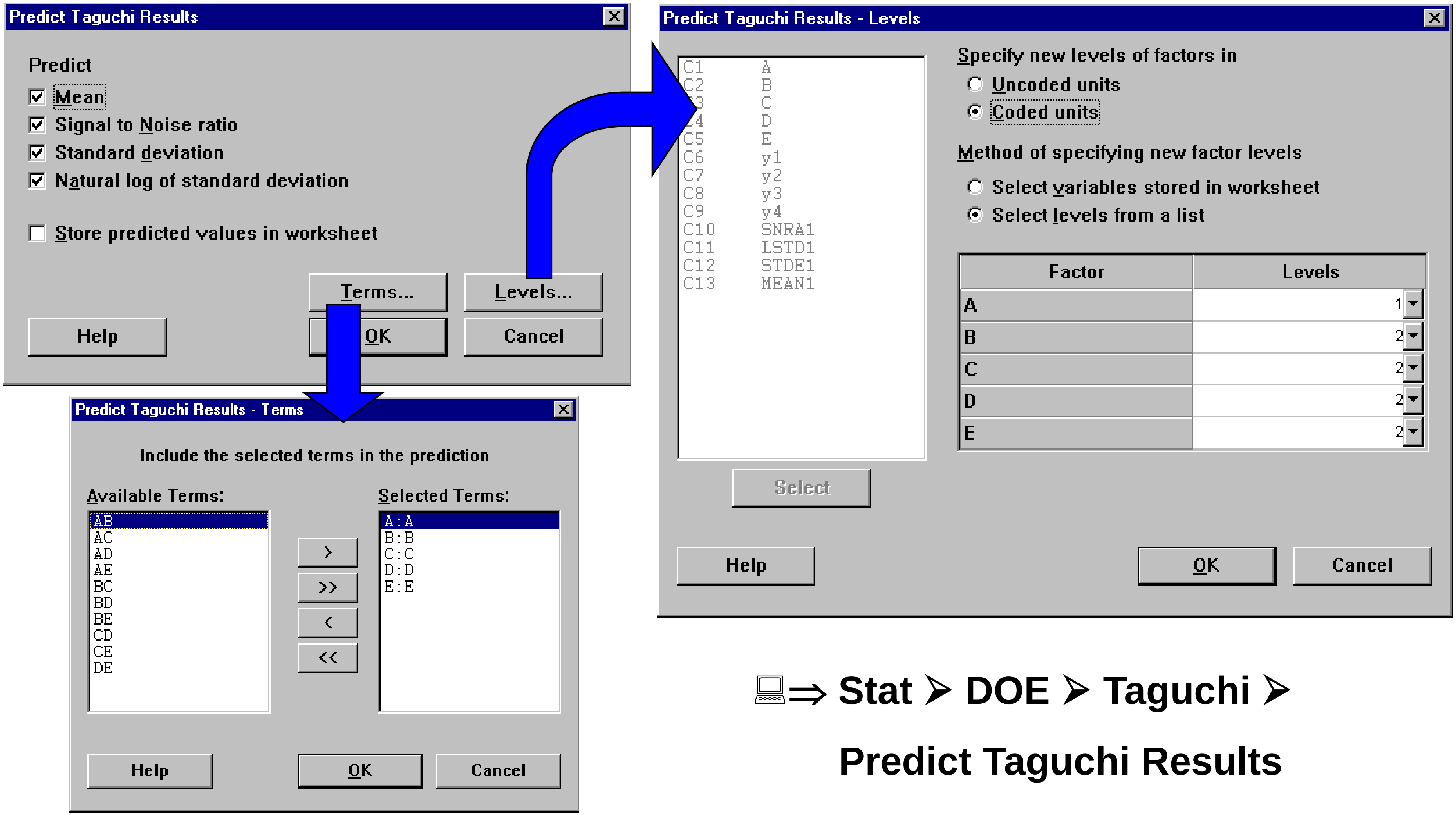
ANOVA for SNR

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	1	84,126	84,126	84,126	28,18	0,034
B	1	312,689	312,689	312,689	104,74	0,009
C	1	18,981	18,981	18,981	6,36	0,128
D	1	67,643	67,643	67,643	22,66	0,041
E	1	38,553	38,553	38,553	12,91	0,069
Residual Error	2	5,970	5,970	2,985		
Total	7	527,962				

💻⇒ **Stat ➤ DOE ➤ Taguchi ➤ Analyze Taguchi Design-Analysis choose 'fit linear model for Signal to Noise ratios'**

Predict Results at the Optimal Levels



⇒ **Stat ➤ DOE ➤ Taguchi ➤**

Predict Taguchi Results

Predict Results at the Optimal Levels

Taguchi Analysis: y1; y2; y3; y4 versus A; B; C; D; E

Predicted values

```
S/N Ratio    Mean     StDev  Log(StDev)
  35,0761  37,25  5,89143     1,83763

Factor levels for predictions
A  B  C  D  E
1  2  2  2  2
```

Conduct confirmation experiments at these levels!

$$\hat{E}(SNR) = \overline{T} + (\overline{A}_1 - \overline{T}) + (\overline{B}_2 - \overline{T}) + (\overline{C}_2 - \overline{T}) + (\overline{D}_2 - \overline{T}) + (\overline{E}_2 - \overline{T})$$

Trabalho em Grupo para dia 09 de abril

Trazer um case de DFSS

Apresentação de até 10 minutos

Grupos de até 6 pessoas