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Test Time Reduction and Predictive Analysis

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Rockwell Collins

Rockwell Collins Today

- Rockwell Collins develops smart and secure communications and advanced aviation electronics solutions for commercial and governmental customers.
- Rockwell Collins is 19,000 employees worldwide (80 locations)
- Over 50 years of presence and innovation in EuMEA (Subsidiaries in France, Germany, the UK and the UAE) with $1B sales & 2000 employees

Rockwell Collins France

Headquarters located in Toulouse-Blagnac since 1978

Headcount: 750 employees (> 250 engineers)

Rockwell Collins France activity:

- Avionics for military transport aircraft & helicopters
- Avionics for commercial solutions
- Communications & Navigation products
- UAV systems

Context

- Over the last decade, established aeronautic and military product manufacturers saw **a rise in competition, putting pressure on production costs.**

- While the **requirements on quality and reliability cannot be relaxed**, testing is a significant share of the production cost.

- In this context, **new methods are required to optimise the production test time.**

- This study will describe a customised analytical process based on advanced statistical tools available in JMP platforms:
  - measurement system analysis optimisation using D-optimal design
  - gauge Repeatability & Reproducibility
  - principal component analysis
  - hierarchical component analysis.
  - regression analysis is used to predict tests to be removed

Problem to be solved

Problem → Increase the production capacity with the same production test bench quantity and without any impact on quality and reliability.

On one of our complex equipment, the final production test includes:

- 2.500 electrical measurements (test time ~ 4 hours)
- 3.400 additional electrical measurements on 10% of the production (test time ~ 9 hours 40 min)

The cost of a production test bench is higher than 400K$

Solution → Apply DMAIC process and analyse data to propose a test time reduction without any impact on quality and reliability.

Important Notes:

Technical information's related to the equipment and final application can't be shared.

All data and graphs are unidentifiable via the anonymize JMP's menu

Methodology

DMAIC process

DEFINE → MEASURE → ANALYZE → IMPROVE → CONTROL

DEFINE	MEASURE	ANALYZE	IMPROVE	CONTROL
Define The problem	Measure the performance	Find solutions to Improve the performance	Implement and verify the solution	Monitor the performance

Test Time reduction Flow

Measurement System Analysis → Statistical regression, correlation and test removal

Challenge N°1:

Optimise Measurement System Analysis and data collection

Challenge N°2:

Analyse table of 10^6 data

Measurement System Analysis

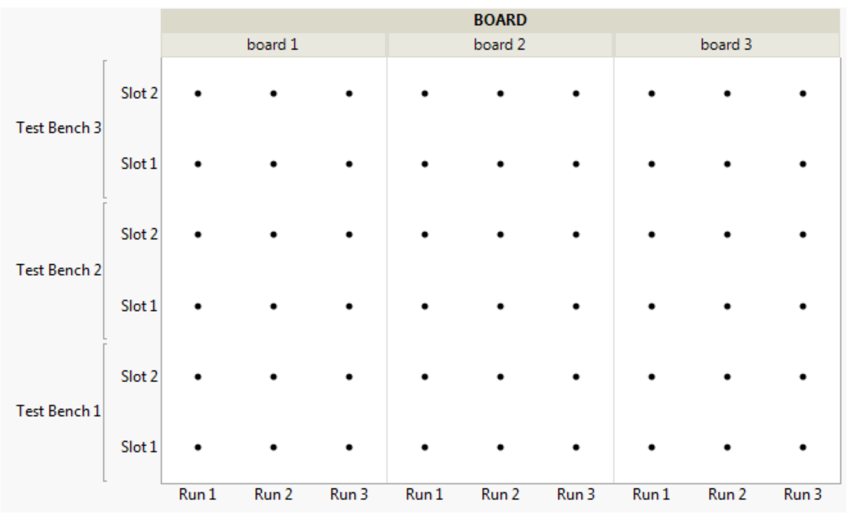
Definition

Measurement System Analysis (MSA) is a critical first step that should precede any data-based decision making. MSA consist of understanding the variation of the measurement system in term of Repeatability and Reproducibility with a Gage R&R analysis

Gage Repeatability & Reproducibility

The Gage R&R consists to analyse data collected from several reference units tested several times on each measurement systems.

Example: 3 reference units tested 3 times on 3 production test benches with 2 slots each.



Problem!

Data collection = 220hours * 9 days full time

* Test time ~ 4hrs

Solutions ?

→Remove 1 factor from analysis ?

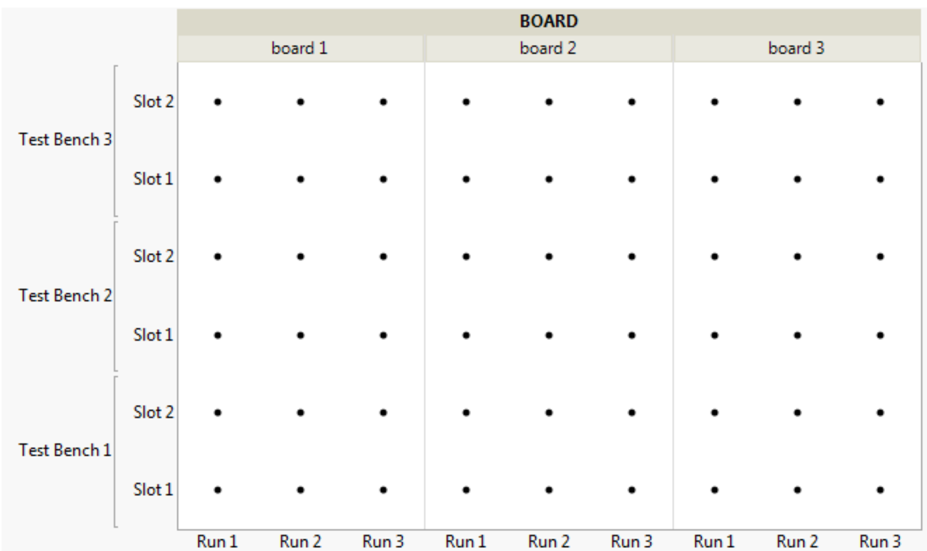
→Find a way to optimise data collection?

Gage R&R with D-Optimal design

Creation of a D-Optimal design (Design Of Experiment)

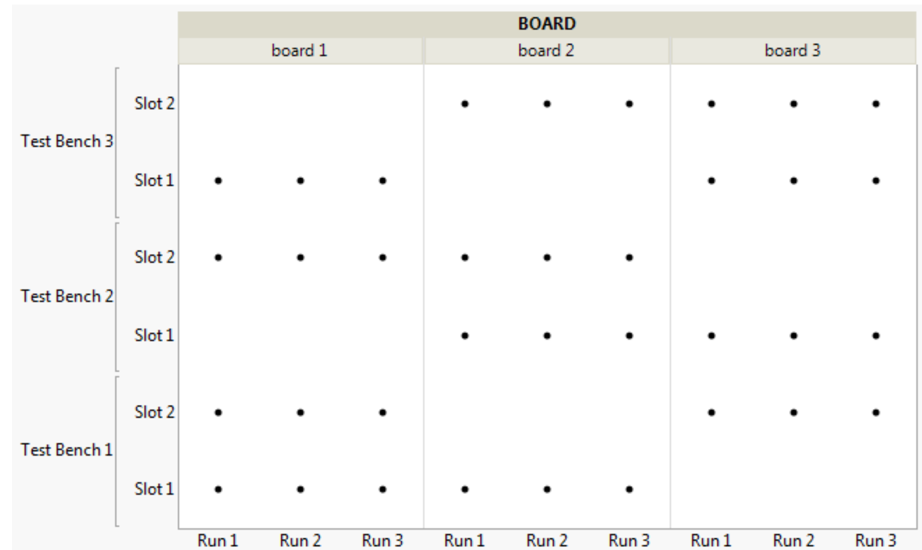
The aim of D-Optimal design is to collect less data but keep information's from all factors.

Representation of a standard Gage R&R design



Data collection: 220hrs/9d full time

Representation of a D-Optimal Gage R&R design



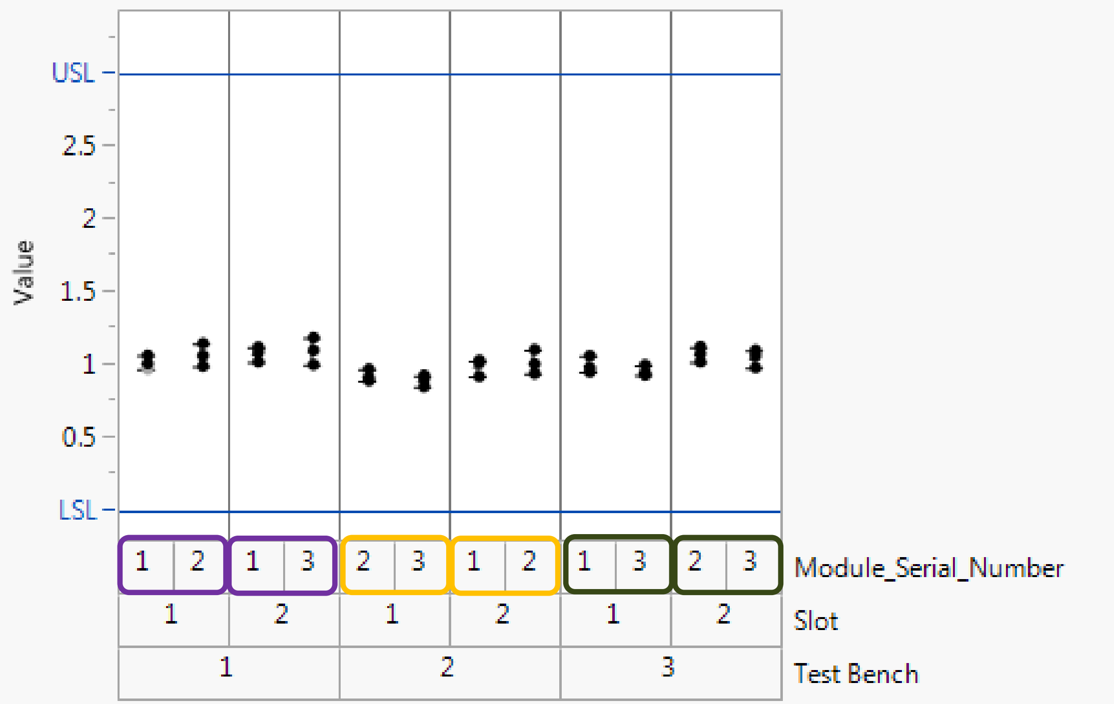
Data collection: 140hrs/6d full time → **-33%**

DEMO

Gage R&R with D-Optimal design

Example of Gage R&R results with D-Optimal design

Variability Gauge with D-Optimal Design (DOE)



Gauge R&R

Measurement Source		Variation (6*StdDev)	% of Tolerance	
Repeatability	(EV)	0.33649124	11.22	Equipment Variation
Reproducibility	(AV)	0.43876415	14.63	Appraiser Variation
Test Bench		0.31627800	10.54	
Slot		0.30410887	10.14	
Gauge R&R	(RR)	0.55293791	18.43	Measurement Variation
Part Variation	(PV)	0.06523649	2.17	Part Variation
Total Variation	(TV)	0.55677297	18.56	Total Variation

6	k
99.3112	% Gauge R&R = 100*(RR/TV)
8.4759	Precision to Part Variation = RR/PV
0	Number of Distinct Categories = 1.41(PV/RR)
0	LSL
3	USL
3	Tolerance = USL-LSL
0.18431	Precision/Tolerance Ratio = RR/(USL-LSL)

Using last column 'Module_Serial_Number' for Part.

Variance Components for Gauge R&R

Component	Var Component	% of Total	20 40 60 80
Gauge R&R	0.00849279	98.63	
Repeatability	0.00314518	36.53	
Reproducibility	0.00534761	62.10	
Part-to-Part	0.00011822	1.37	

Note: With D-Optimal design, the Gage R&R analysis is focused on main effects

DEMO

Gage R&R with D-Optimal design

Benefits

➔ Gage R&R data collection could be optimised by using a D-Optimal Design

➔ Even with long test time, D-Optimal design allows to perform Gage R&R with all factors

➔ Gage R&R analysis with D-Optimal design is focused on main effects.

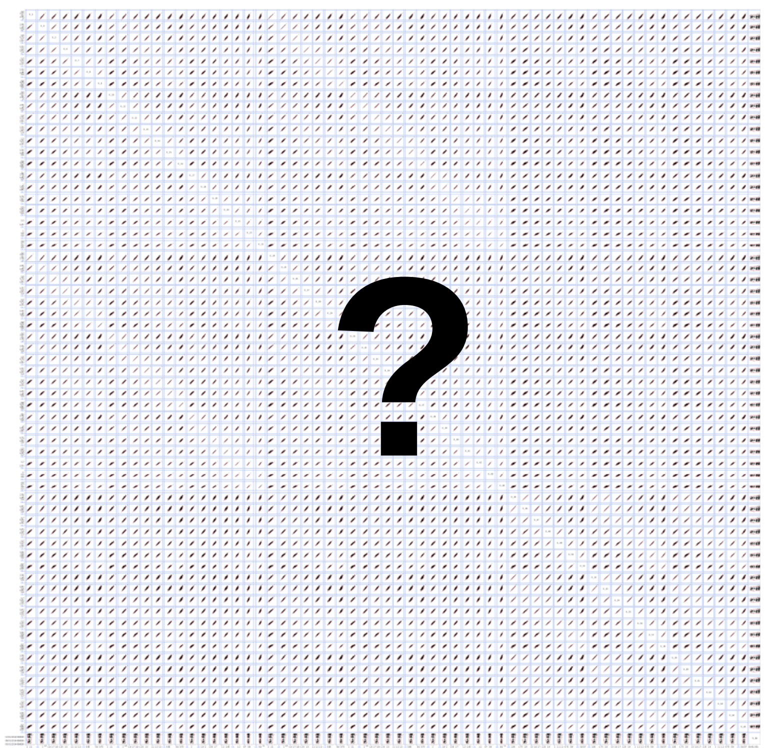
➔ D-Optimal and standard designs provide similar results

Data collection and production Test bench availability have been improved by 33% on our program !

Analysis of a large dataset

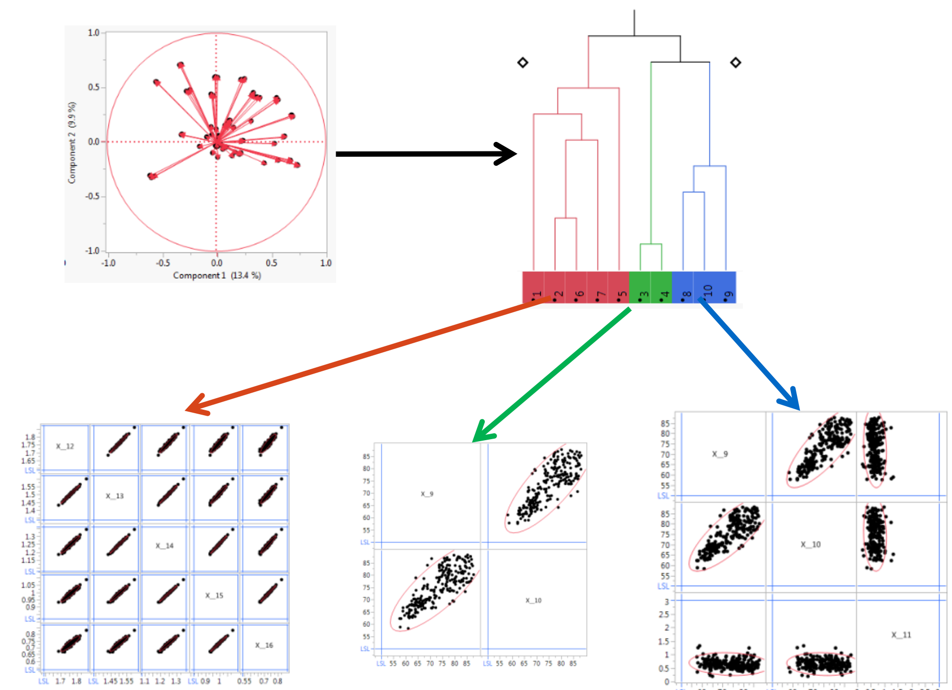
After Gage R&R step, the challenge is to identify good correlations between parameters on large dataset

Option 1
Multivarite analysis
(scatterplot matrix)



➔ Hard to identify correlations

Option 2
Principal Component Analysis +
Hierarchical clustering analysis +
regression analysis



➔ Multi steps analysis helps to identify good correlations

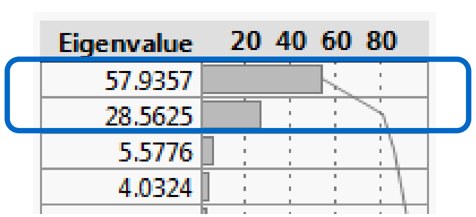
Principal Component Analysis (PCA) is a dimension-reduction technique.

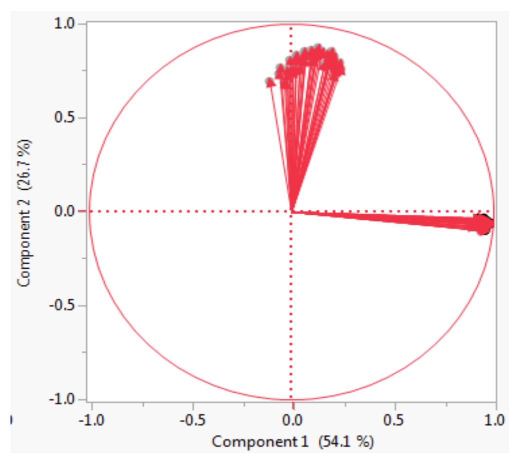
The Principal Component Analysis consist of:

- reducing a large dataset into a lower number of independent linear combinations called principal components
- capturing the most of the variability in the original variables

On this example, a PCA is computed on 100 electrical tests.

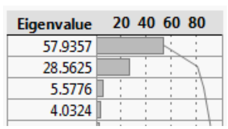
- 2 dimensions summarise approx. 85% of the dataset information (variance).
- 2 dimensions are plotted on a correlation circle.

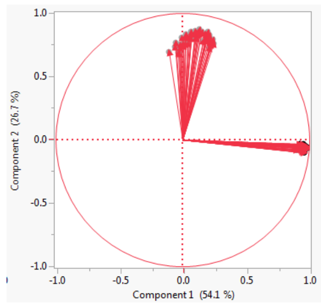




Examples of Principal Component Analysis

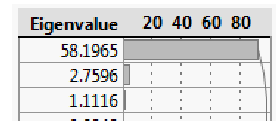
PCA on test category 1 (100 tests)

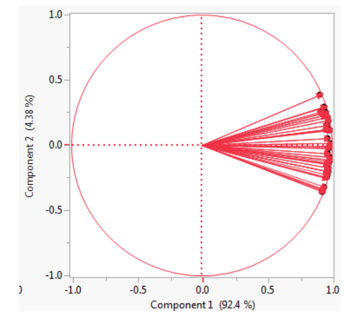




85% of the dataset information is summarized by 2 eigenvalues

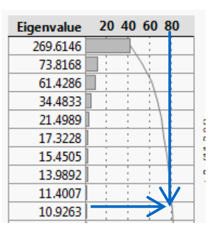
PCA on test category 2 (65 tests)

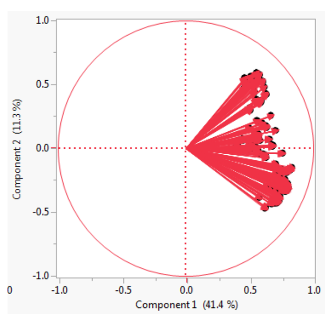




98% of the dataset information is summarized by 2 eigenvalues

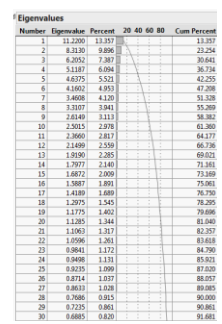
PCA on test category 3 (650 tests)

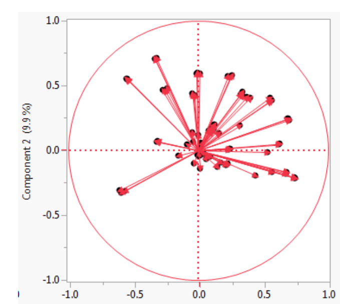




80% of the dataset information is summarized by 10 eigenvalues

PCA on test category 4 (105 tests)





90% of the dataset information is summarized by 30 eigenvalues

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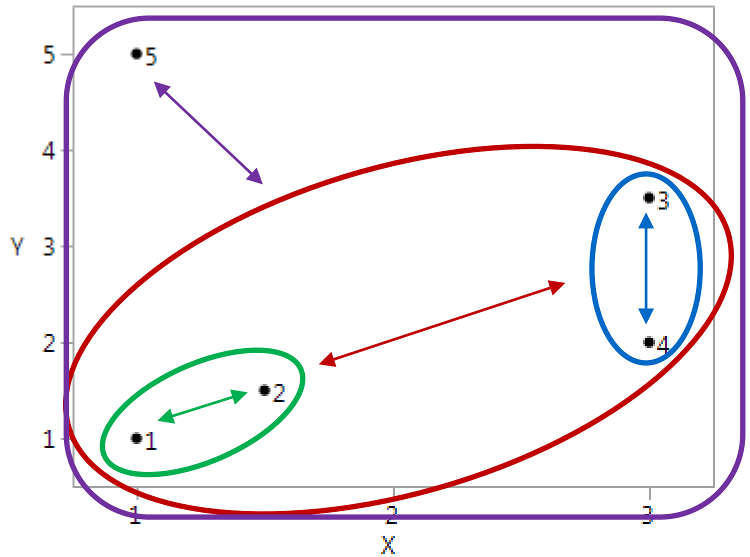
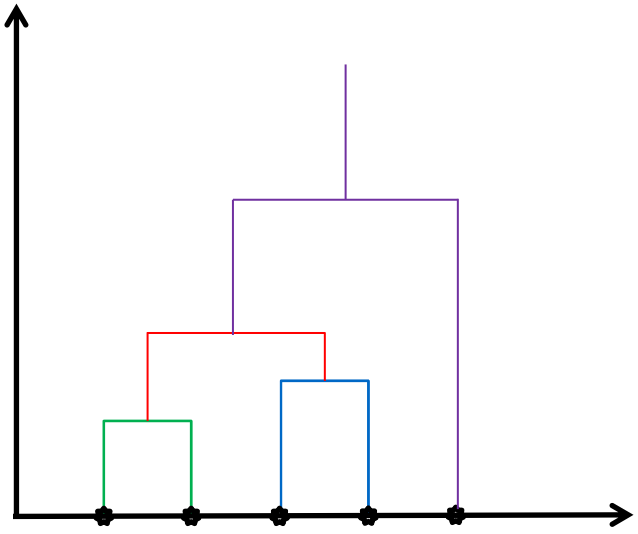
Hierarchical Clustering Analysis (HCA) is used to

- Find similarity or dissimilarity between each pairs of object in the data set.
- Classify and illustrate clusters arrangement on a Dendrogram

Dendrogram

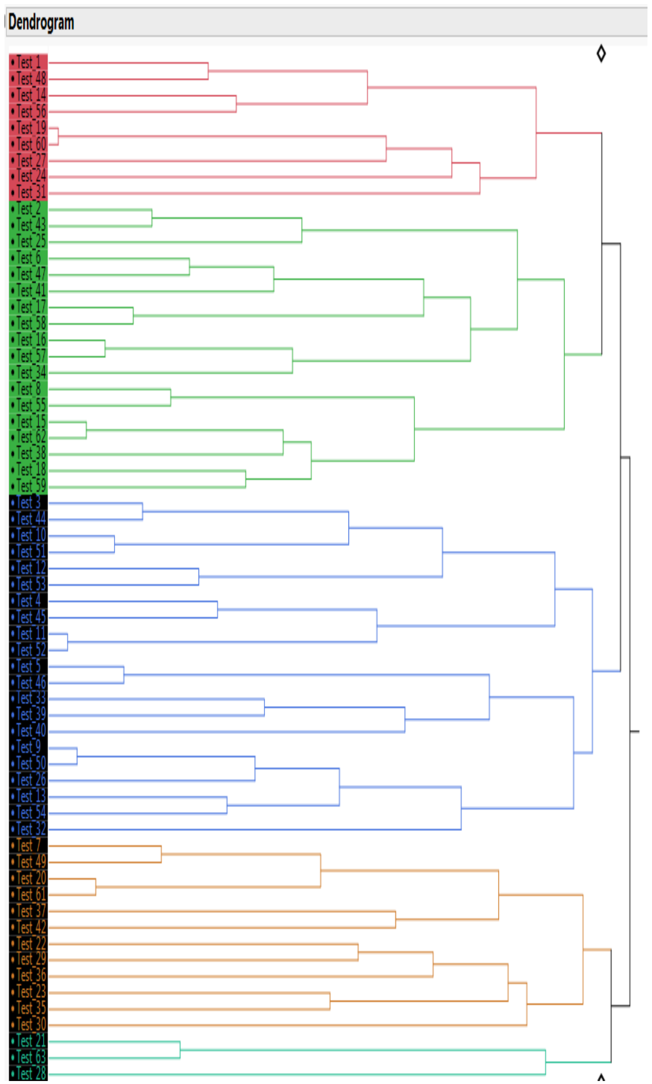




Dendrogram

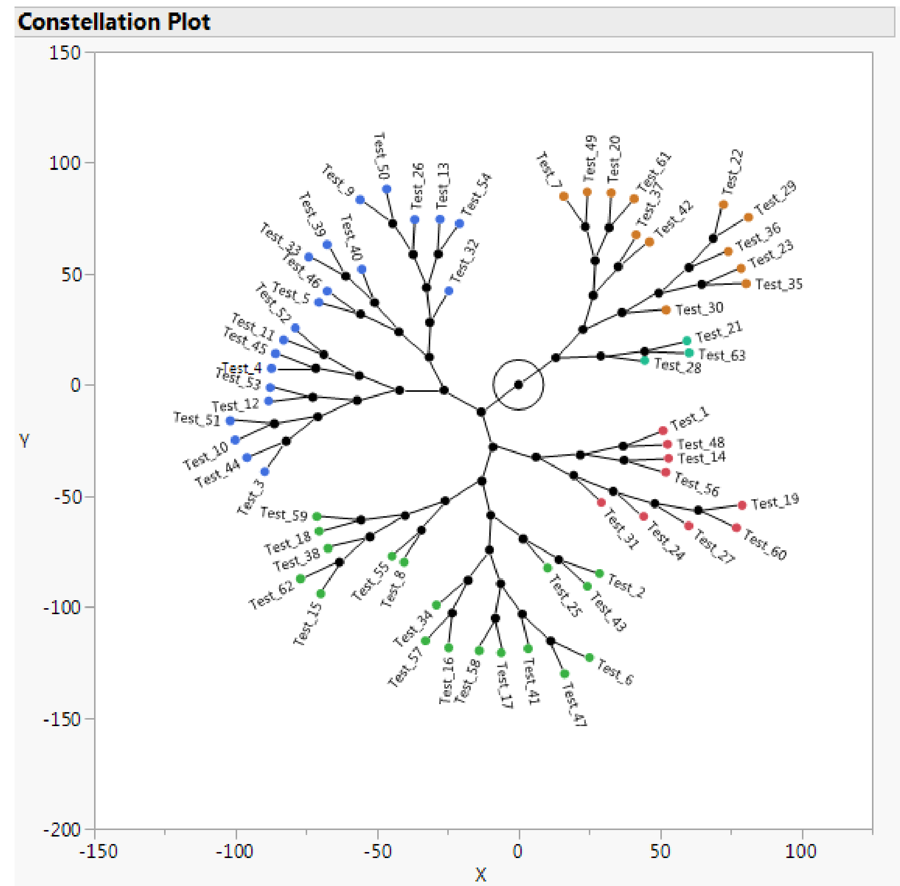
Hierarchical Clustering Analysis

Different types of illustrations of Hierarchical Clustering Analysis



5 clusters: test groups with "similar" behaviors

(example from 65 electrical parameters)



DEMO

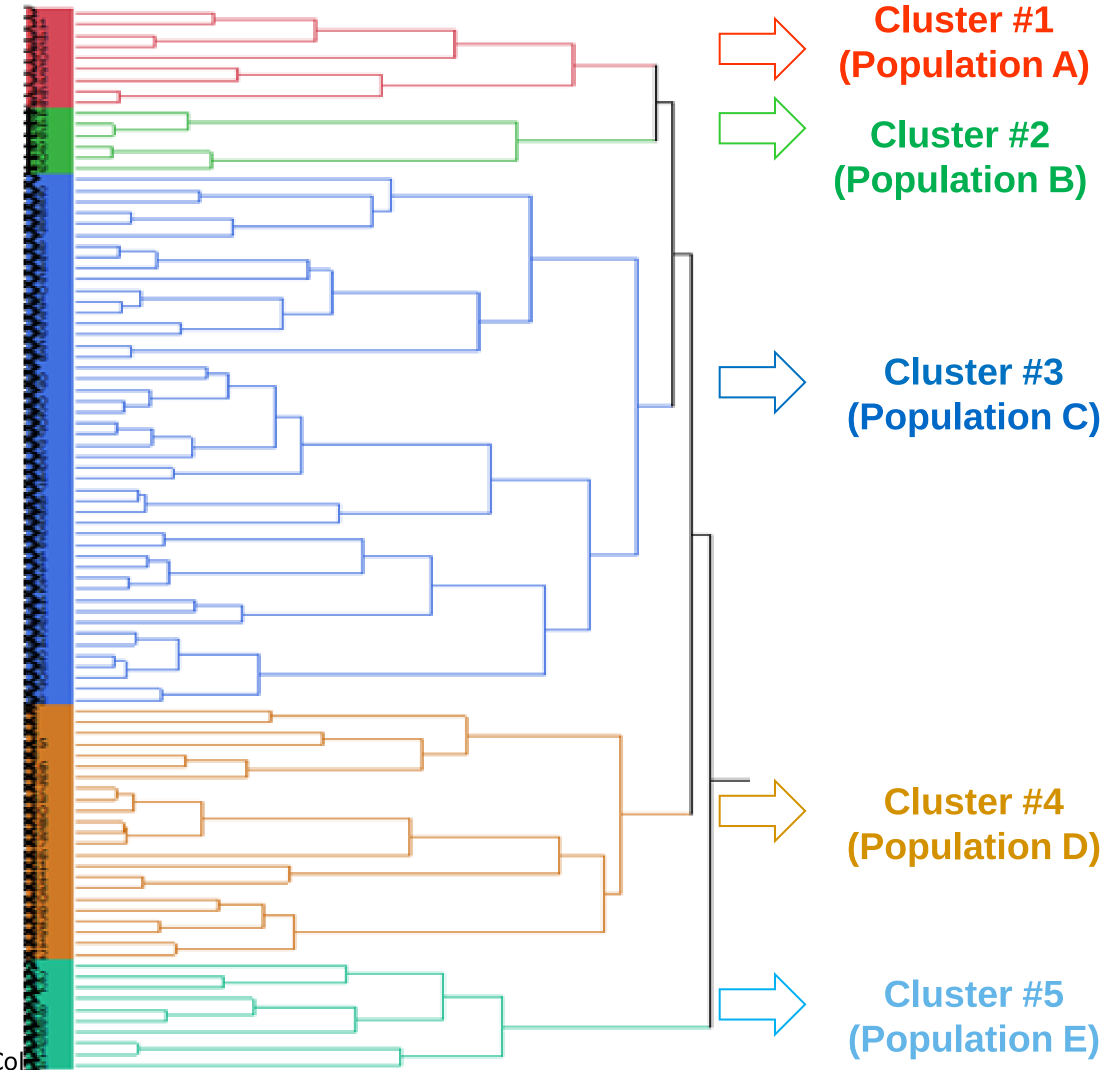
Hierarchical Clustering Analysis

Another use of Hierarchical Clustering Analysis

HCA could be used to identify elements with “similar” behavior.

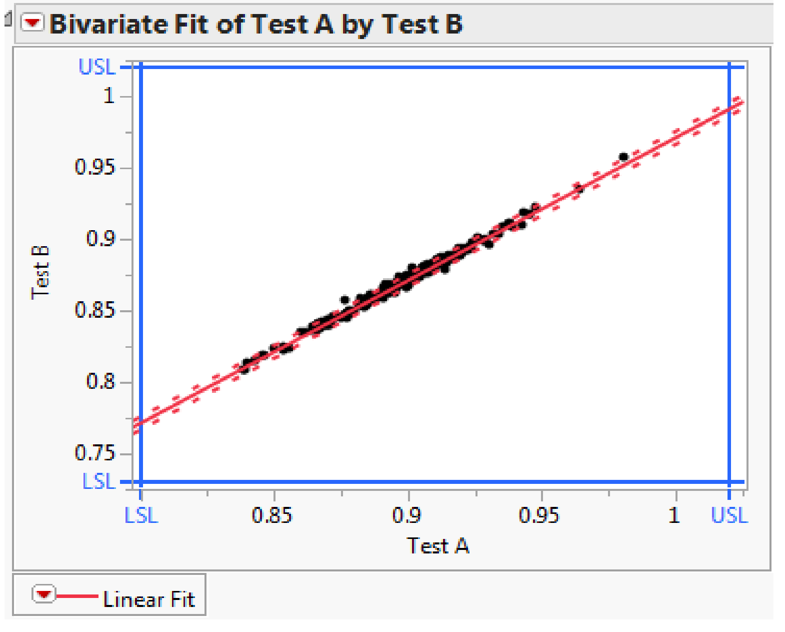
Benefits in:

- ➔ reliability analysis
- ➔ yield improvement
- ➔ Process flow improvement



Statistical Regression

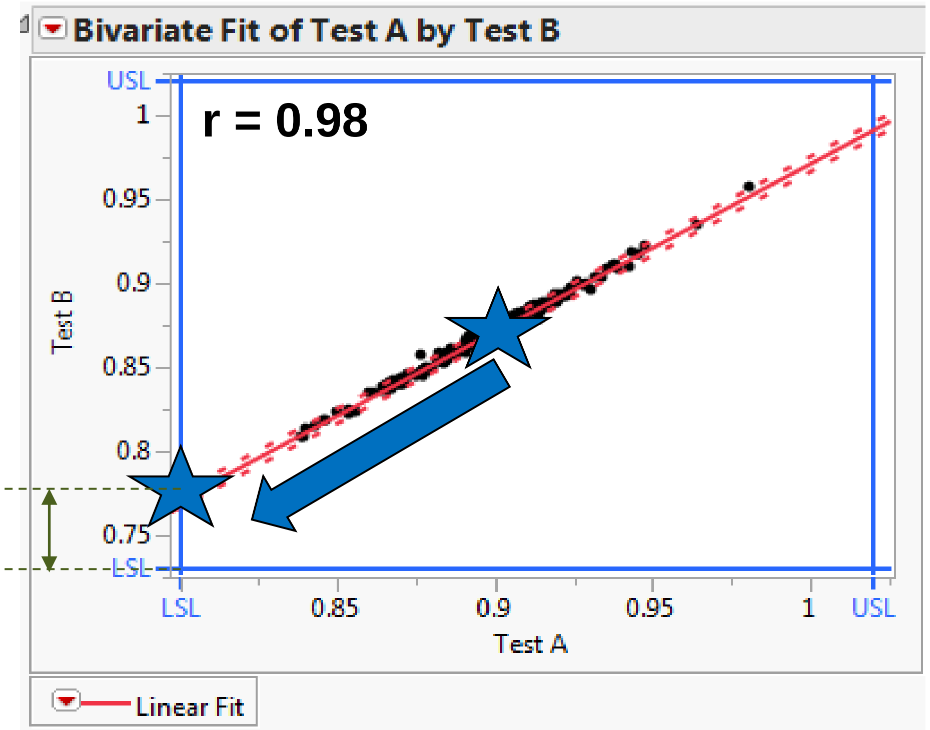
Statistical Regression is used to explain Y parameter by X parameter and to predict electrical tests that could be removed

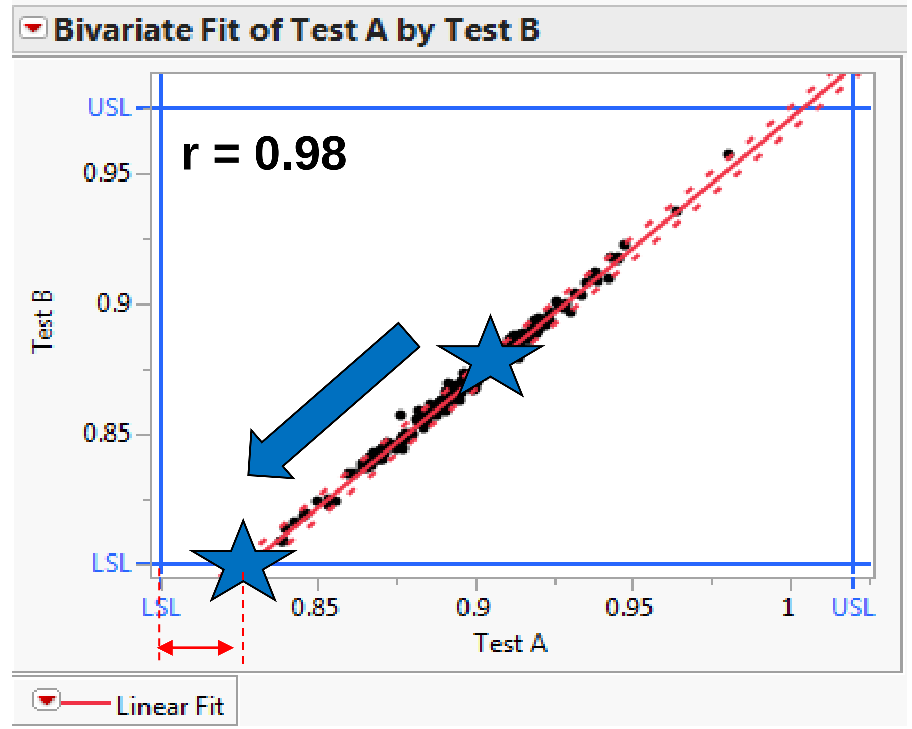


The correlation between both tests is very good: r = 0.98

Conclusion:
We could predict with a **confidence level at 95%** test B by measuring only test A

Good correlation is not enough for Test Time Reduction !



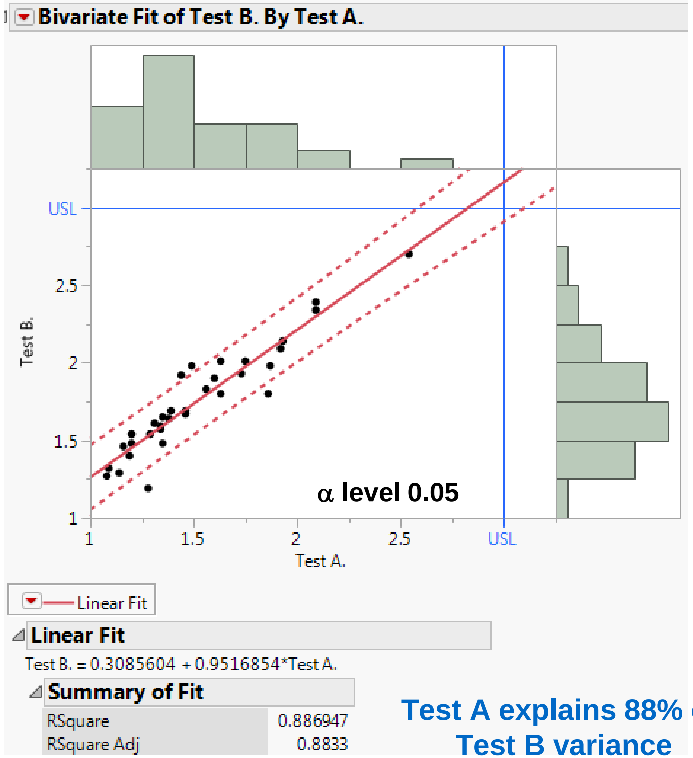


More constraints on test A
➔ Test B could be removed

More constraints on test B
➔ Test B could not be removed

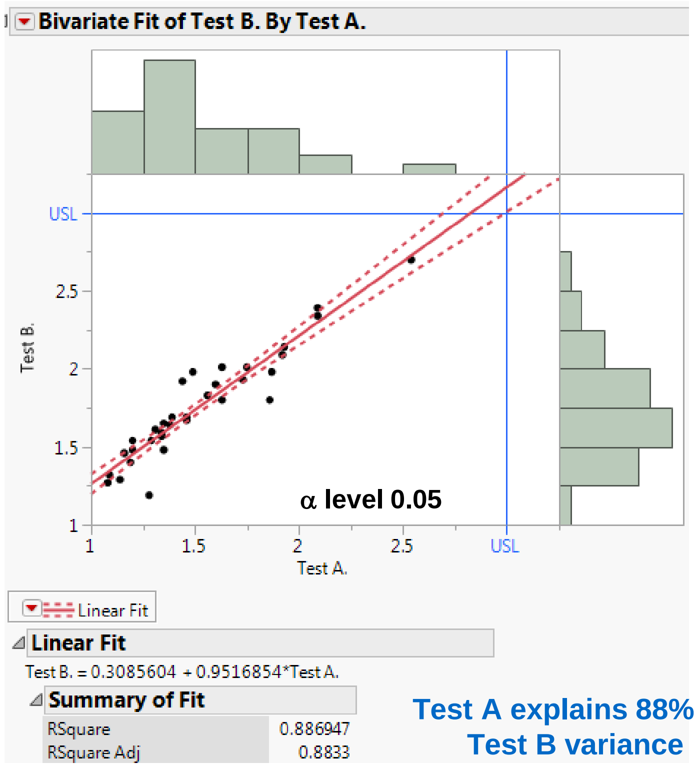
Choice of confidence curve and α level

➔ "Confidence curve Indiv" option displays the confidence limits for each individual predicted values.



Test A explains 88% of Test B variance

➔ "Confidence curve Fit" option displays the confidence limits for the expected value (mean).



Test A explains 88% of Test B variance

The choice of the "confidence curve" and α level depends on your application and quality constraints

Take away

- **Gage R&R data collection's impact could be reduced by using a D-Optimal Design : Data collection reduced by 33% on our program.**
- **Principal Components and clustering procedures combined with multivariate techniques are very useful tools for variable reduction.**
- **Statistical regression combined with confidence interval helps to predicts test behaviors, identify good correlations and reduce production test time with no impact on quality.**

Benefits on our program

→Test quantity reduced by 40%
→Test time reduced by 30%
→No impact on quality
→New business opportunity due to capacity increase

THANKS for your attention !

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Building trust every day