Implementing Lean Six Sigma Using Statgraphics

Neil W. Polhemus, CTO, StatPoint Technologies, Inc.

Web site: www.statgraphics.com

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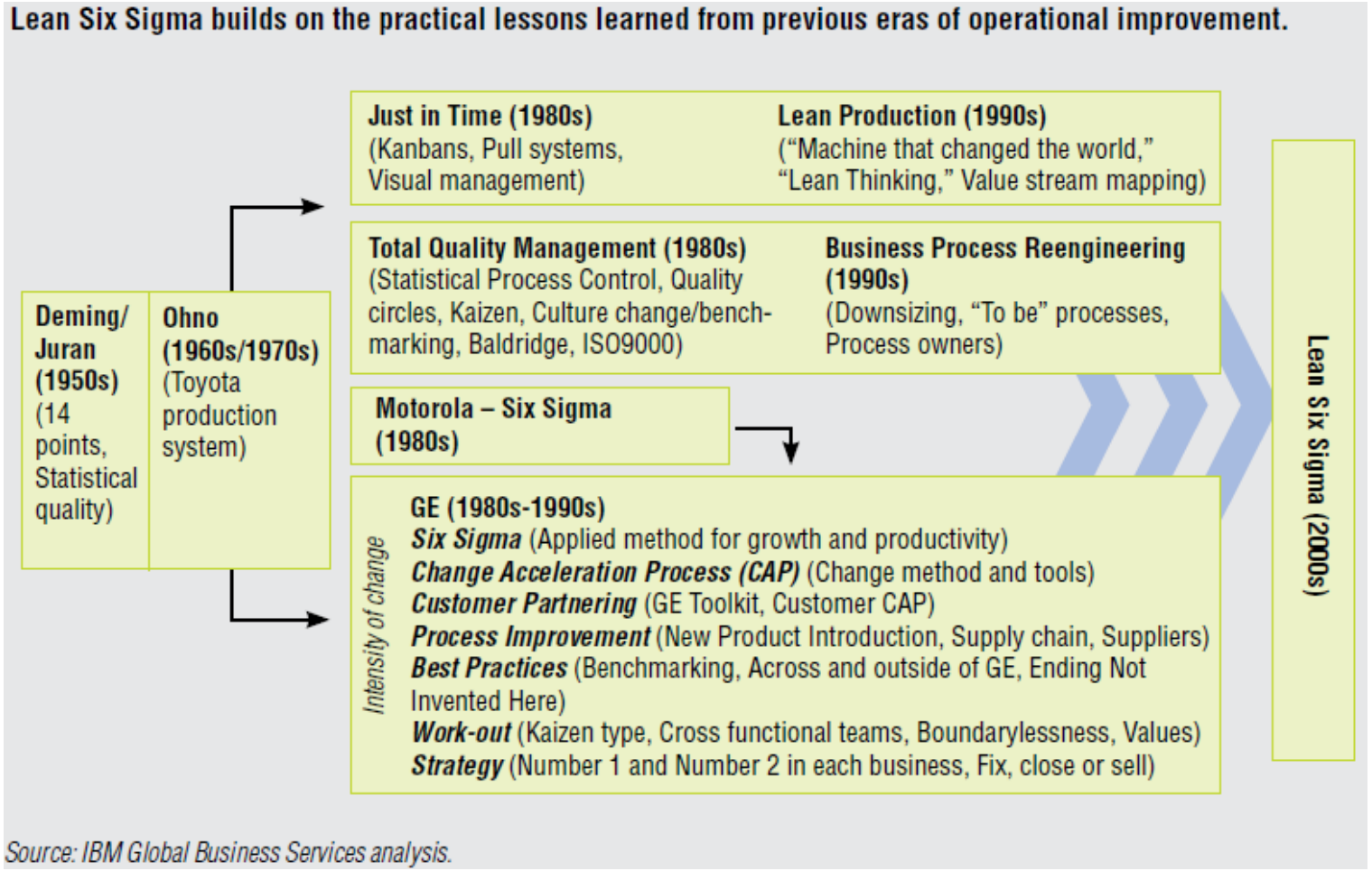
Lean Six Sigma



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Lean Six Sigma

- Lean manufacturing – focuses on reducing cost through process optimization.

- Six Sigma – focuses on meeting customer requirements and stakeholder expectations, and improving quality by measuring and eliminating defects.

www-935.ibm.com/services/uk/bcs/pdf
/driving_operational_innovation_using_lean_six_sigma.pdf

Statgraphics Software

- *Statgraphics Centurion XVI.I* – Windows standalone application with over 170 basic and advanced statistical methods.

- *Statgraphics Sigma Express 1.1* – Excel add-in with 70+ procedures covering the needs of Six Sigma green belts and most black belts. Available for Excel 2003, 2007, 2010.*

*Pre-release evaluation version available by sending contact information to info@statgraphics.com

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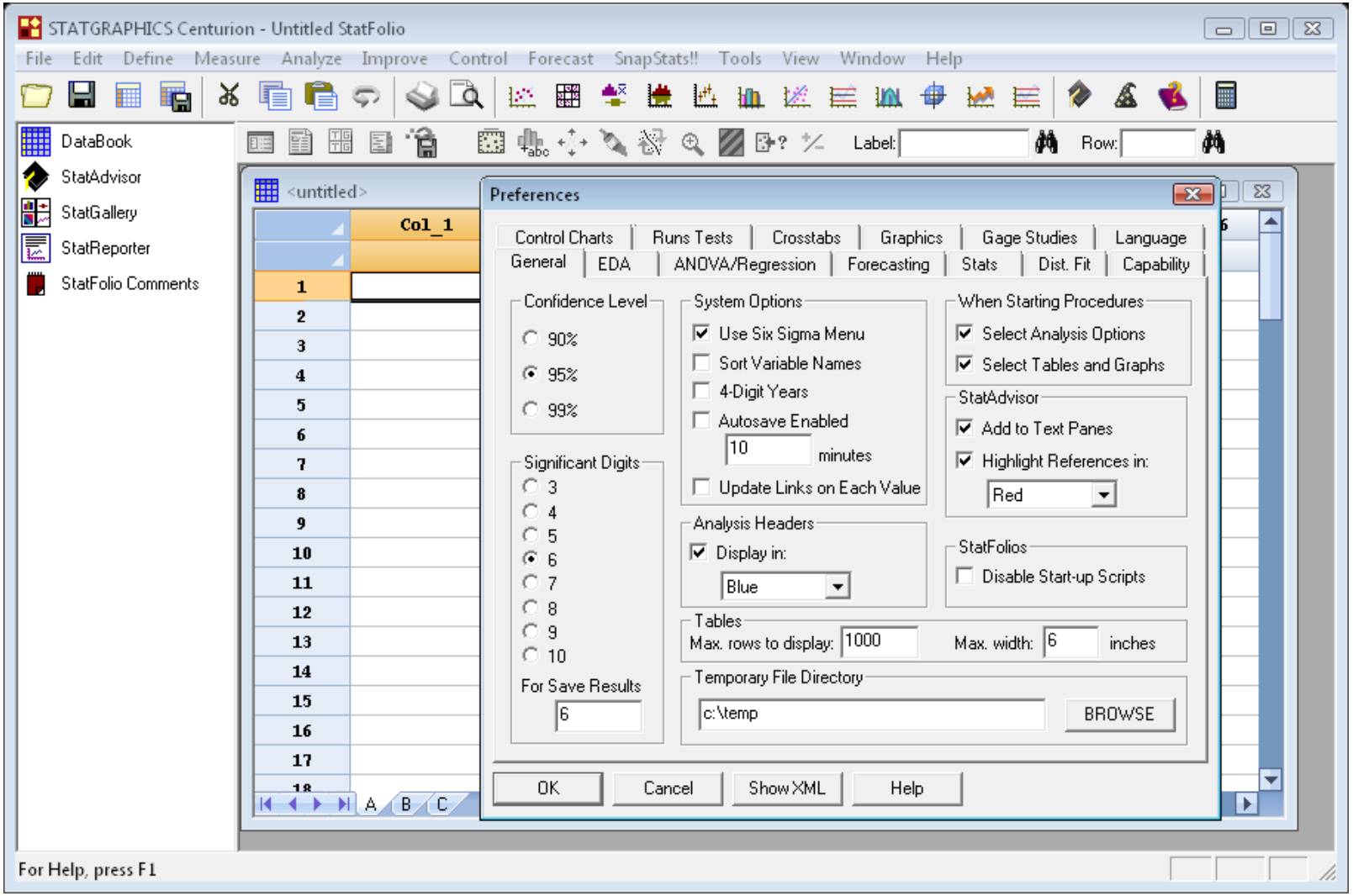
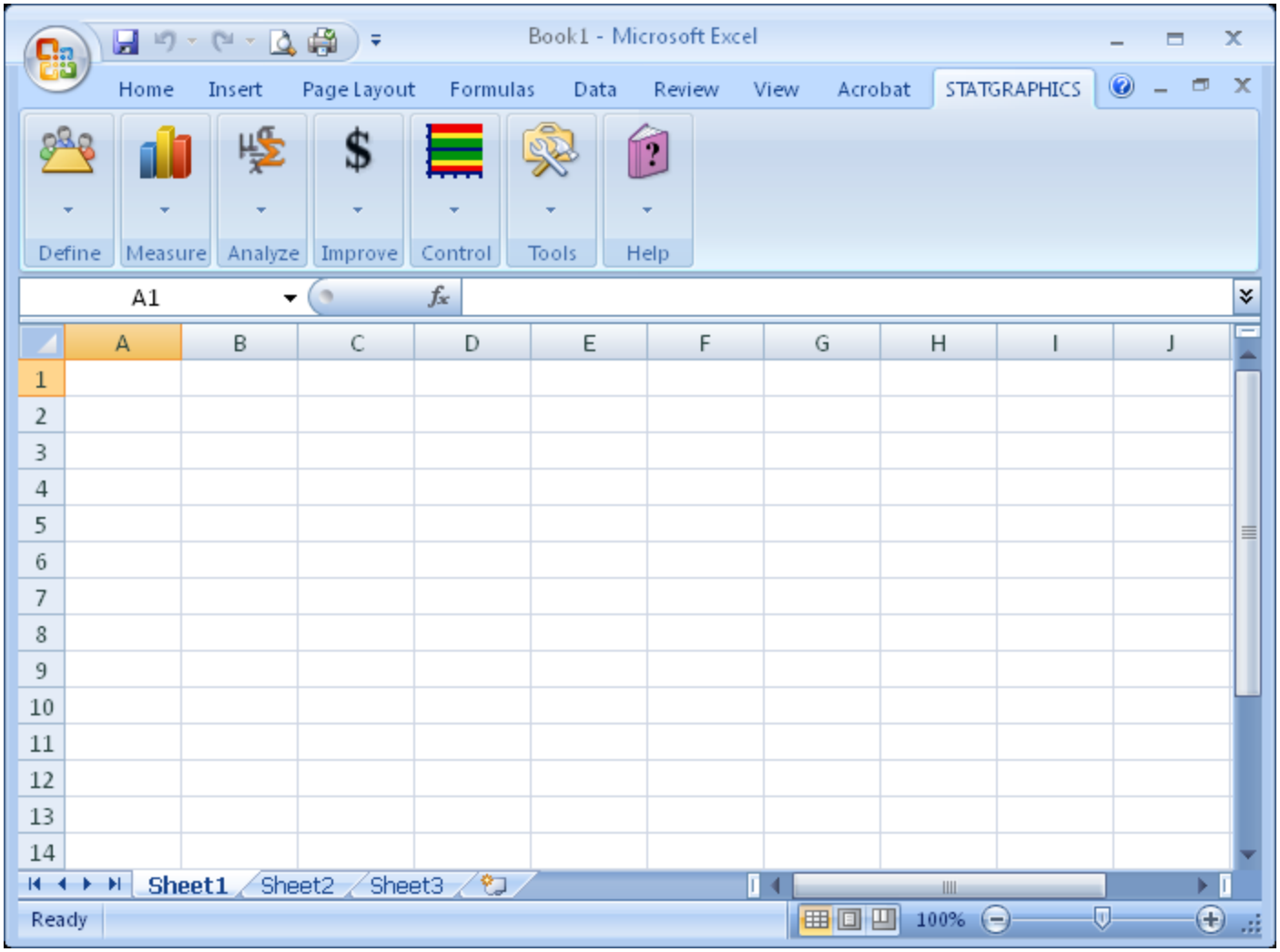
Statgraphics Centurion XVI.I



Statgraphics Sigma Express



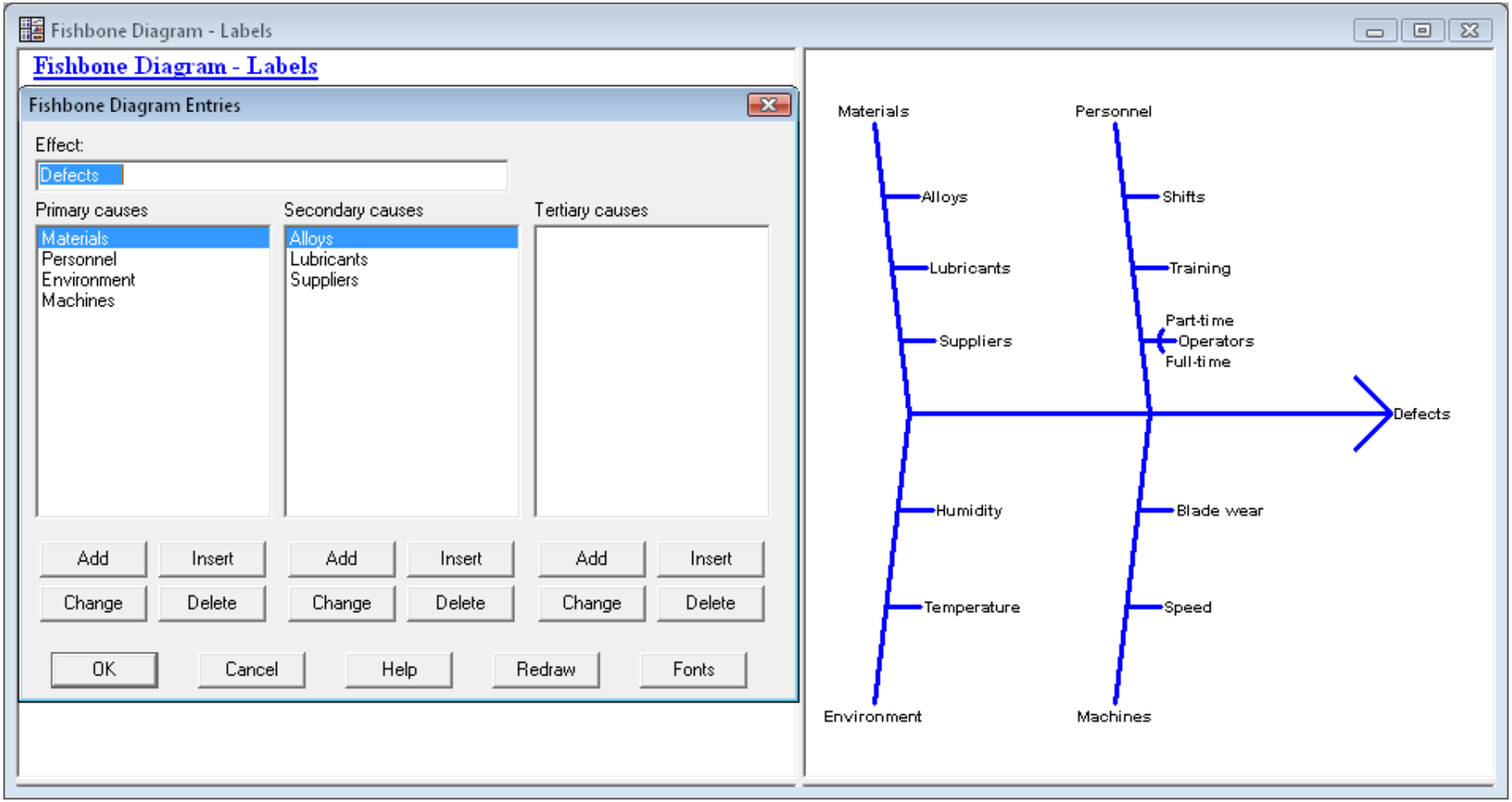
Example #1 (Define) – Cause-and-Effect Diagram

Cause-and-effect diagrams (also called fishbone or Ishikawa diagrams) illustrate the causes of specific events.

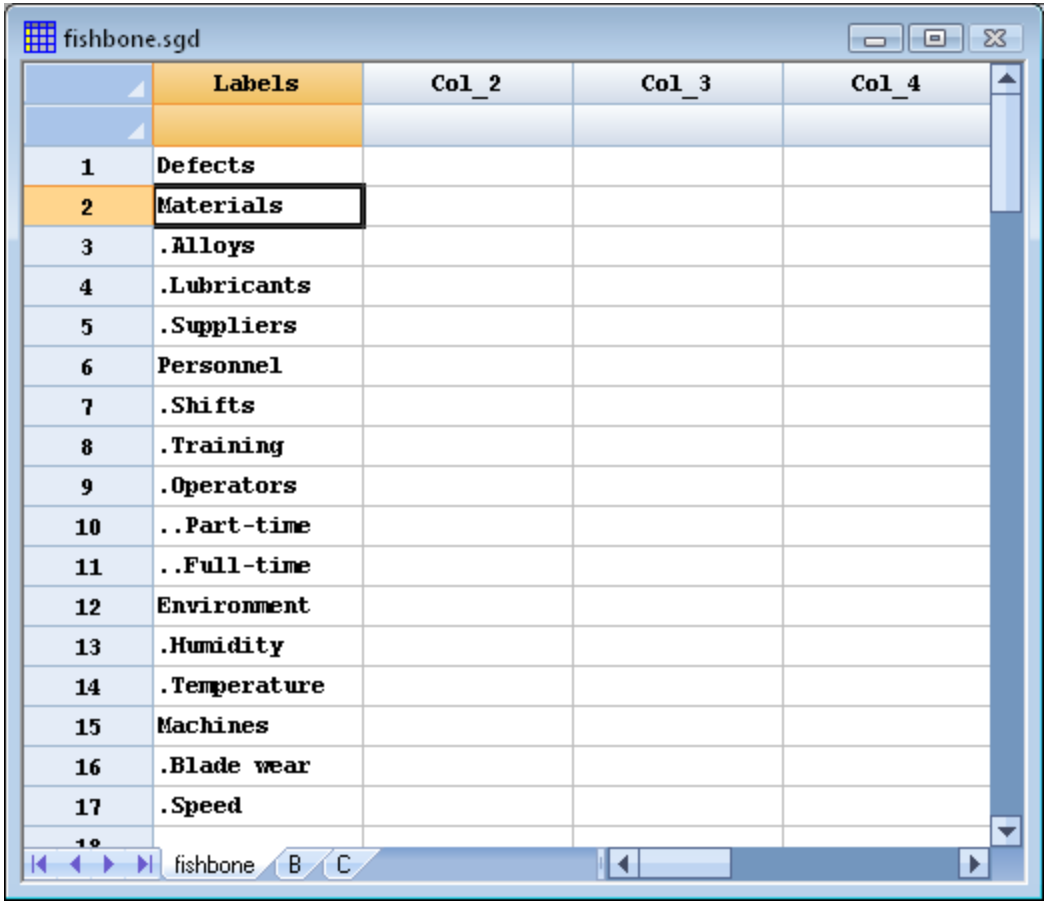
Event: defects

Major causes: material, personnel, environment, machines, …

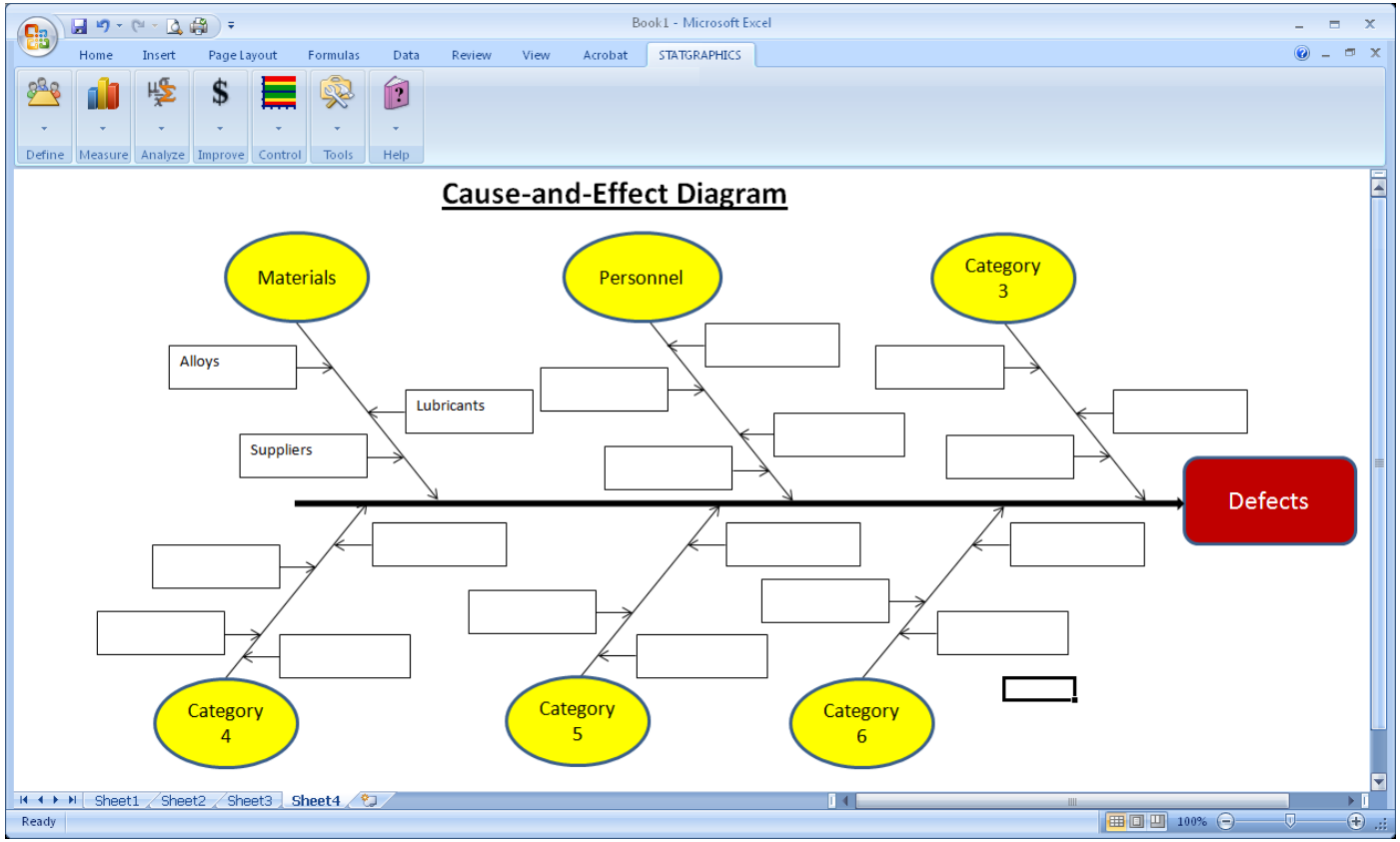
Input – Analysis Options dialog box creates diagram



Data structure for saving



Sigma Express also provides Excel template



Example #2 (Measure) – Gage Studies

"Gage Studies" refers to the process of evaluating measurement processes to verify that they are capable of measuring responses well enough to permit the use of SPC and DOE techniques.

In Statgraphics, the main procedures all follow the AIAG guidelines:

- *Gage Study Setup* – to create a data template.

- Analysis of Variable Data
  1. *Average and Range Method* and *ANOVA Method* evaluate R&R based on full study.
  2. *Range Method* evaluates R&R based on short study.
  3. **Gage Linearity and Accuracy* evaluates bias.

- Analysis of Attribute Data
  1. **Risk Assessment Method* – based on consistency of appraisals
  2. **Analytic Method* and **Signal Theory Method* – other approaches

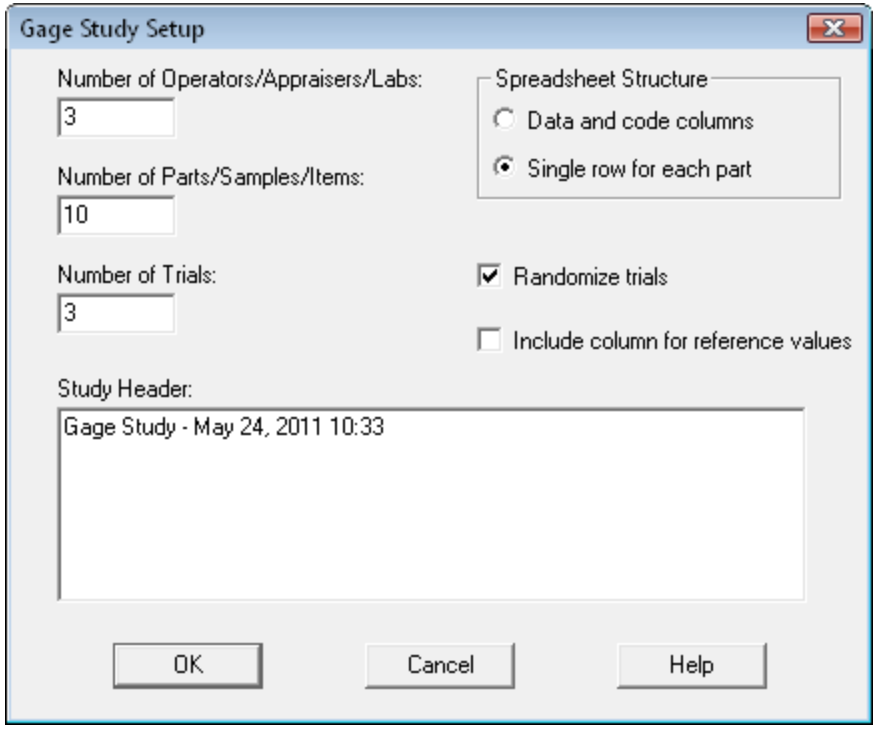
* Not in *Sigma Express* product.

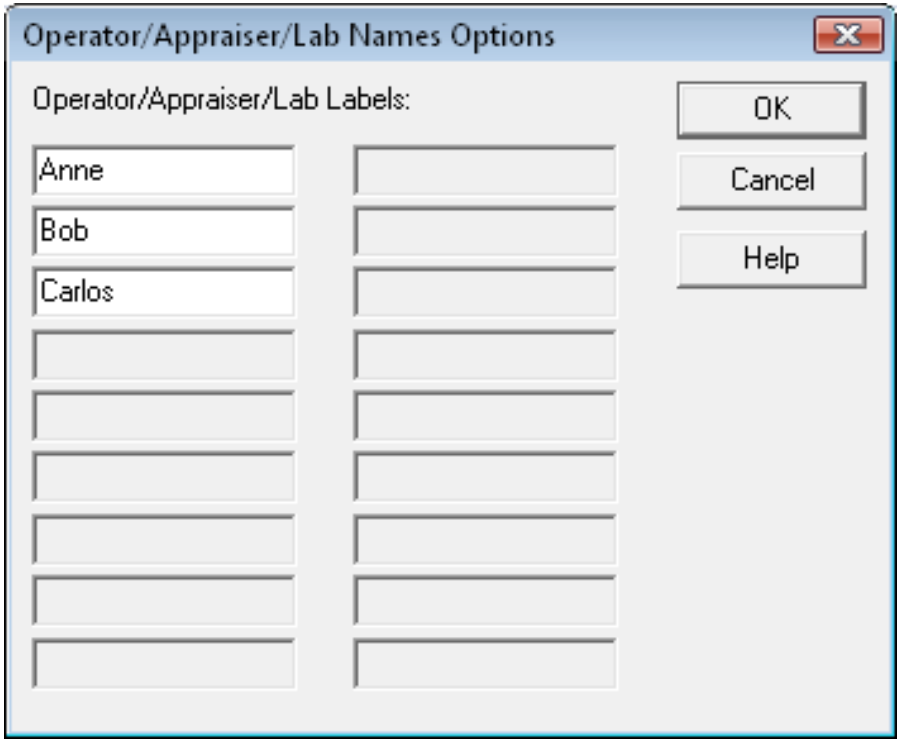
Statistical Model

$$\sigma_{total} = \sqrt{\sigma^2_{product} + \sigma^2_{measurement.process}}$$

$$\sigma_{measurement.process} = \sqrt{\sigma^2_{repeatability} + \sigma^2_{reproducibility}}$$

Gage study setup





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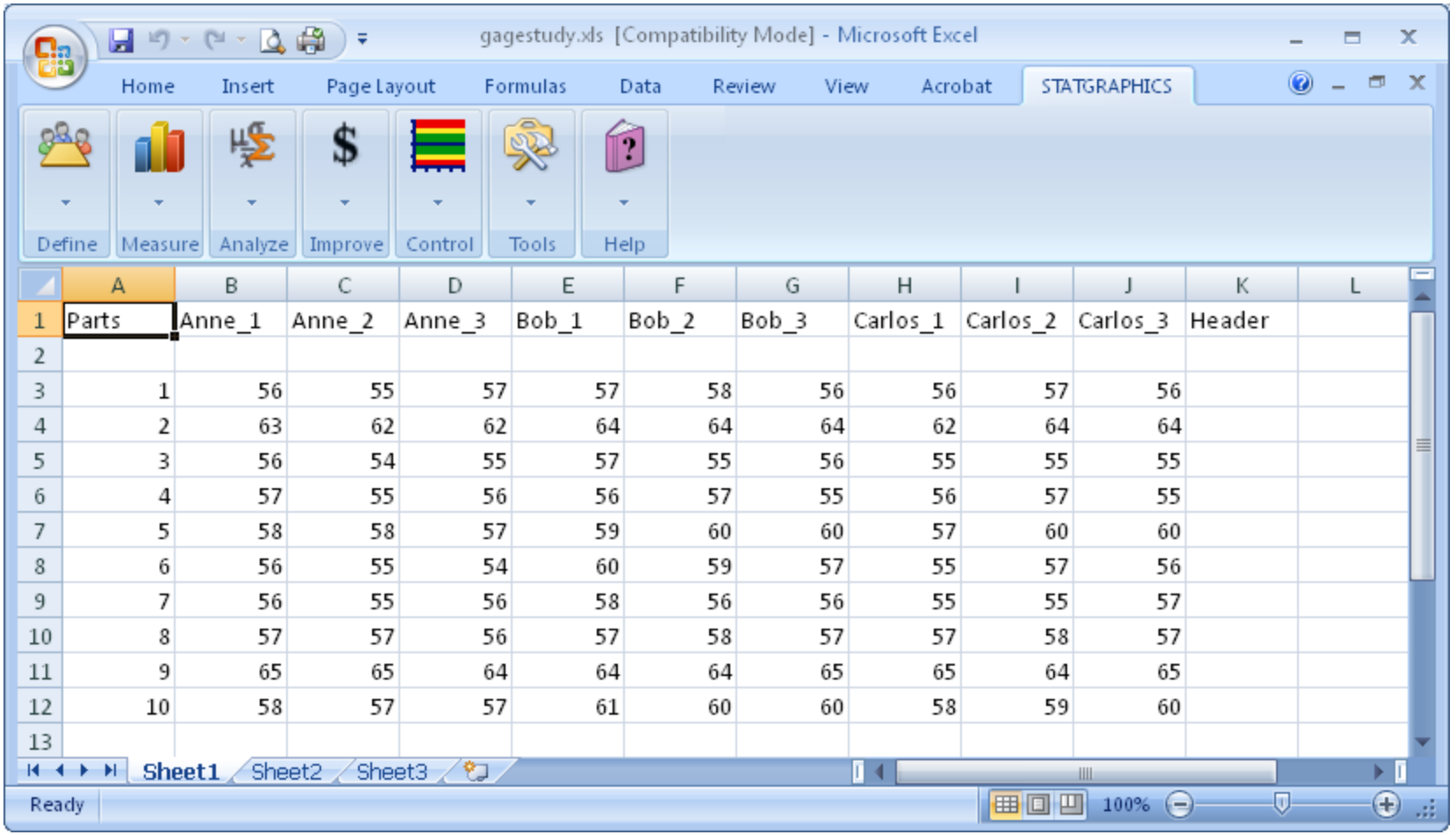
Typical gage study data file



	A	B	C	D	E	F	G	H	I	J	K	L
1	Parts	Anne_1	Anne_2	Anne_3	Bob_1	Bob_2	Bob_3	Carlos_1	Carlos_2	Carlos_3	Header	
2												
3	1	56	55	57	57	58	56	56	57	56		
4	2	63	62	62	64	64	64	62	64	64		
5	3	56	54	55	57	55	56	55	55	55		
6	4	57	55	56	56	57	55	56	57	55		
7	5	58	58	57	59	60	60	57	60	60		
8	6	56	55	54	60	59	57	55	57	56		
9	7	56	55	56	58	56	56	55	55	57		
10	8	57	57	56	57	58	57	57	58	57		
11	9	65	65	64	64	64	65	65	64	65		
12	10	58	57	57	61	60	60	58	59	60		
13												

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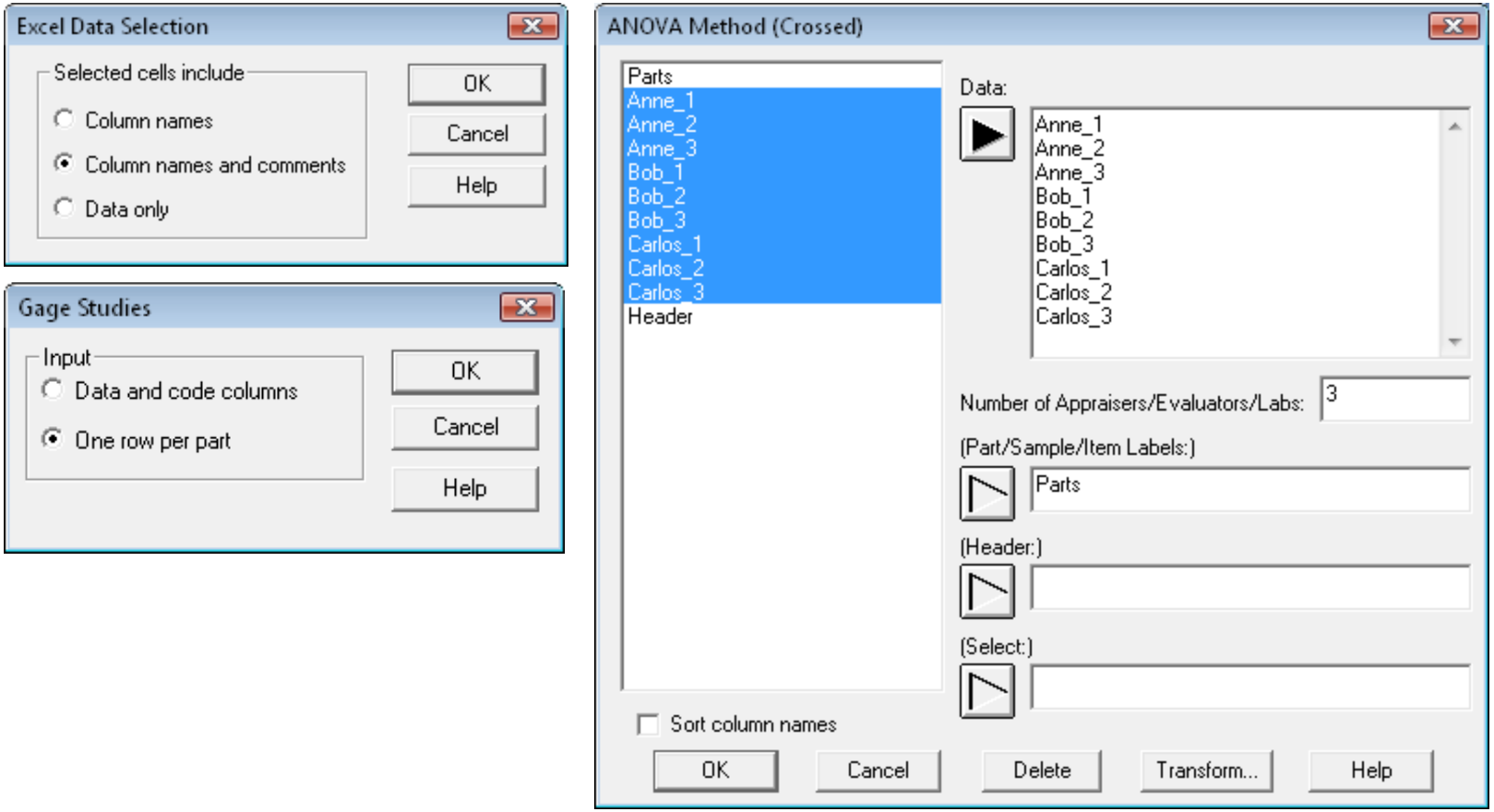
Data input dialog box



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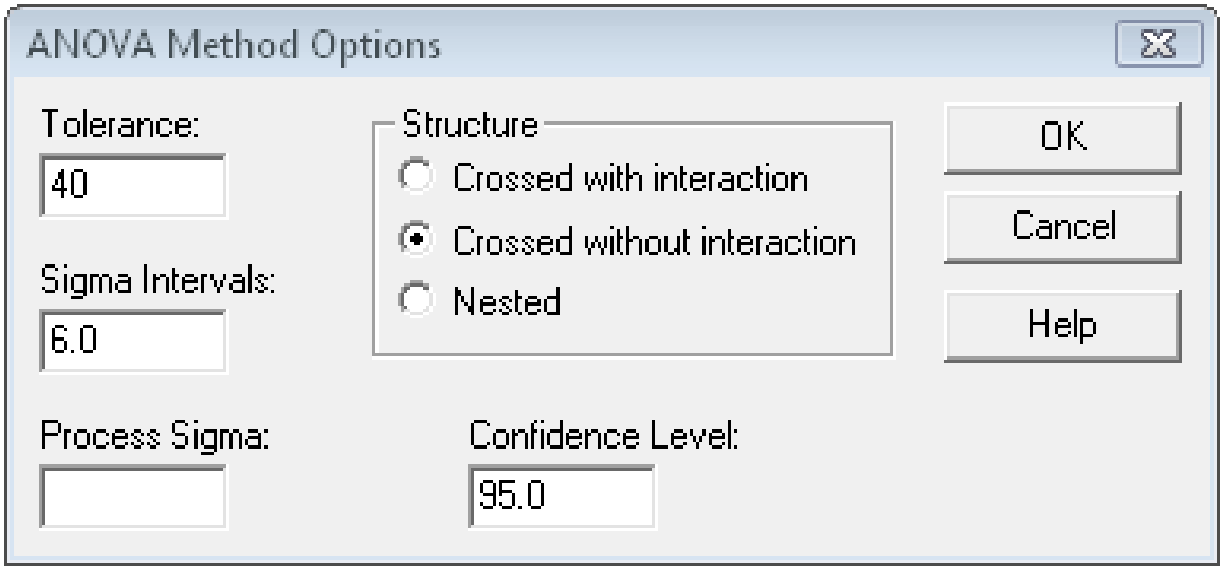
Analysis Options



Tolerance = USL – LSL (distance between specification limits)

If operators measure the same parts, the structure is “crossed”.

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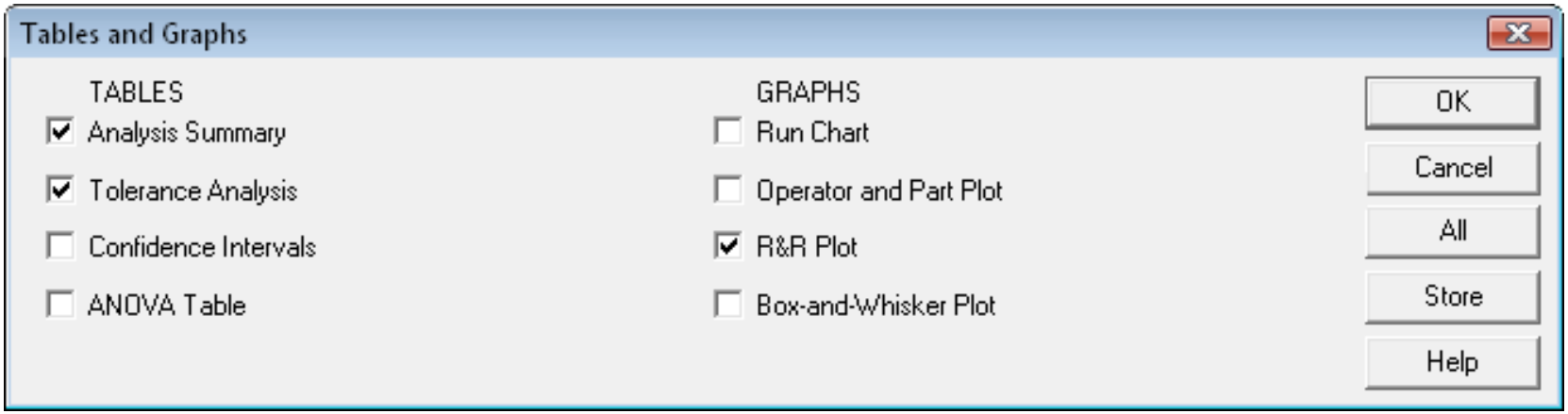
Tables and Graphs



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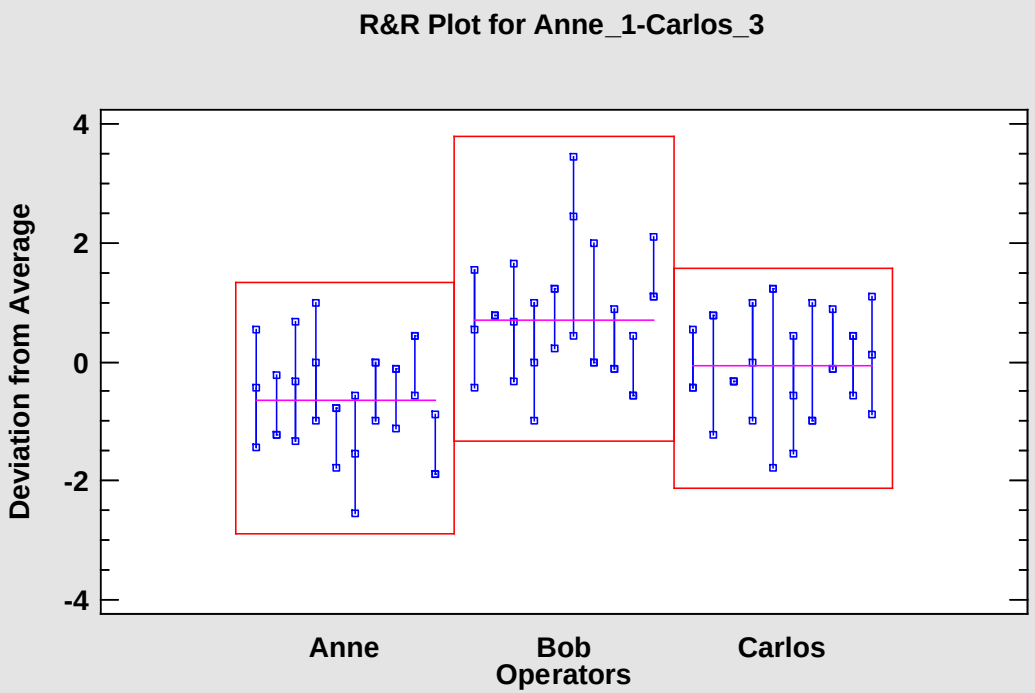
R&R Plot



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R&R Table

Gage Repeatability and Reproducibility Report

Measurement Unit	*Estimated Sigma*	*Percent Total Variation*	*Estimated Variance*	*Percent Contribution*	*Percent of R&R*
Repeatability	0.956757	28.3524	0.915385	8.03857	67.60
Reproducibility	0.662379	19.6288	0.438746	3.85291	32.40
R & R	1.16367	34.484	1.35413	11.8915	100.00
Parts	3.16753	93.8661	10.0333	88.1085	
Total Variation	3.37452	100.0	11.3874		

Number of distinct categories (ndc): 3

Tolerance Analysis

Tolerance Analysis
3 operators 10 parts 3 trials

Tolerance = 40.0

Measurement Unit	*6.0 Std. Dev.*	*Percent of Tolerance*
Repeatability	5.74054	14.3514
Reproducibility	3.97428	9.93569
R & R	6.98203	17.4551
parts	19.0052	47.513

Precision-to-tolerance ratio:

$$100\frac{6\hat{\sigma}_{measurement.process}}{tolerance}\%$$

Example #3 (Analyze) – Capability Analysis

Determines whether a process is “capable” of meeting established specification limits.

DPMO – Defects Per Million Opportunities.

$$DPMO = \frac{1,000,000 \times \text{number of defects}}{\text{number of units} \times \text{number of opportunities per unit}}$$

“Defect” = nonconformance to a specification.

Typical Data

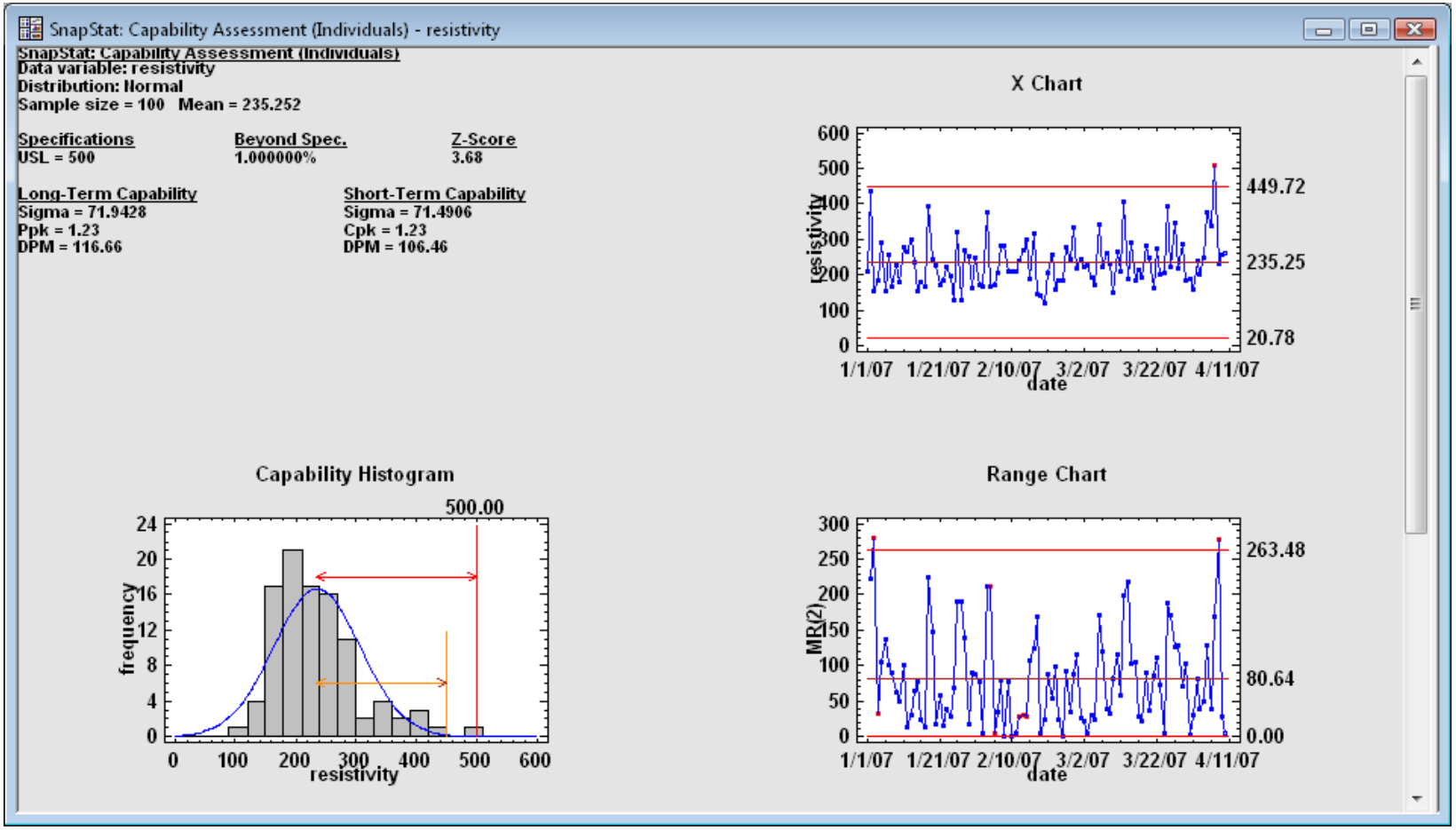
Measured resistivity of n = 100 electronic components. USL = 500.

C:\Webinar\resistivity.sgd

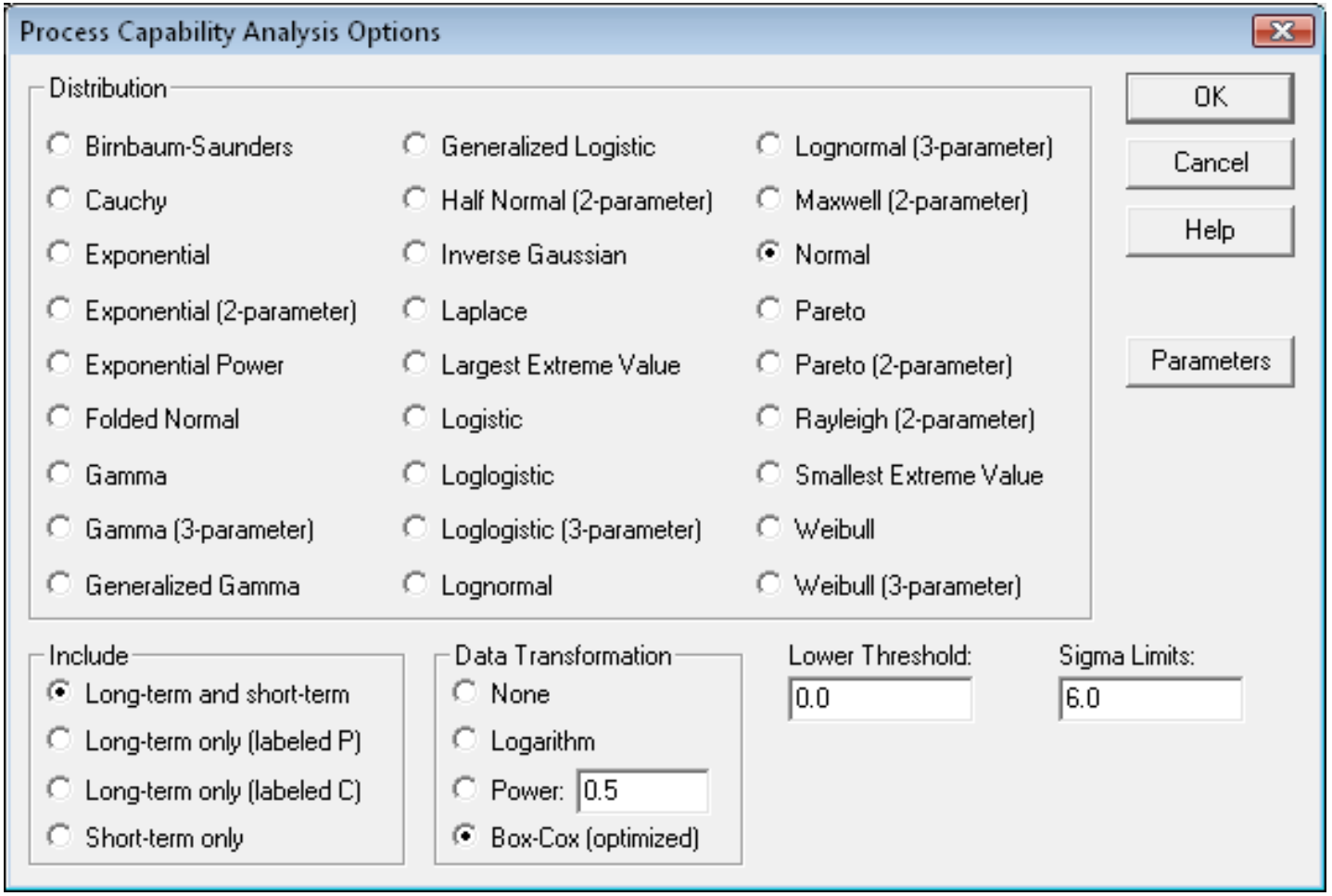
	resistivity	date	Col_3	Col_4	Col_5
1	211.2	1/1/07			
2	435.0	1/2/07			
3	154.9	1/3/07			
4	186.8	1/4/07			
5	292.3	1/5/07			
6	155.4	1/6/07			
7	255.7	1/7/07			
8	165.8	1/8/07			
9	227.9	1/9/07			
10	178.8	1/10/07			
11	279.8	1/11/07			
12	267.5	1/12/07			
13	297.4	1/13/07			
14	233.7	1/14/07			
15	156.7	1/15/07			

resistivity B C

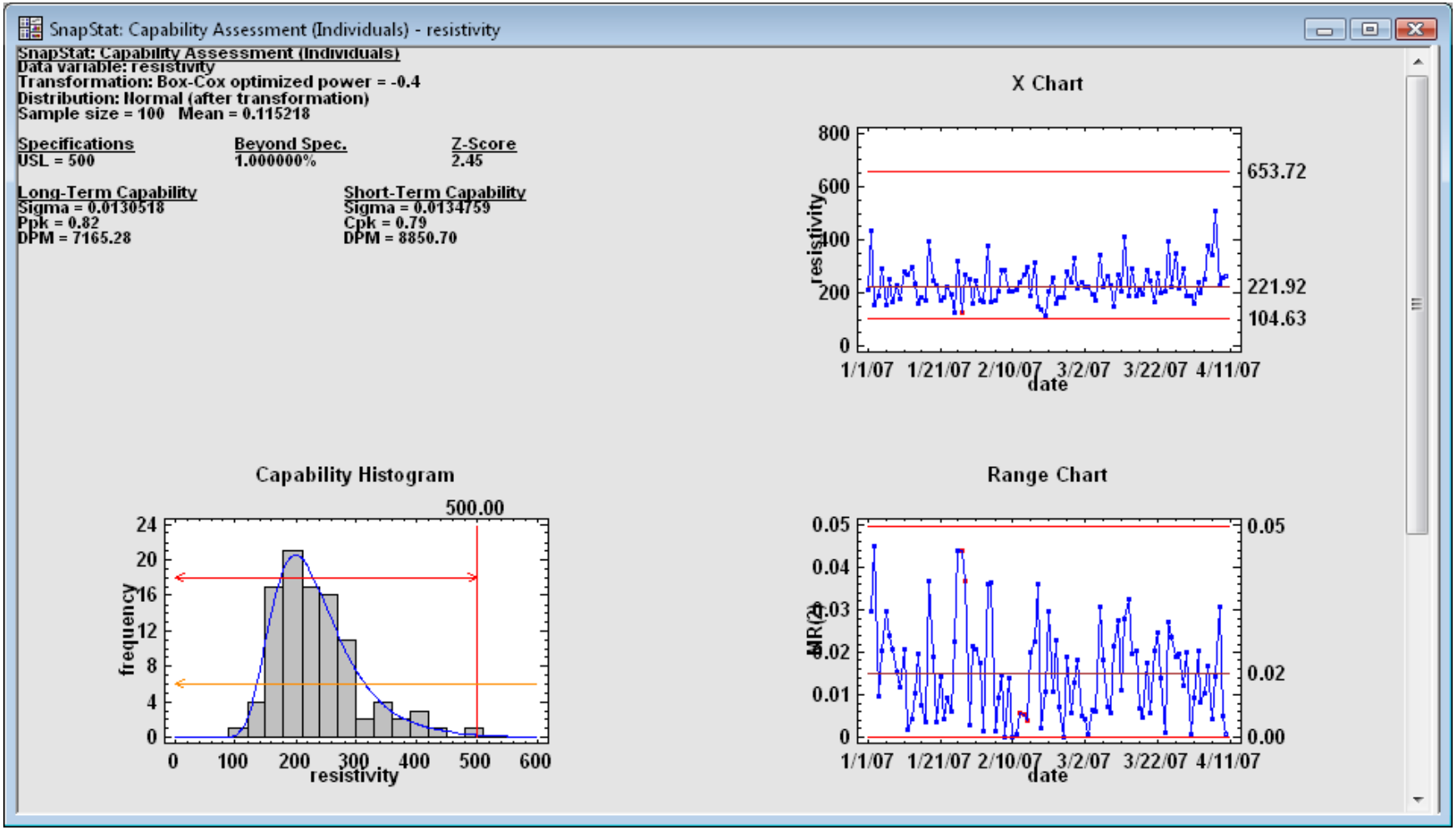
Capability Assessment SnapStat



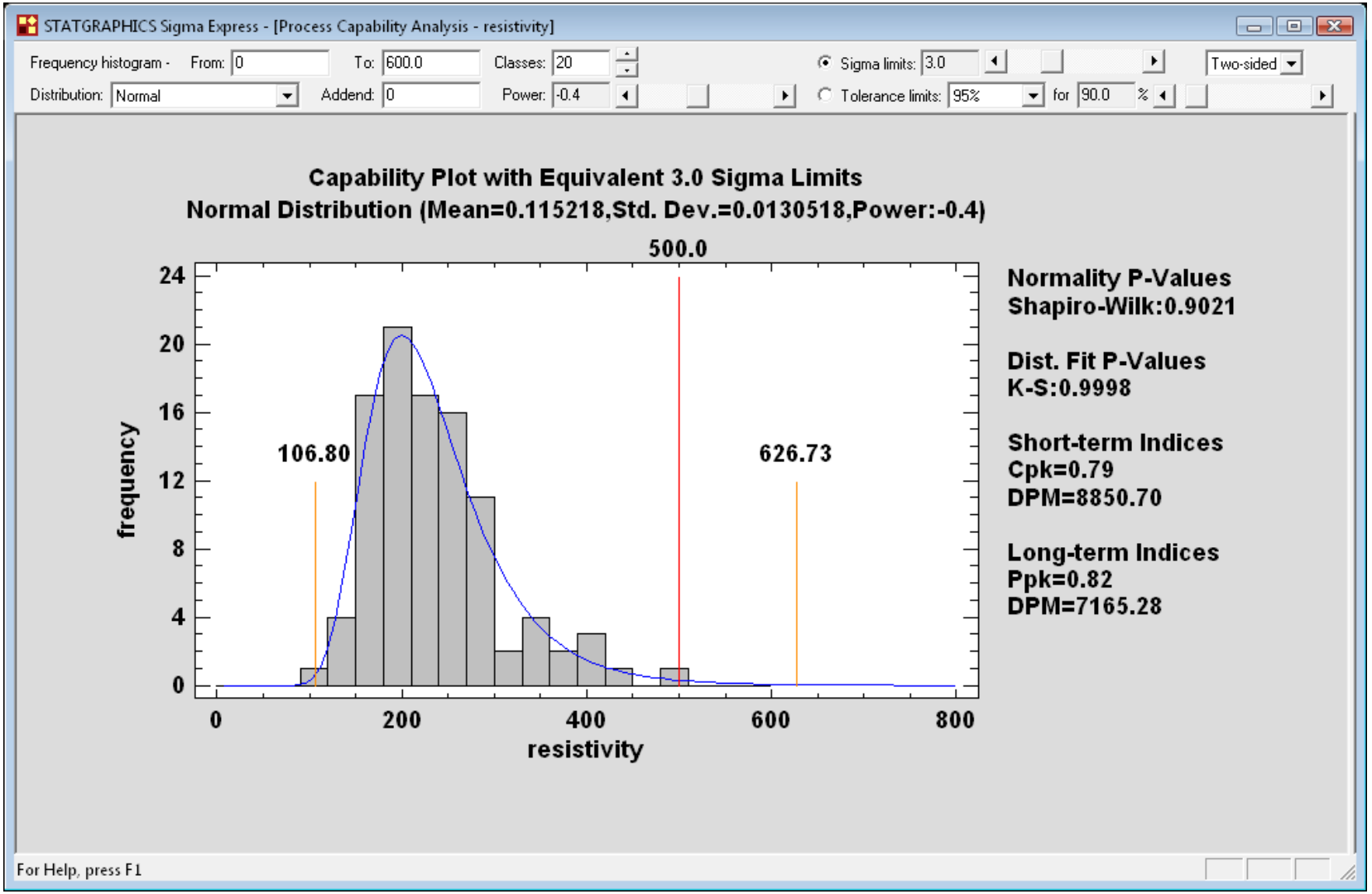
Analysis Options



After Box-Cox Transformation

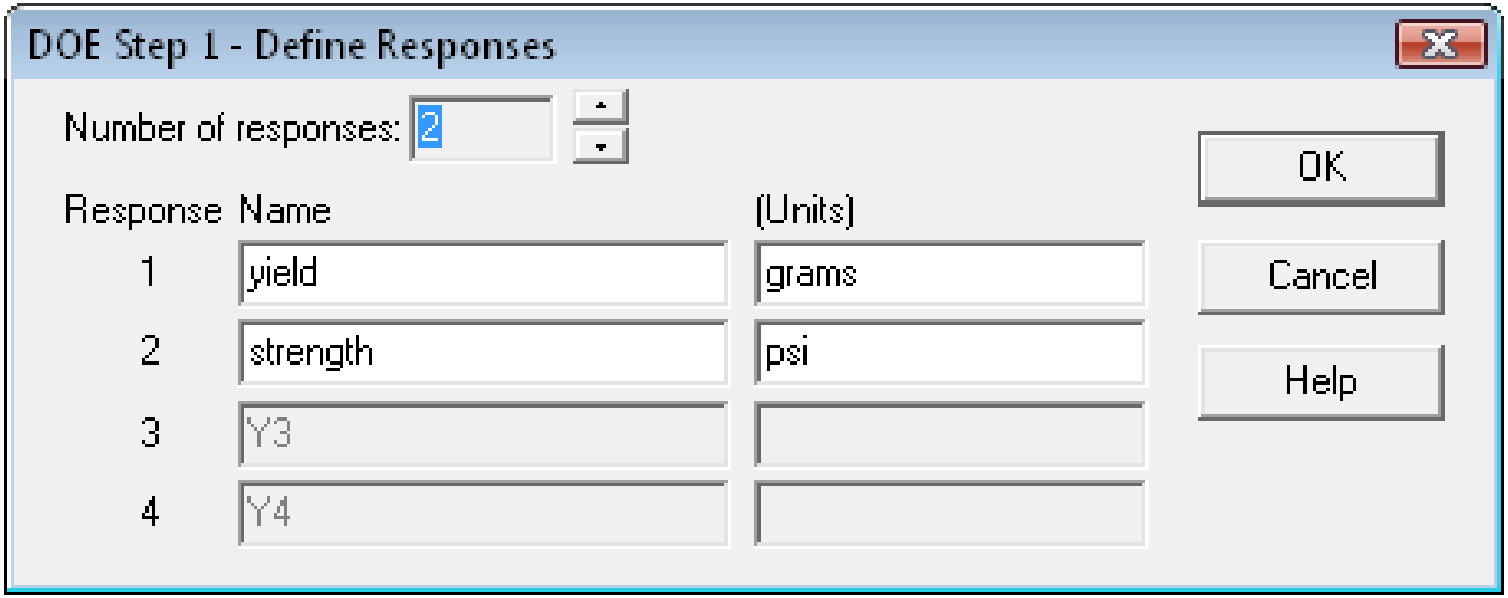


Capability Analysis Statlet®

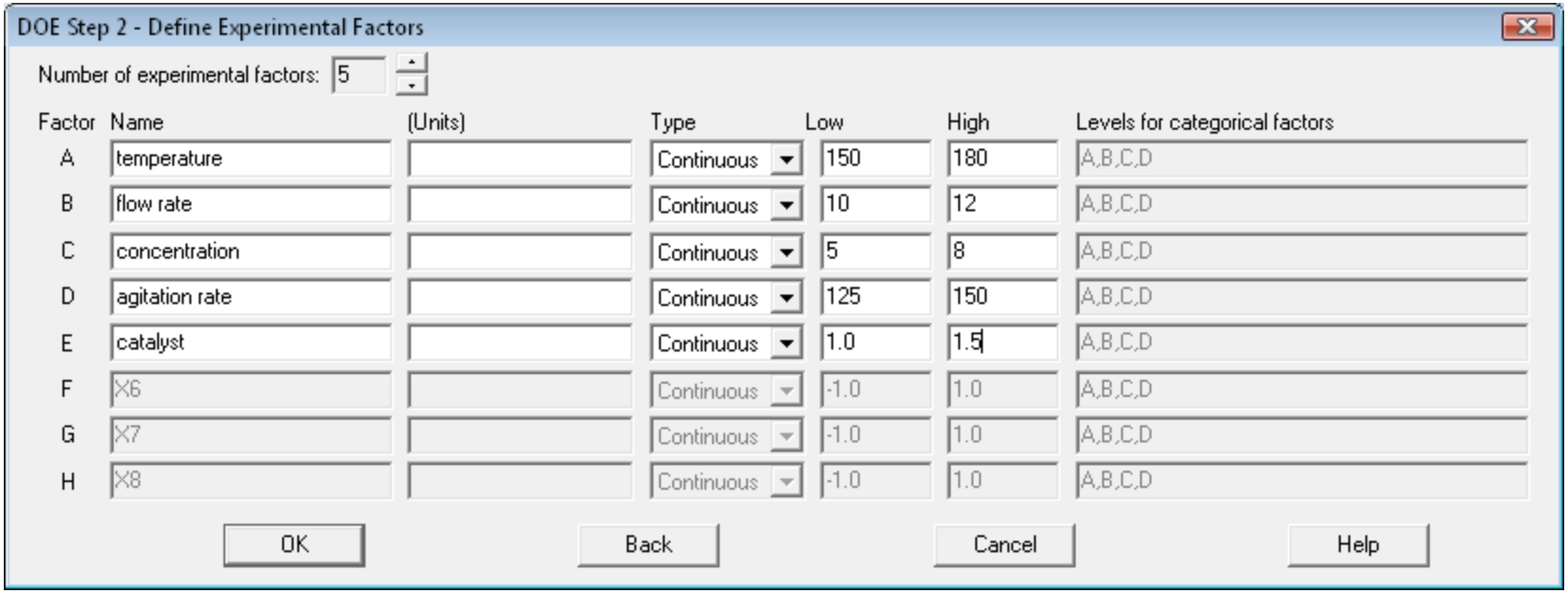


Example #4 (Improve) – DOE

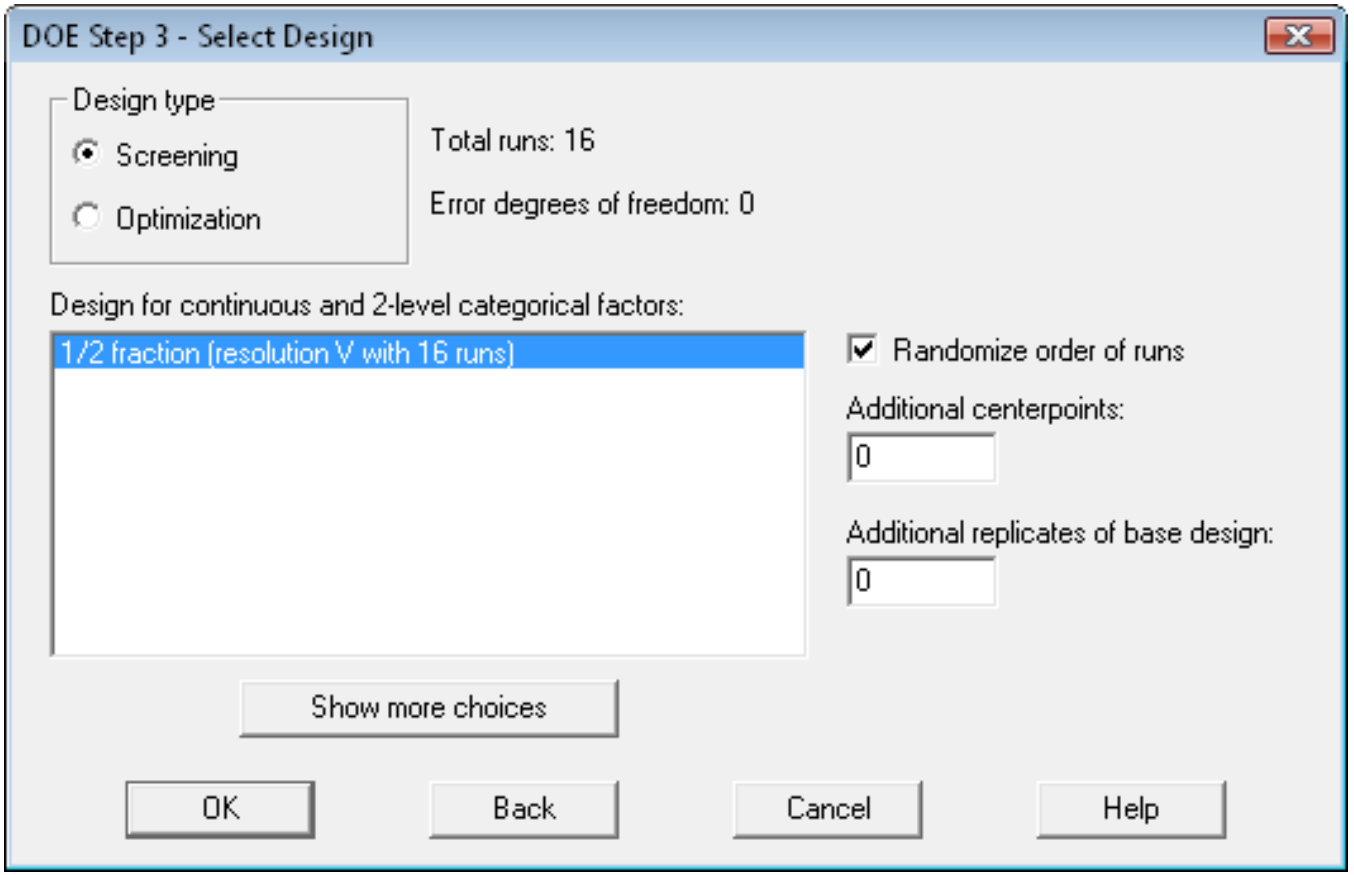
Step 1: Define Responses



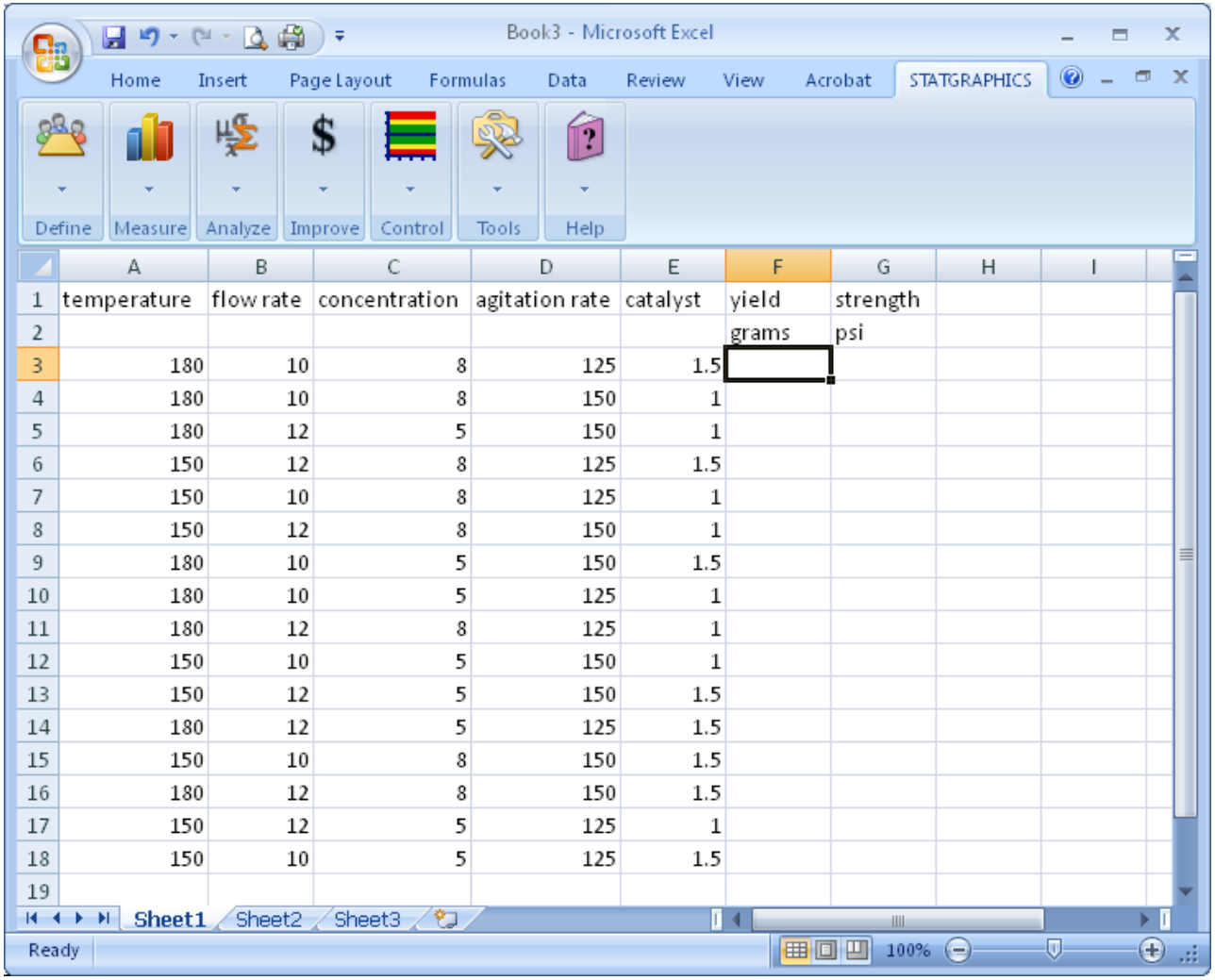
Step 2 – Define Experimental Factors



Step 3 – Select Design

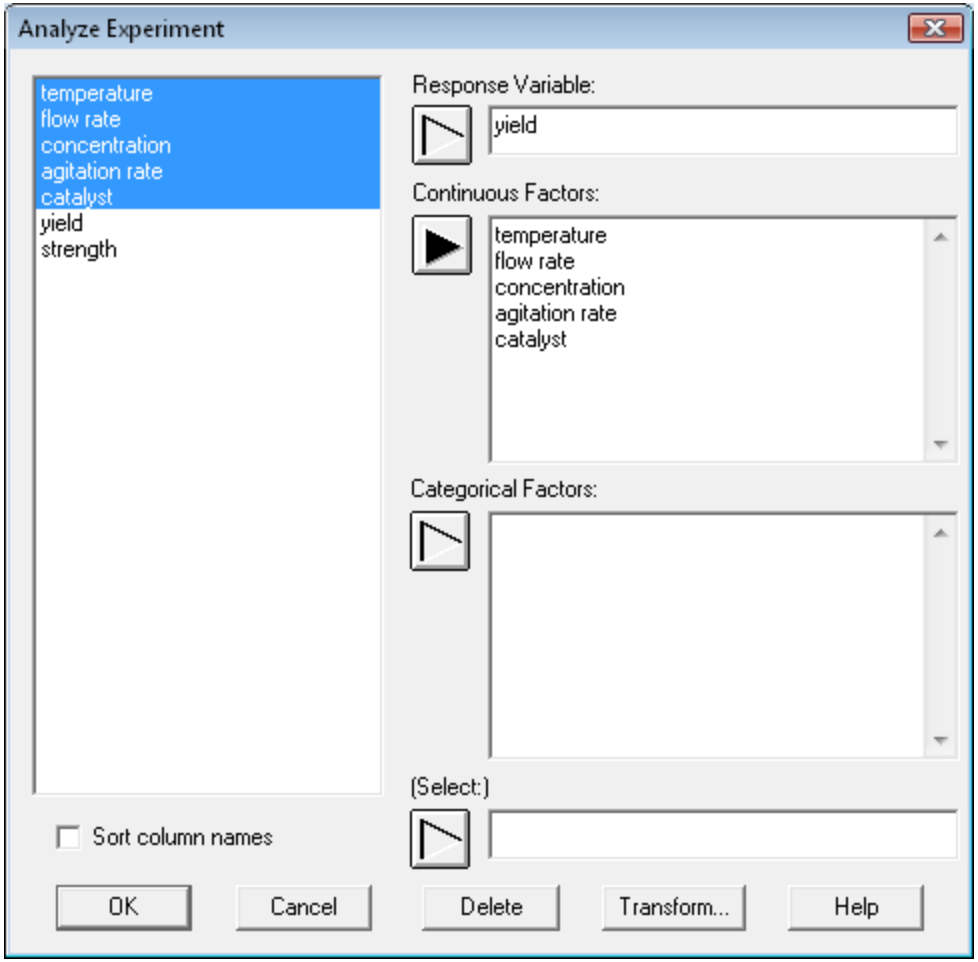


Step 4 – Paste to Excel Worksheet

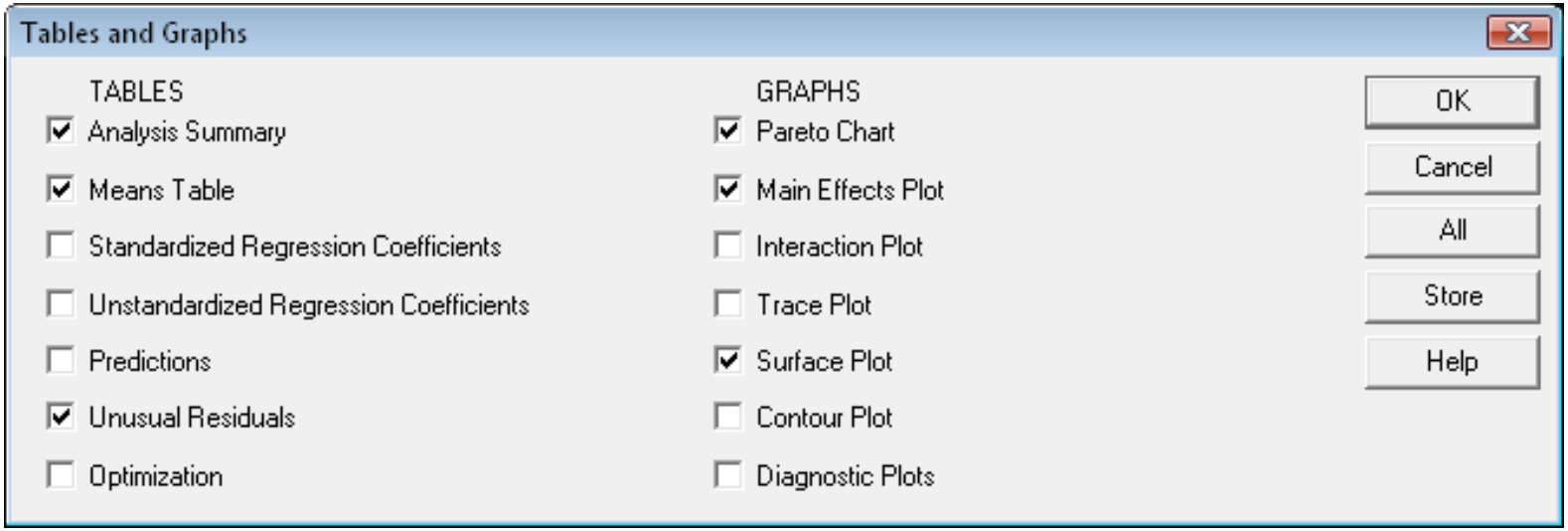


	A	B	C	D	E	F	G	H	I
1	temperature	flow rate	concentration	agitation rate	catalyst	yield	strength		
2						grams	psi		
3	180	10	8	125	1.5				
4	180	10	8	150	1				
5	180	12	5	150	1				
6	150	12	8	125	1.5				
7	150	10	8	125	1				
8	150	12	8	150	1				
9	180	10	5	150	1.5				
10	180	10	5	125	1				
11	180	12	8	125	1				
12	150	10	5	150	1				
13	150	12	5	150	1.5				
14	180	12	5	125	1.5				
15	150	10	8	150	1.5				
16	180	12	8	150	1.5				
17	150	12	5	125	1				
18	150	10	5	125	1.5				
19									

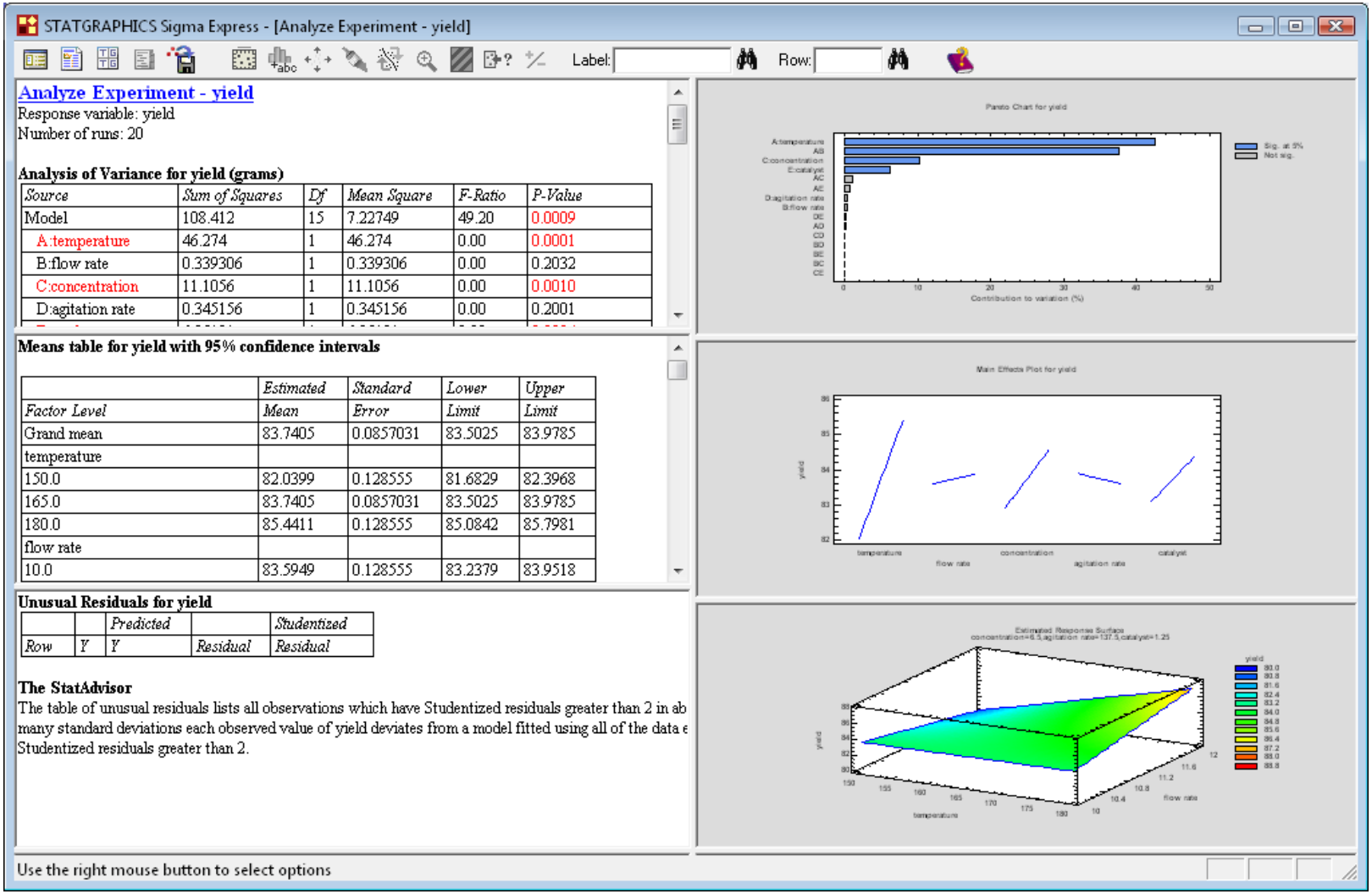
Analyze Experiment



Tables and Graphs



Analysis Window



Paste Back to Excel

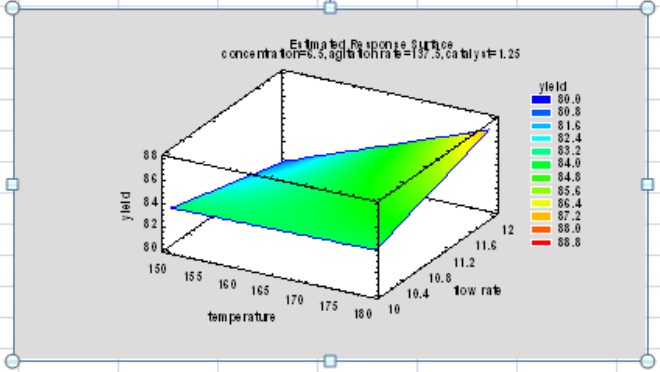
experiment.xls - Microsoft Excel

Picture Tools

Home | Insert | Page Layout | Formulas | Data | Review | View | Acrobat | STATGRAPHICS | Format

Define | Measure | Analyze | Improve | Control | Tools | Help

	A	B	C	D	E	F	G
1	temperature	flow rate	concentration	agitation rate	catalyst	yield	strength
2	degrees C	liters/min	%	rpm	%	grams	psi
3	150	10	8	125	1	83.54	198
4	150	12	5	150	1.5	81.1	272
5	180	12	8	125	1	88.1	227
6	180	10	5	150	1.5	82.84	305
7	150	12	8	125	1.5	82.04	196
8	180	12	5	150	1	85.45	300
9	165	11	6.5	137.5	1.25	84.12	251
10	150	10	5	150	1	81.9	274
11	165	11	6.5	137.5	1.25	83.3	249
12	180	10	8	125	1.5	85.45	228
13	150	12	8	150	1	79.98	271
14	180	12	5	125	1.5	86.58	228
15	150	10	5	125	1.5	83.65	198
16	150	12	5	125	1	79.26	195
17	165	11	6.5	137.5	1.25	84.05	248
18	180	12	8	150	1.5	88.65	301
19	180	10	5	125	1	82.55	230
20	180	10	8	150	1	83.98	304
21	165	11	6.5	137.5	1.25	83.35	249
22	150	10	8	150	1.5	84.92	274
23							



Sheet1 | Sheet2 | Sheet3

Ready

100%

Example #5 (Control) – Individuals with EWMA

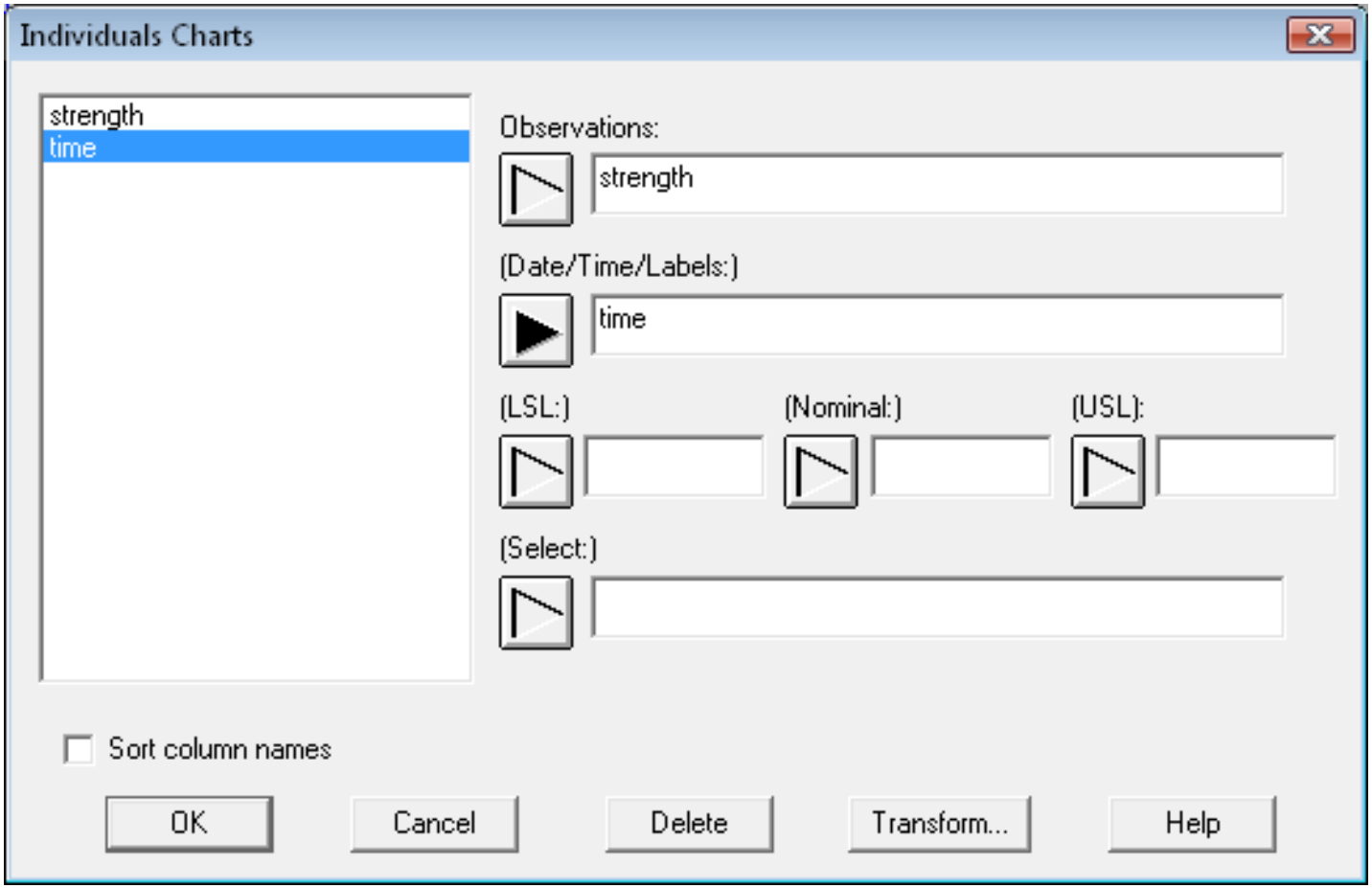
Suggested by Stu Hunter

C:\Webinar\bottles.sgd

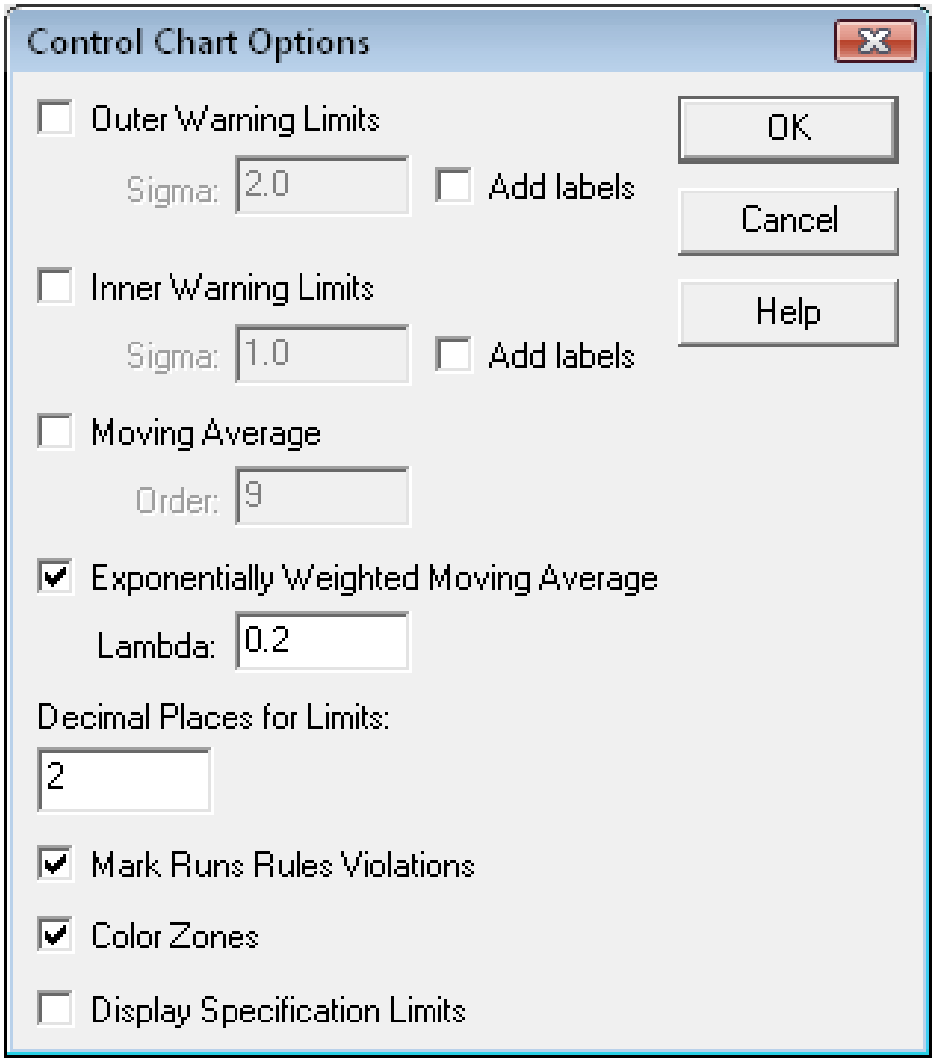
	strength	time
1	255	0:10
2	232	0:20
3	282	0:30
4	260	0:40
5	255	0:50
6	233	1:00
7	240	1:10
8	255	1:20
9	254	1:30
10	259	1:40
11	235	1:50
12	262	2:00
13	272	2:10
14	247	2:20
15	251	2:30
16	245	2:40

bottles B C

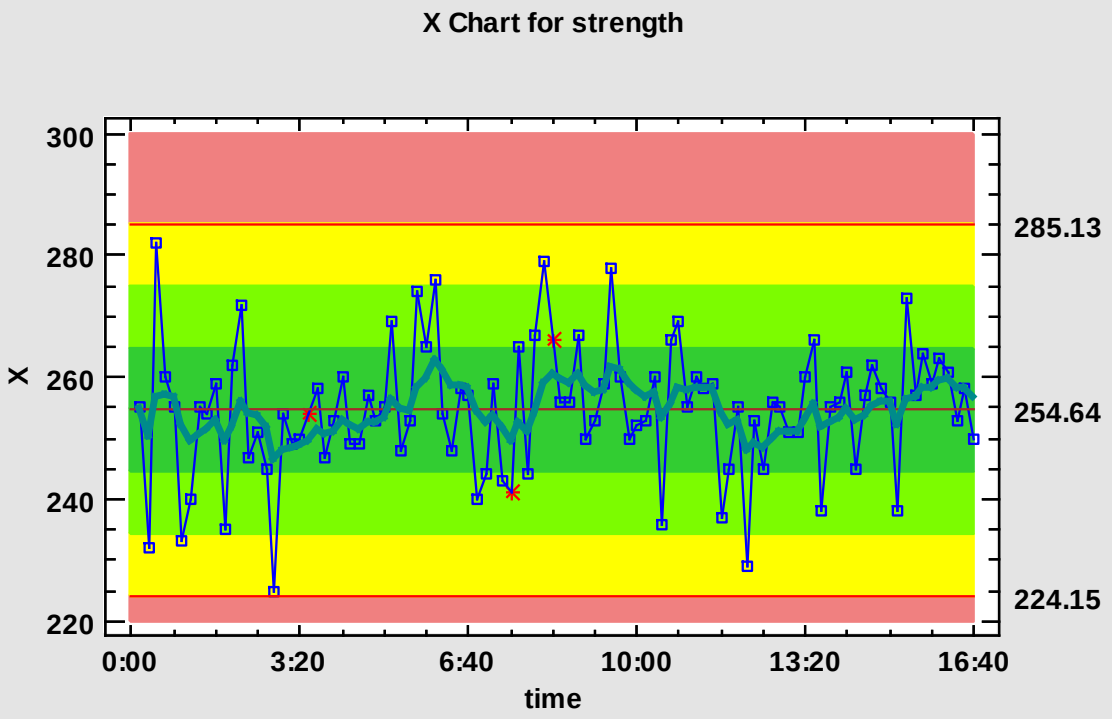
Data Input Dialog Box



X Chart – Pane Options

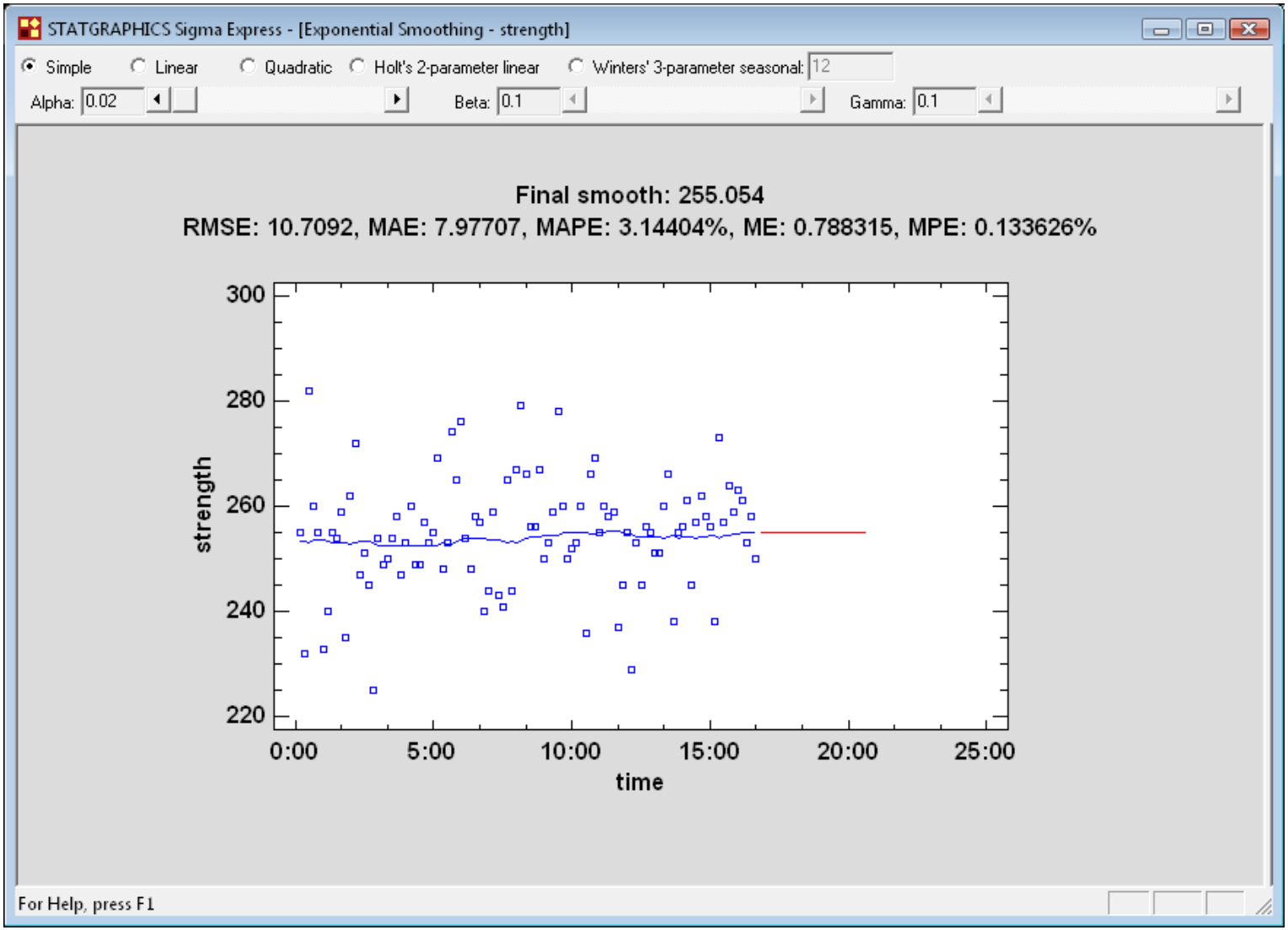


X Chart with EWMA ($\lambda = 0.2$)



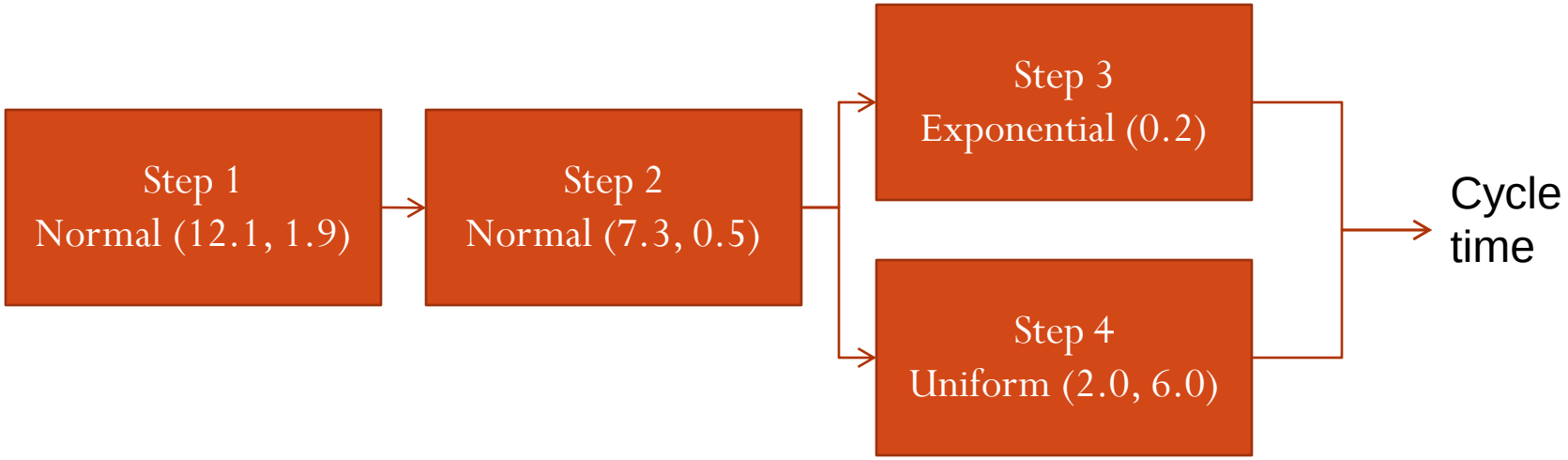
Note: inner zone provides 3-sigma limits for the EWMA.

Exponential Smoothing Statlet

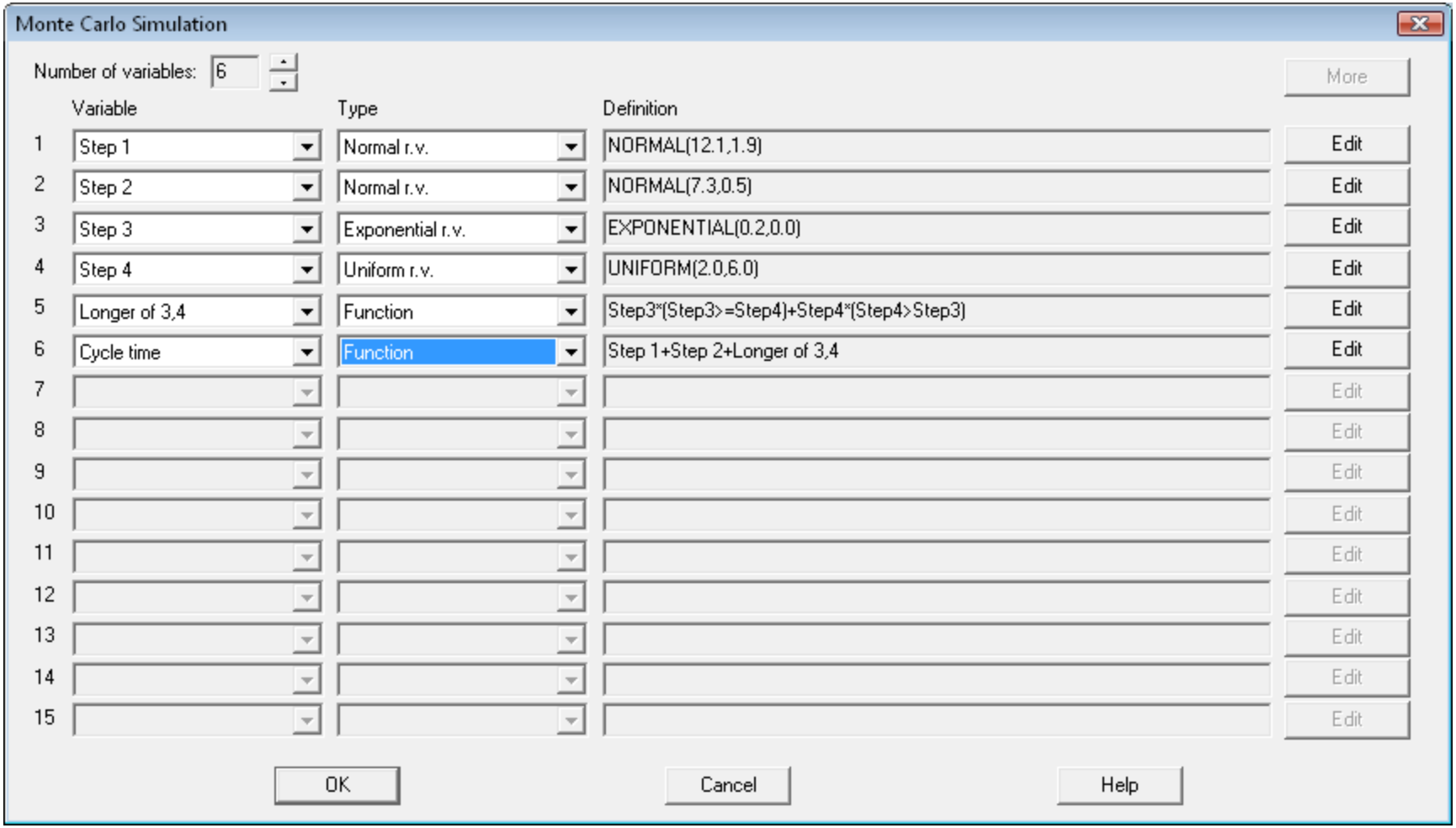


Example #6 - Monte Carlo Simulation

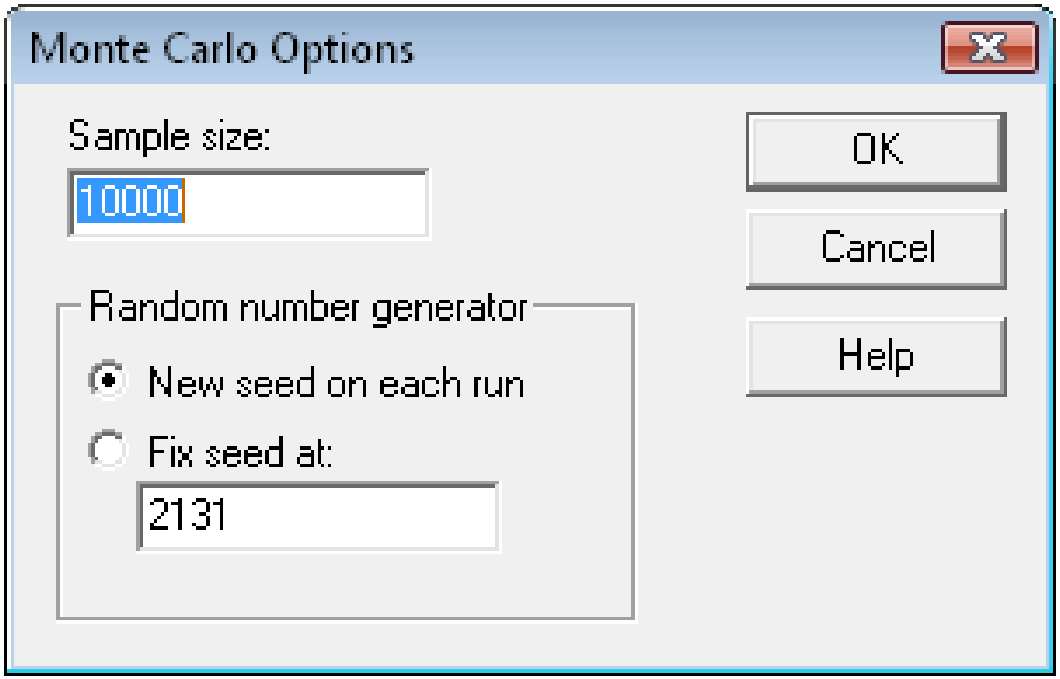
Cycle time = Step 1 + Step 2 + MAX(Step 3, Step 4)



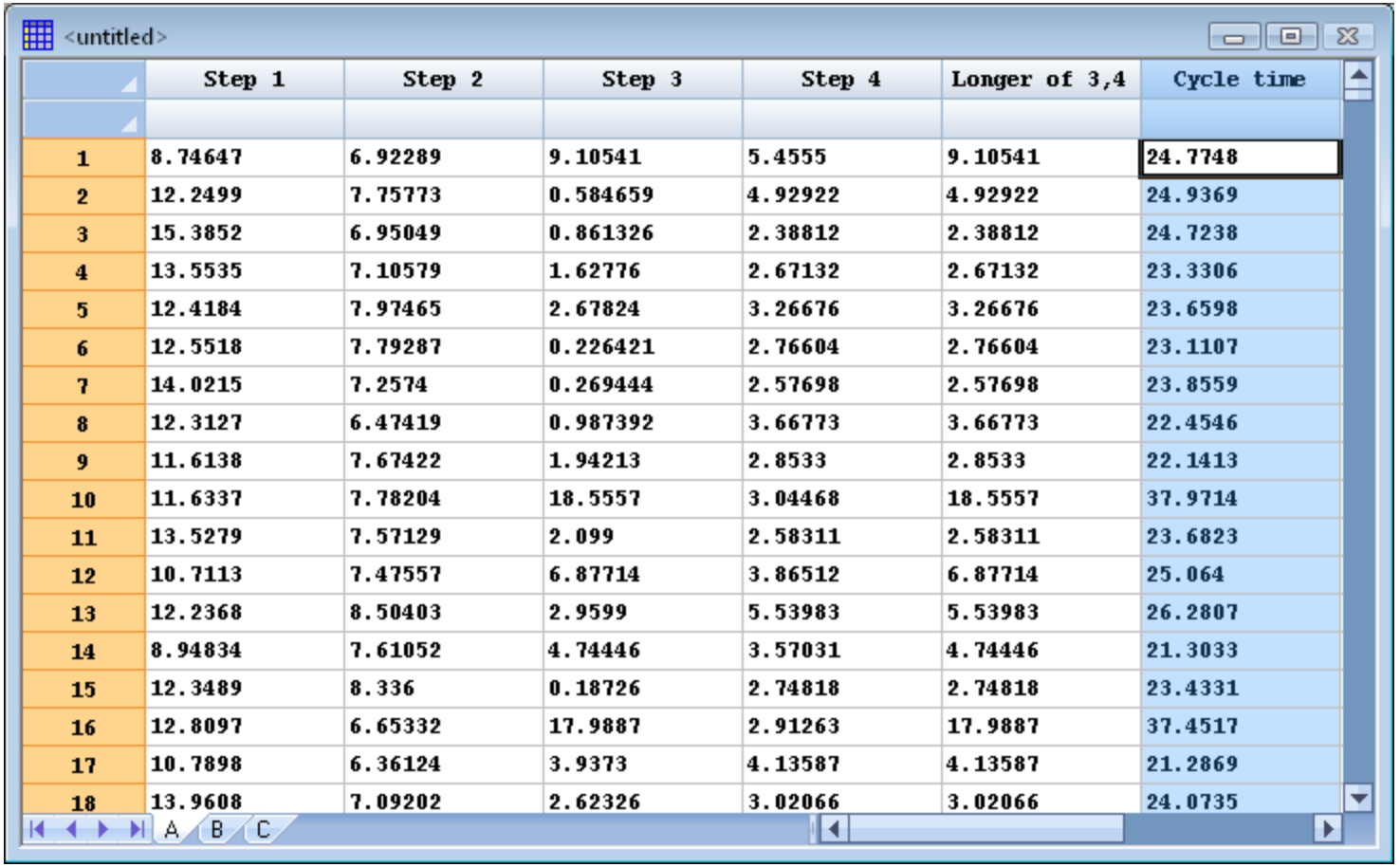
Data Input Dialog Box



Analysis Options

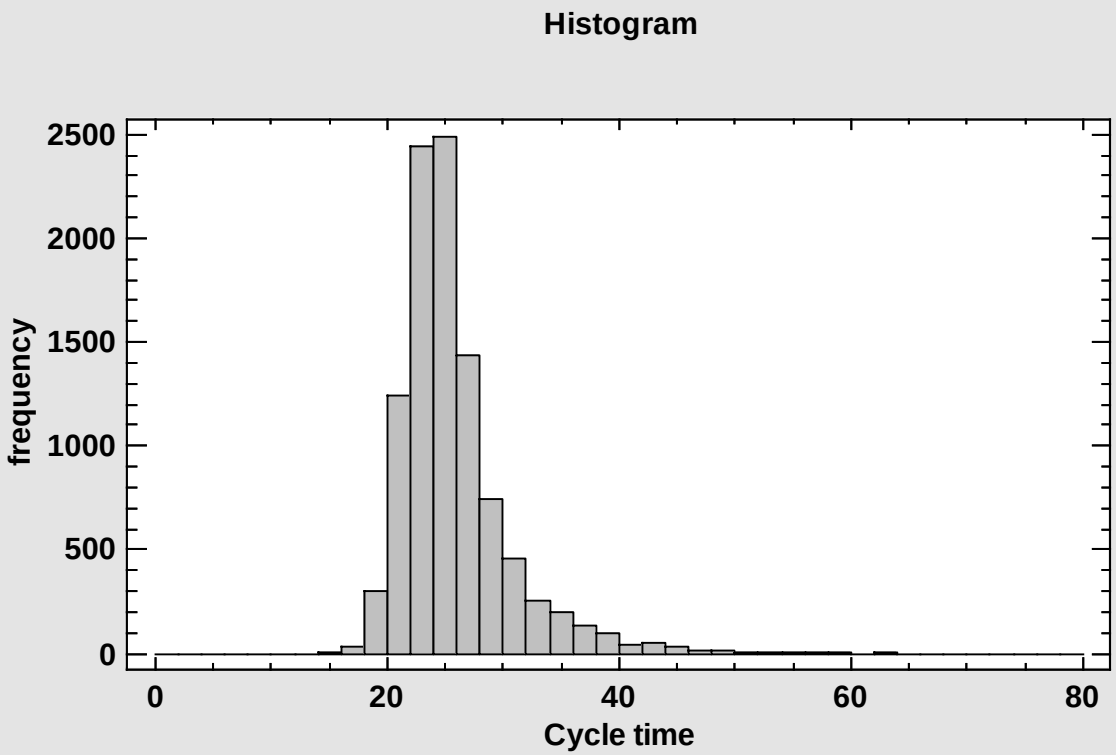


Results



	Step 1	Step 2	Step 3	Step 4	Longer of 3,4	Cycle time
1	8.74647	6.92289	9.10541	5.4555	9.10541	24.7748
2	12.2499	7.75773	0.584659	4.92922	4.92922	24.9369
3	15.3852	6.95049	0.861326	2.38812	2.38812	24.7238
4	13.5535	7.10579	1.62776	2.67132	2.67132	23.3306
5	12.4184	7.97465	2.67824	3.26676	3.26676	23.6598
6	12.5518	7.79287	0.226421	2.76604	2.76604	23.1107
7	14.0215	7.2574	0.269444	2.57698	2.57698	23.8559
8	12.3127	6.47419	0.987392	3.66773	3.66773	22.4546
9	11.6138	7.67422	1.94213	2.8533	2.8533	22.1413
10	11.6337	7.78204	18.5557	3.04468	18.5557	37.9714
11	13.5279	7.57129	2.099	2.58311	2.58311	23.6823
12	10.7113	7.47557	6.87714	3.86512	6.87714	25.064
13	12.2368	8.50403	2.9599	5.53983	5.53983	26.2807
14	8.94834	7.61052	4.74446	3.57031	4.74446	21.3033
15	12.3489	8.336	0.18726	2.74818	2.74818	23.4331
16	12.8097	6.65332	17.9887	2.91263	17.9887	37.4517
17	10.7898	6.36124	3.9373	4.13587	4.13587	21.2869
18	13.9608	7.09202	2.62326	3.02066	3.02066	24.0735

Histogram of cycle time



More Information

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