CORNING

Process Capability Analysis for Non-Normal processes with JSL extensions to detect process shifts.

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Overview

- Problem statement
- Challenges
- Solution – JSL (JMP® Scripting Language) Code
  - Organize data
  - Convert data into format suitable for PCA and PS
  - Perform Process Capability Analysis and Process screening
  - Create customized reports
- Live Demo
- Conclusions

Problem Statement

Current State, Improvement Needs, and Proposed Solution

- The Task
  - Quality Department generates a Yearly report on capability of Corning's products/processes

PROBLEM → SOLUTION

Current State of Report Generation	Need for Improvement	Proposed Solution
Performed yearly	Perform quarterly	Perform monthly
Manual	Semi-automated	Fully automated
Takes 5-6 weeks	2 weeks	2-3 days
Excel, Minitab	Other tools?	JMP®, JMP® Scripting
Aggregated results on product type level at best	Less aggregation	Detailed results on product and test level
Error-prone Data collection challenges Inconsistent calculations	Organize data Repeatability Accurate results	Standardized results Compare all in one place Monitor process shifts

The Solution Path

- Used JMP® and the JMP® Scripting Language to resolve all the data related and analytical challenges

Challenges	JMP® Tools
Collect and Organize data Hundreds of Product Codes, Tests Data for 1 year = millions of rows	Query Builder Platform
Convert data into format suitable for Process Capability Analysis and Process Screening Transform "Long" data into "Wide" data	Various JMP® Functions
Perform Process Capability Analysis Computationally intensive	Process Capability Platform Process Screening Platform
Create customized reports	JSL Coding

SOLUTION - JSL (JMP® Scripting Language) Code

#1

ORGANIZE DATA

- ***Query Builder***

- Join data tables with
  - Measurements, spec limits
  - Products, tests, other info
- Transform data to format ready for PCA

INPUT:
Names of database schemas and tables

#2

ANALYZE DATA AND GENERATE REPORT

- ***PCA Platform***
- ***Process Screening Platform***

- Calculate Capability Indices
- Examine Shifts
- Create Summary Plots and Tables

#3

CUSTOMIZE REPORTS

- ***JSL coding***

- Organize all results
- Summarize findings
- Connect all the pieces

Process capability and Process Screening formulae

- Process capability

  Ability of the process to perform consistently within customer specification limits

- Capability indices

  Short-term

  $$C_p = \frac{USL - LSL}{6 * \sigma_{st}}$$

  $$C_{pk} = \min\left(\frac{USL - \bar{X}}{3 * \sigma_{st}} , \frac{\bar{X} - LSL}{3 * \sigma_{st}} \right)$$

  Long-term

  P_p , P_{pk} - use σ_t instead of σ_{st}

- Target values

  >1 (e.g. 1.33, 1.5, 2)

  Values <1 indicate less capable processes

- Process stability

  Refers to a process without drifts/shifts

- Stability Ratio

  Measure of stability of the process

  $$= \left(\frac{\sigma_t}{\sigma_{st}} \right)^2$$

  σ_t - Overall Sigma

  - Long-term variability

  σ_{st} - Within Sigma

  - Short-term variability

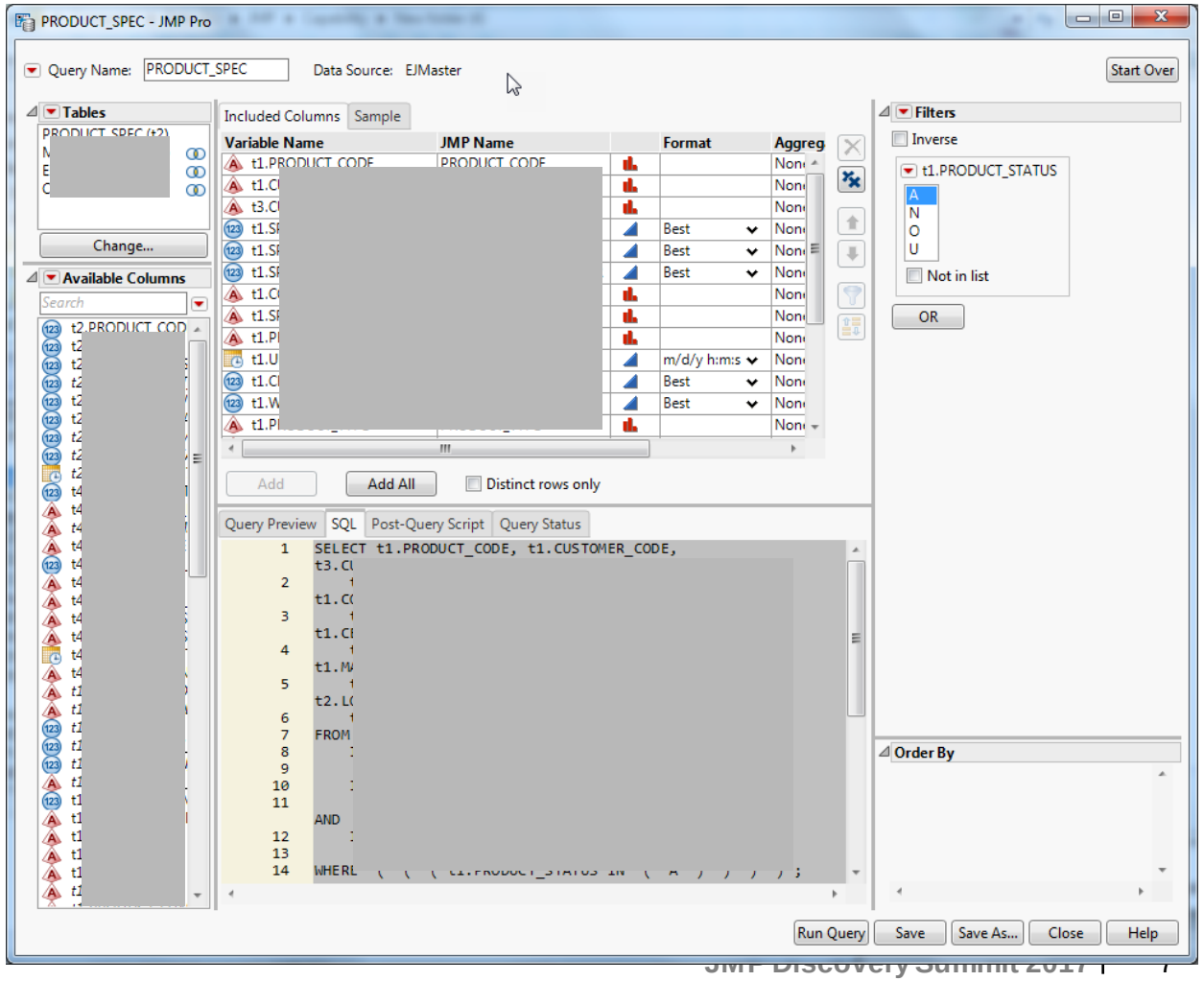
- Target values

  Close to 1

  Values higher than 1 indicate less stable processes

Organize Data

- Use JMP® Query Builder
  - Join, filter, import tables
- Join 4 data tables with
  - Measurements
  - Spec limits
  - Product codes
  - Tests
- Transform data to format ready for PCA
- Automatic update



Convert data into format suitable for PCA and PS
Table Split

PRODUCT_CODE	MEASUREMENT_ID	TEST_NAME	_LSL	_USL	MEAS_VALUE
PC1	36	PC1_36	-1.14	1.14	0.00273
PC1	36	PC1_36	-1.14	1.14	0.00976
PC1	36	PC1_36	-1.14	1.14	0.00576
PC1	36	PC1_36	-1.14	1.14	0.01867
PC1	36	PC1_36	-1.14	1.14	-0.004...
PC1	36	PC1_36	-1.14	1.14	0.00687
PC1	36	PC1_36	-1.14	1.14	0.00730
PC1	36	PC1_36	-1.14	1.14	-0.001...
PC1	36	PC1_36	-1.14	1.14	0.01545
PC1	36	PC1_36	-1.14	1.14	0.00252
PC1	36	PC1_36	-1.14	1.14	0.00158
PC1	62	PC1_62	•	1.28	0.00801
PC1	62	PC1_62	•	1.28	0.01402
PC1	62	PC1_62	•	1.28	0.01543
PC1	62	PC1_62	•	1.28	0.01266
PC1	62	PC1_62	•	1.28	0.01365
PC1	62	PC1_62	•	1.28	0.01958
PC1	62	PC1_62	•	1.28	0.01082
PC1	62	PC1_62	•	1.28	0.01616
PC1	62	PC1_62	•	1.28	0.01681
PC1	62	PC1_62	•	1.28	0.01619
PC1	62	PC1_62	•	1.28	0.01572
PC1	62	PC1_62	•	1.28	0.02050

Table with measurements

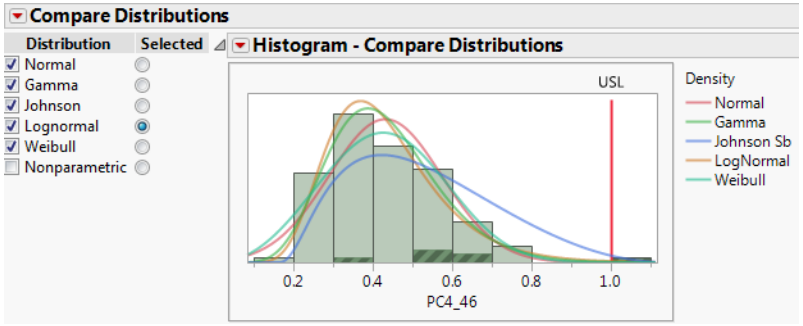
PC1_7	PC1_8	PC1_36	PC1_62	PC1_63	PC1_99	PC2_7
-0.62536578	0.186966098	-0.0841756	0.203524956	0.067319652	303.9	-0.50377761
-0.8136382	0.3486785	-0.03899...	0.3561010...	0.214958422	304.4	-0.86885506
-0.93071188	0.236045502	-0.08230...	0.392033754	0.163802822	304.5	-0.23212999
-1.03988616	0.059676538	-0.15079...	0.3215806...	0.138271504	304	-0.30712757

Table with spec limits

Process	LSL	USL
PC1_7	-1.6	1.2
PC1_8	-1.6	1.2
PC1_36	-1.14	1.14
PC1_99	266	345
PC3_25	-2	2
PC3_26	-2	2
PC3_36	-1.2	1.2
PC3_57	-0.99	0.99
PC3_99	2,168	2,932
PC4_18	-1.6	•
PC4_19	•	1.6
PC4_36	-0.7	0.4
PC4_99	1,600	1,840

Analyze Data and Generate Report

- Process Capability Platform
  - Summary Plots and Tables
  - Individual Detail Reports



Overall Sigma Capability

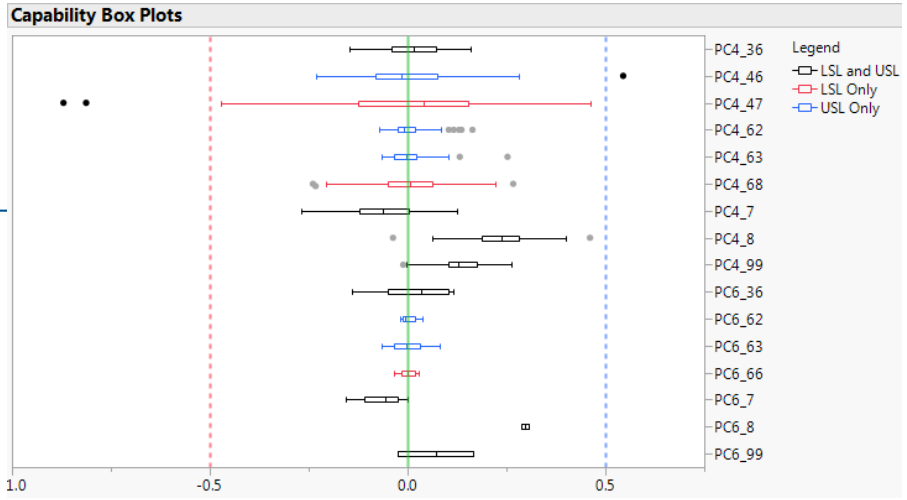
Index	Estimate
Ppk	0.880
Ppu	0.880

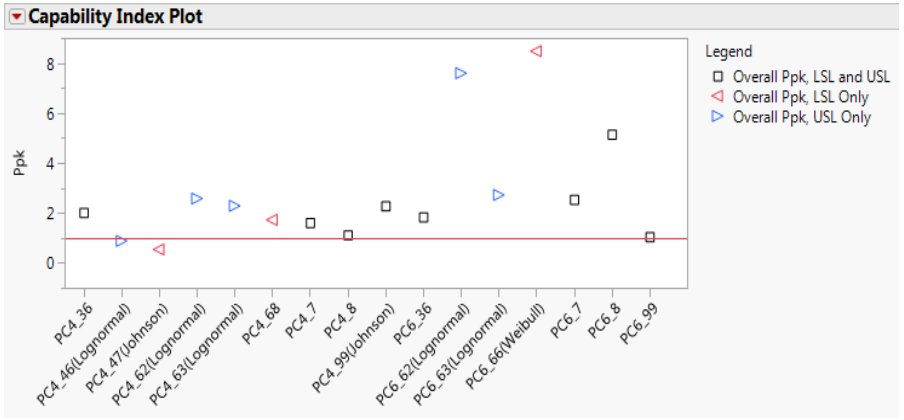
Parameter Estimates

Parameter		Estimate
Scale	μ	-0.891499
Shape	σ	0.322866

Nonconformance

Portion	Observed %	Expected Overall %
Above USL	0.7874	0.2879
Total Outside	0.7874	0.2879





Overall Sigma Capability Summary Report

Process	LSL	Target	USL	Sample Mean	Sample Std Dev	Overall Sigma	Stability Ratio	Ppk	Ppl	Ppu	Pp	Cpm	Expected % Outside	Expected % Below LSL	Expected % Above USL	Observed % Outside	Observed % Below LSL	Observed % Above USL
PC1_7	-1.6	.	1.2	-0.65094	0.226216	0.226216	1.32406	1.398	1.398	2.727	2.063	.	0.0014	0.0014	0.0000	0.0000	0.0000	0.0000
PC1_8(Johnson)	-1.6	.	1.2	0.273683	0.247448	.	.	1.004	3.339	1.004	1.867	.	0.1305	0.0000	0.1305	0.0000	0.0000	0.0000
PC1_36	-1.14	.	1.14	-0.00193	0.140021	0.140021	1.276846	2.709	2.709	2.718	2.714	.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PC1_99	266	.	345	297.3937	45.0726	45.0726	11.81409	0.232	0.232	0.352	0.292	.	38.8489	24.3053	14.5435	2.8504	2.1378	0.7126
PC3_25(Johnson)	-2	.	2	-0.59409	0.240344	.	.	1.951	1.951	4.828	3.163	.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PC3_26(Weibull)	-2	.	2	0.721815	0.226747	.	.	1.940	4.521	1.940	3.172	.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PC3_36	-1.2	.	1.2	0.006741	0.047566	0.047566	1.221526	8.362	8.457	8.362	8.409	.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PC3_57	-0.99	.	0.99	0.050133	0.200944	0.200944	1.563702	1.559	1.725	1.559	1.642	.	0.0002	0.0000	0.0001	0.0000	0.0000	0.0000
PC3_99(Johnson)	2,168	.	2,932	2454.782	15.75084	.	.	2.129	2.129	2.200	2.173	.	0.0336	0.0173	0.0163	0.0000	0.0000	0.0000
PC4_18	-1.6	.	.	0.04248	0.317808	0.317808	1.239631	1.723	1.723	.	.	.	0.0000	0.0000	.	0.0000	0.0000	.
PC4_19(Johnson)	.	.	1.6	0.269777	0.292562	.	.	1.905	.	1.905	.	.	0.0000	.	0.0000	0.0000	.	0.0000
PC4_36	-0.7	.	0.4	0.023969	0.050639	0.050639	1.582212	2.475	4.766	2.475	3.620	.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PC4_99(Lognormal)	1,600	.	1,840	1,737.69	25.98112	.	.	1.291	1.811	1.291	1.545	.	0.0059	0.0000	0.0059	0.0000	0.0000	0.0000

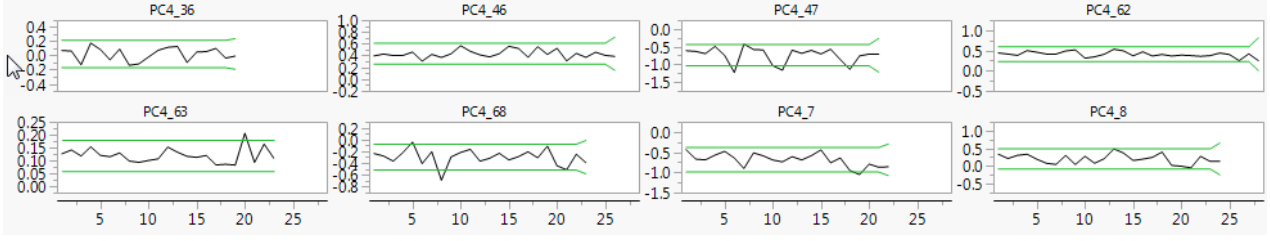
Monitor process shifts using Process Screening

- Capability and Stability summary
- Process Performance Chart
- Examine Process Shifts

Process Screening

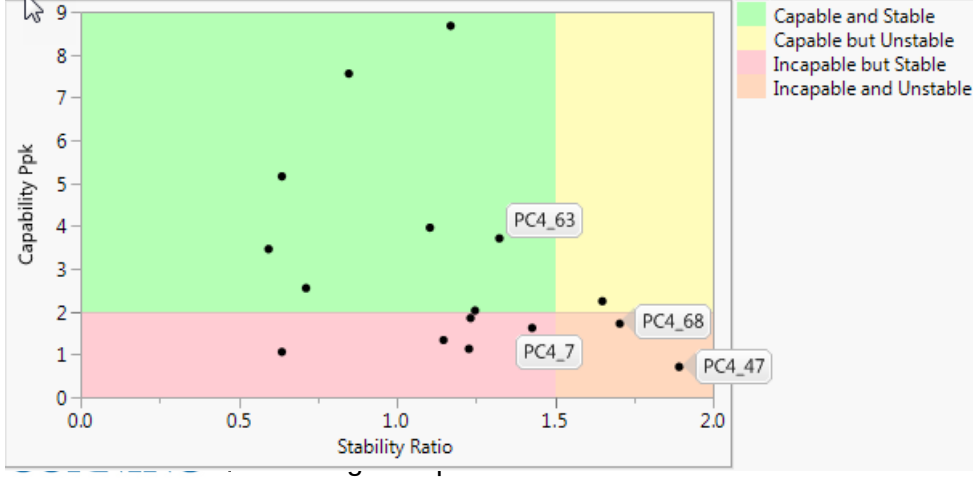
Column	Alarm Rate	Any Alarm	Western Electric - Nelson Rules								Range Limit Exceeded	Latest Alarm	Within Sigma	Overall Sigma	Stability Ratio	Mean	Count	Subgroups	Capability				
			Test1	Test2	Test3	Test4	Test5	Test6	Test7	Test8									Out of Spec Count	Out of Spec Rate	Latest Out of Spec	Cpk	Ppk
PC4_7	0.14286	4	1	0	0	0	1	2	0	0	1	7	0.22603	0.27009	1.43	-0.6865	108	28	0	0	.	1.937	1.621
PC4_68	0.10714	3	2	0	0	0	1	0	0	0	0	8	0.16341	0.21339	1.71	-0.2976	113	28	0	0	.	2.249	1.722
PC4_8	0.07143	2	1	0	0	0	1	0	0	0	0	8	0.21174	0.23466	1.23	0.20307	117	28	0	0	.	1.255	1.132
PC4_47	0.17857	5	4	0	0	0	1	0	0	0	2	11	0.22494	0.30946	1.89	-0.7391	102	28	2	0.0196	92	0.979	0.712
PC4_36	0.07143	2	0	0	1	0	1	0	0	0	0	16	0.14394	0.16076	1.25	0.02291	94	28	0	0	.	2.263	2.026
PC4_46	0.03571	1	0	0	0	0	0	0	0	0	1	19	0.13223	0.14166	1.15	0.43178	127	28	1	0.0079	97	1.432	1.337
PC4_62	0.03571	1	0	0	0	0	0	0	0	0	1	15	0.13527	0.14218	1.10	0.41046	136	28	0	0	.	4.163	3.961
PC4_63	0.10714	3	1	0	0	0	1	1	0	0	1	7	0.04528	0.05211	1.32	0.11981	115	28	0	0	.	4.271	3.712
PC4_99	0.13793	4	3	0	0	0	0	1	0	0	0	2	4.19714	5.39104	1.65	259.681	140	29	0	0	.	2.884	2.246
PC6_36	0.00000	0	0	0	0	0	0	0	0	0	0	.	0.1544	0.17146	1.23	0.04835	10	28	0	0	.	2.054	1.850
PC6_62	0.00000	0	0	0	0	0	0	0	0	0	0	.	0.0606	0.05581	0.85	0.38479	5	28	0	0	.	6.960	7.557
PC6_63	0.00000	0	0	0	0	0	0	0	0	0	0	.	0.08354	0.06442	0.59	0.2511	6	28	0	0	.	2.669	3.461
PC6_66	0.00000	0	0	0	0	0	0	0	0	0	0	.	0.0455	0.04922	1.17	0.22073	10	28	0	0	.	9.382	8.673
PC6_7	0.00000	0	0	0	0	0	0	0	0	0	0	.	0.20237	0.17087	0.71	-0.1926	5	28	0	0	.	2.153	2.550
PC6_8	0.00000	0	0	0	0	0	0	0	0	0	0	.	0.04906	0.03915	0.64	0.89423	2	28	0	0	.	4.116	5.158
PC6_99	0.00000	0	0	0	0	0	0	0	0	0	0	.	14.1796	11.3137	0.64	391	2	28	0	0	.	0.846	1.061

Graphs of Selected Items



NOTE: Currently works with normal distribution only !!

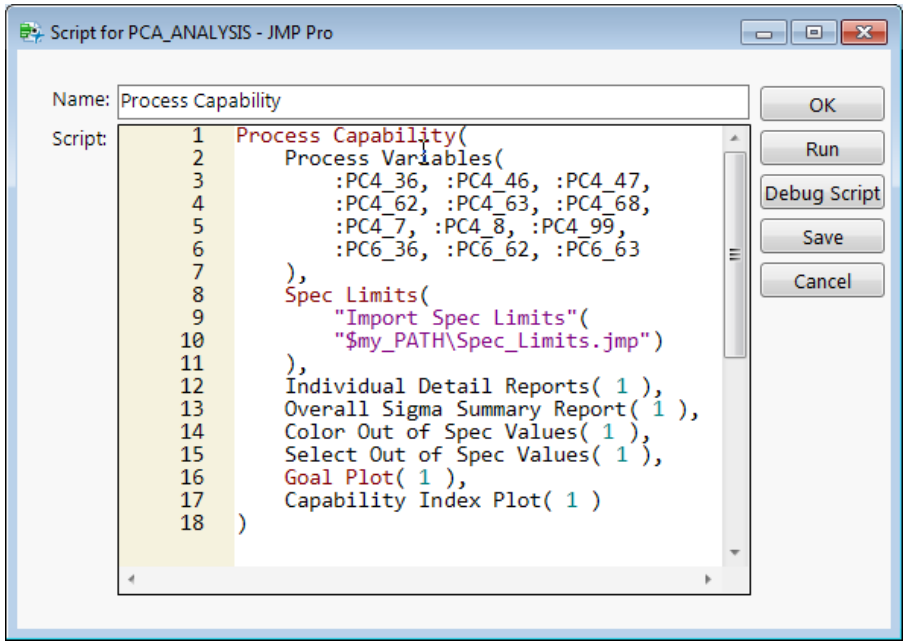
Process Performance Graph



Process	Alarm Rate	Any Alarm	Within Sigma	Overall Sigma	Stability Ratio	Cpk	Ppk	Largest Upshift	Largest Downshift
PC4_7	0.143	4	0.226	0.270	1.43	1.937	1.621	•	1.253
PC4_68	0.107	3	0.163	0.213	1.71	2.249	1.722	•	1.110
PC4_8	0.071	2	0.212	0.235	1.23	1.255	1.132	•	1.085
PC4_47	0.179	5	0.225	0.309	1.89	0.979	0.712	•	1.074
PC4_36	0.071	2	0.144	0.161	1.25	2.263	2.026	•	•
PC4_46	0.036	1	0.132	0.142	1.15	1.432	1.337	•	•
PC4_62	0.036	1	0.135	0.142	1.10	4.163	3.961	•	•
PC4_63	0.107	3	0.045	0.052	1.32	4.271	3.712	1.039	•
PC4_99	0.138	4	4.197	5.391	1.65	2.884	2.246	1.073	•
PC6_36	0.000	0	0.154	0.171	1.23	2.054	1.850	•	•
PC6_62	0.000	0	0.061	0.056	0.85	6.960	7.557	•	•
PC6_63	0.000	0	0.084	0.064	0.59	2.669	3.461	•	•
PC6_66	0.000	0	0.046	0.049	1.17	9.382	8.673	•	•
PC6_7	0.000	0	0.202	0.171	0.71	2.153	2.550	•	•
PC6_8	0.000	0	0.049	0.039	0.64	4.116	5.158	•	•
PC6_99	0.000	0	14.180	11.314	0.64	0.846	1.061	•	•

JSL Details

Coding Process variables needed by PCA and PS platforms




```
pca_cols = dt_pca << GetColumnNames( Continuous );

/*:
{PC4_36, PC4_46, PC4_47, PC4_62, PC4_63, PC4_68,
 PC4_7, PC4_8, PC4_99, PC6_36, PC6_62, PC6_63 }
//:*/
show( my_columns );

/*:
"Process Variables( :PC4_36, :PC4_46, :PC4_47, :PC4_62, :PC4_63,
 :PC4_68, :PC4_7, :PC4_8, :PC4_99, :PC6_36, :PC6_62, :PC6_63 )"
//:*/
```

```
// Script by Mark Bailey (Dan Obermiller's team)

// create a list of selected column names
pca_cols = dt_pca << GetColumnNames( Continuous );

// begin Process Variables argument of Process Capability as a string
my_columns = "Process Variables( ";

For( c = 1, c <= N Items( pca_cols ), c++,
    my_columns ||= ":" || pca_cols[c] || ", ";
);

my_columns ||= ")";

// substitute placeholder "ppp" with finished argument,
// parse it into an expression, and evaluate the expression.
Eval(
    Parse(
        Substitute(
            "pca = dt_split << Process Capability(
                ppp,
                Spec Limits(
                    Import Spec Limits( \!"Spec_Limits.jmp\!" )
                ),
                Individual Detail Reports( 1 ),
                Capability Index Plot( 1 ),
                Overall Sigma Summary Report( 1 ),
                Color Out of Spec Values( 1 ),
                Select Out of Spec Values( 1 ),
            )",
            "ppp",
            my_columns
        )
    )
);
```

Conclusions

- The solution in a form of a JSL code provides the following advantages compared to the current report generation

  - Speeds up the whole process from weeks to days
  - Organizes and cleans the data by reusing scripts
  - Standardizes the analytics portion of the process
  - Provides a deeper level of detail
  - Provides easy repeatability
  - Enables future improvements and new opportunities

References & Acknowledgements

- JMP® Scripting Guide and Scripting Index
- JMP® Online Documentation
  - Build SQL Queries in Query Builder
  - Quality and Process methods: Process capability
  - Predictive and Specialized Modeling: Process Screening
  - JSL Syntax Reference
- JMP® Newsletters
  - Process Capability in JMP® 12 (JMPer Cable Issue Summer 2015 by Laura Lancaster)
  - New in JMP ® 13: Analyzing Non-Normal Process Capability (by Brady Brady)
- JMP® Webcasts
  - Advanced Mastering JMP: Accessing Databases (by Chris Kirchberg)
  - Advanced Mastering JMP: Monitoring and Controlling Complex Manufacturing Processes (by Scott Wise)
  - JMP Scripting Language for Experienced JSL Users (by Brady Brady)
- Acknowledgement
  - Dan Obermiller
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Q&A