

MAY 18, 2022

Scaling AI – Albemarle Intelligence

Leveraging PI Asset Framework for SPC & Machine Learning

Presented By: Jonathan Alexander

AVEVA



Merriam-Webster Dictionary

artificial intelligence: noun

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1: a branch of computer science dealing with the simulation of intelligent behavior in computers

2: the capability of a machine to imitate intelligent human behavior

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2. "Every time we figure out a piece of it, it stops being magical; we say, 'Oh, that's just a computation.'“

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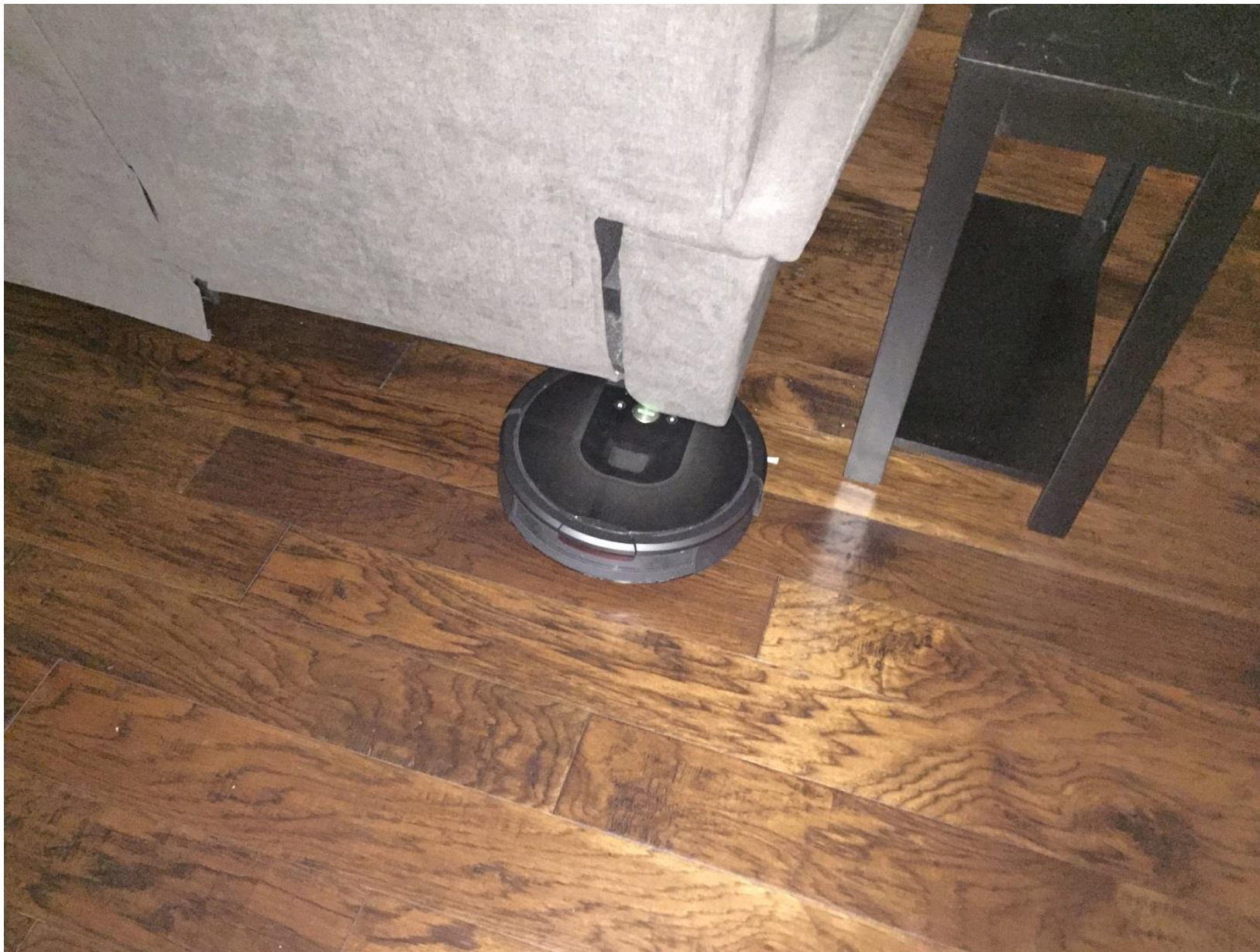










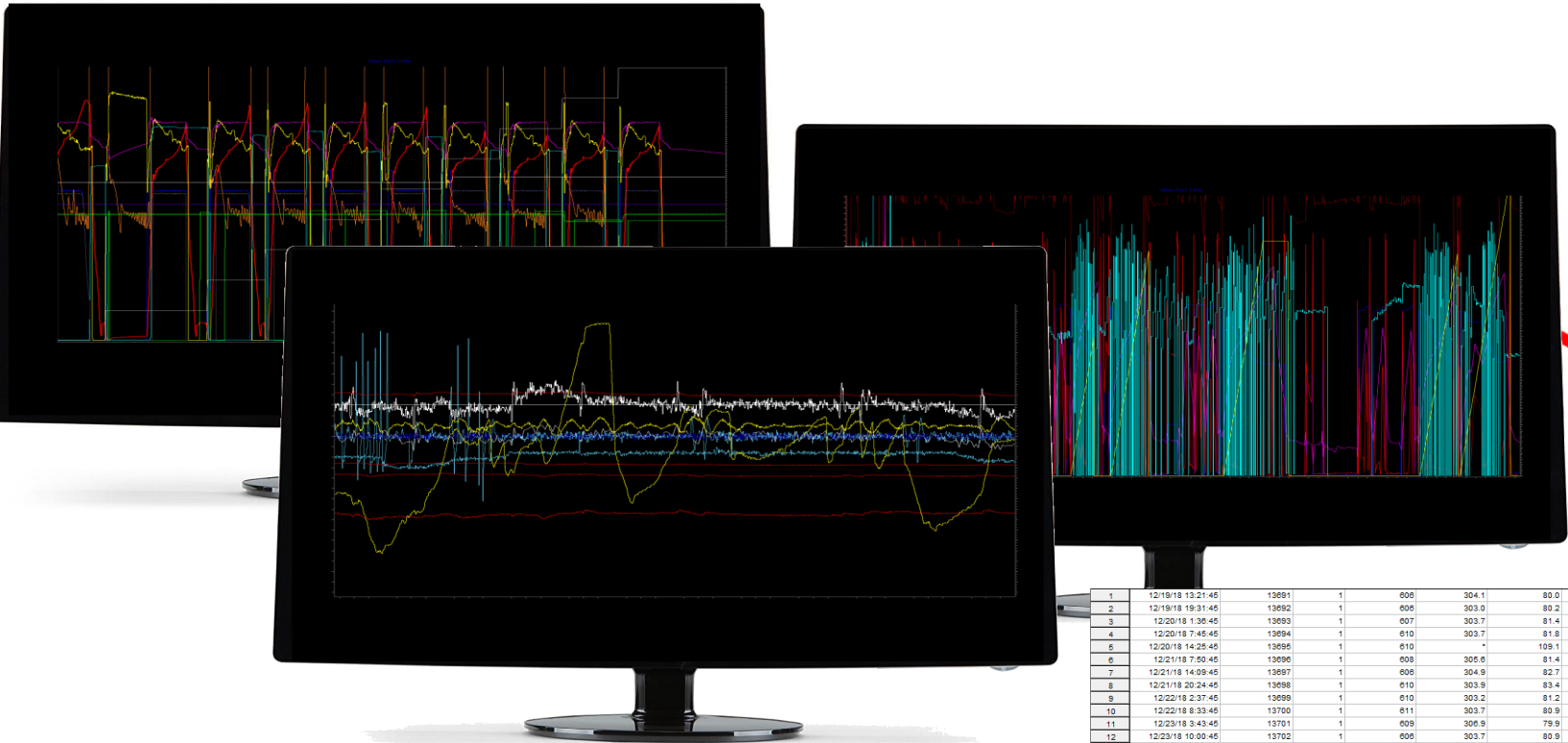


Are you ready for AI?





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2	12/19/18 19:31:45	13692	1	606	303.0	80.2	2048	44.5	23	101	136	77	164.01	7148	6390.6	2.3	8409.193
3	12/20/18 1:30:45	13693	1	607	303.7	81.4	2226	44.5	24	101	125	77	164.13	7149	6390.1	2.3	8478.928
4	12/20/18 7:45:45	13694	1	610	303.7	81.5	2316	44.5	25	98	132	77	164.01	7151	6327.4	2.3	8499.395
5	12/20/18 14:25:45	13695	1	610	*	109.1	2090	44.5	26	99	160	79	162.23	7150	6338.3	2.3	8611.953
6	12/21/18 7:50:45	13696	1	608	305.6	81.4	1227	45	27	108	148	80	162.42	7149	6447.5	2.3	8683.598
7	12/21/18 14:09:45	13697	1	606	304.9	82.7	2054	45	28	98	146	79	162.27	7151	6362.6	2.3	8832.448
8	12/21/18 20:24:45	13698	1	610	303.9	83.4	2061	45	29	97	144	80	162.08	7150	6406.9	2.2	7730.921
9	12/22/18 2:37:45	13699	1	610	303.2	81.2	-	45	30	97	87	80	162.21	7150	6440.3	2.2	8021.211
10	12/22/18 8:33:45	13700	1	611	303.7	80.9	2013	45	31	117	78	78	162.12	7150	6323.9	2.3	8285.421
11	12/23/18 3:43:45	13701	1	609	306.9	79.9	2140	45	32	107	87	80	162.38	7148	6525.2	2.3	7762.932
12	12/23/18 10:00:45	13702	1	606	303.7	80.9	2176	45	33	98	137	81	162.26	7149	6197.5	2.2	6291.746
13	12/23/18 16:50:45	13703	1	611	306.2	85.1	2064	45	34	98	137	82	162.29	7151	6414.4	2.2	7666.285
14	12/23/18 22:54:45	13704	1	*	311.6	81.9	2048	45	35	102	125	74	162.70	7152	6028.4	2.3	10093.03
15	12/24/18 7:31:45	13705	1	602	309.4	81.4	2090	45	36	94	280	71	162.48	7155	5982.3	2.4	11320.12
16	12/24/18 14:37:45	13706	1	645	309.5	84.2	2043	45	37	95	183	74	161.79	7157	5705.0	2.3	11832.73
17	12/24/18 20:33:45	13707	1	603	312.2	85.8	2088	45	38	99	105	79	162.27	7153	6245.2	2.2	9638.71
18	12/25/18 2:45:45	13708	1	603	309.8	82.2	2050	45	39	94	119	70	162.32	7156	5818.0	2.2	11451.3
19	12/25/18 10:40:45	13709	1	603	310.2	81.5	1877	45	40	96	244	72	162.21	7153	6043.8	3.0	11545.26
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21	12/26/18 0:00:45	13711	1	609	309.1	84.7	2022	45	42	96	168	80	158.78	7151	6091.4	2.8	8602.66
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24	12/26/18 18:22:45	13714	1	605	307.8	85.4	2051	45	45	98	137	81	162.18	7150	6102.3	2.9	7056.47
25	12/27/18 1:04:45	13715	1	606	308.3	84.7	1971	45	46	100	111	81	162.20	7150	6211.3	2.9	7109.498
26	12/27/18 6:48:45	13716	1	606	308.8	83.8	2158	45	47	101	109	80	162.03	7149	6233.1	2.9	8123.546
27	12/27/18 12:44:45	13717	1	609	313.8	84.4	2019	45	48	106	112	80	161.58	7147	6333.8	2.9	8759.883
28	12/27/18 18:53:45	13718	1	603	307.8	84.7	1897	45	49	104	130	78	161.39	7149	6197.8	2.8	8932.923
29	12/28/18 0:59:45	13719	1	602	307.0	85.2	2097	45	50	104	128	79	161.53	7150	6237.0	2.9	9211.07
30	12/28/18 7:06:45	13720	1	602	309.8	85.0	2012	45	51	103	130	78	161.62	7151	6163.3	2.7	9938.528
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36	1/12/19 8:16:45	13727	1	577	305.3	85.4	1956	45	58	117	109	84	160.97	7151	6336.5	2.8	10049.31
37	1/12/19 15:02:45	13728	1	602	303.1	83.5	1944	45	59	117	162	82	160.99	7148	6277.2	2.8	8655.688
38	1/12/19 21:23:45	13729	1	602	306.0	84.0	1797	45	60	118	125	85	160.93	7148	6433.7	2.9	9941.389
39	1/13/19 4:11:45	13730	1	605	302.9	82.6	1735	45	61	119	156	83	160.85	7144	6283.6	2.9	8540.879
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41	1/13/19 17:18:45	13732	1	603	302.9	82.5	1946	45	63	116	124	80	160.97	7147	6046.4	2.9	9181.318
42	1/13/19 23:45:45	13733	1	602	304.9	83.1	2076	45	64	119	122	81	160.89	7145	6235.5	2.9	9758.116
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44	1/14/19 12:50:45	13735	1	602	303.7	83.9	2025	45	66	117	136	81	161.01	7147	6171.1	2.9	9540.422
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46	1/15/19 1:47:45	13737	1	602	305.9	83.6	2004	45	68	120	120	82	161.73	7146	6279.8	2.9	9932.086
47	1/15/19 8:09:45	13738	1	603	309.9	83.7	1973	45	69	121	121	82	161.88	7146	6287.2	2.9	9644.036
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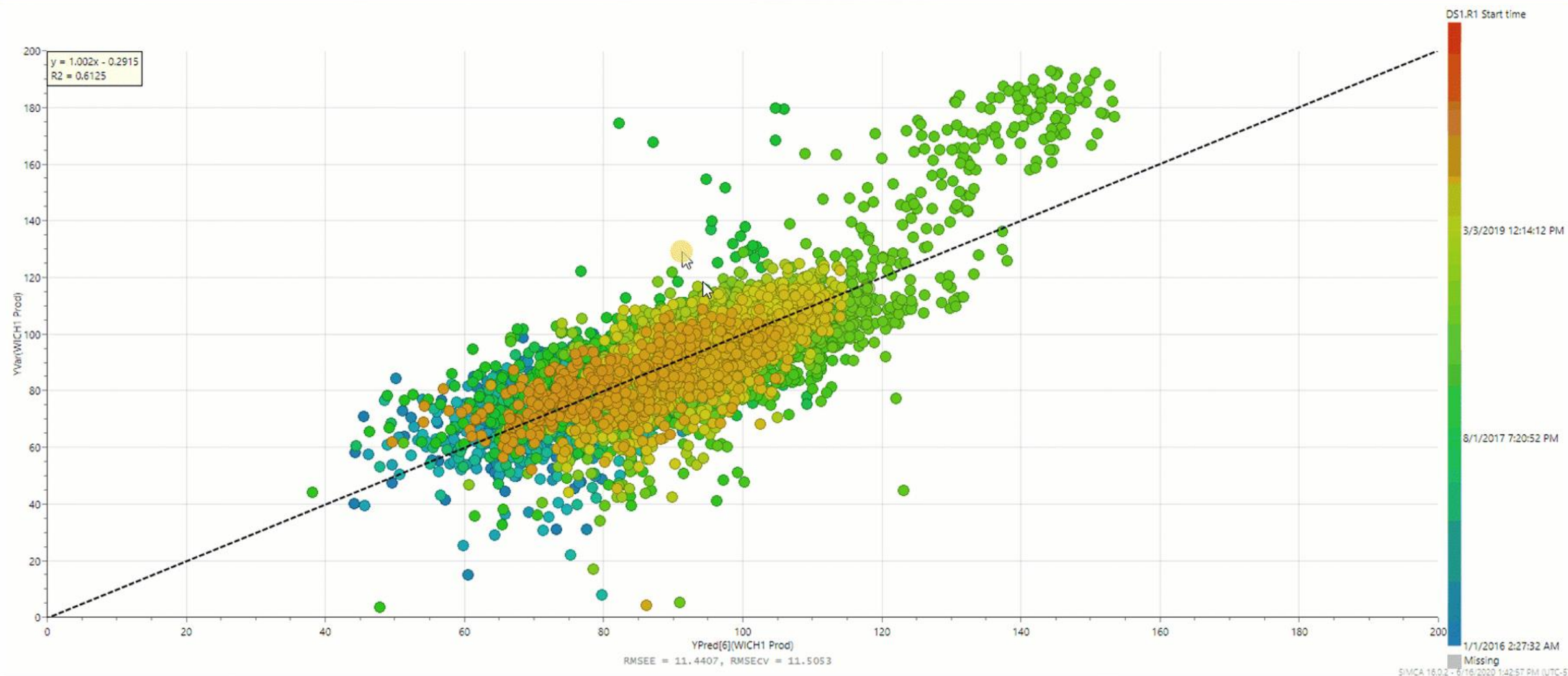


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5	12/20/18 14:25:45	13695	1	610	*	109.1	2090	44.5	26	98	160	79	162.23	7150	6338.3	2.3	8611.953
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18	12/25/18 2:45:45	13708	1	603	309.8	82.2	2050	45	39	94	119	70	162.32	7156	5818.0	2.2	11451.3
19	12/25/18 10:40:45	13709	1	603	310.2	81.5	1877	45	40	96	244	72	162.21	7153	6043.8	3.0	11545.26
20	12/25/18 17:26:45	13710	1	602	312.4	85.1	2055	45	41	96	167	77	162.22	7154	6183.0	2.9	10347.01
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24	12/26/18 18:22:45	13714	1	605	307.8	85.4	2051	45	45	98	137	81	162.18	7150	6102.3	2.9	7056.47
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32	12/28/18 22:40:45	13722	1	597	312.8	86.3	1953	45	53	120	120	85	161.08	7151	6000.9	2.9	10469.81
33	12/29/18 5:20:45	13723	1	596	307.0	85.0	1852	45	54	117	130	83	161.17	7151	6356.3	2.7	9537.63
34	1/11/19 19:03:45	13725	3	595	307.9	86.4	2031	45	56	108	438	66	160.93	7148	6067.6	2.9	10104.2
35	1/12/19 2:10:45	13726	1	599	300.7	87.9	1907	45	57	119	166	88	160.92	7150	6326.3	2.8	7165.784
36	1/12/19 8:16:45	13727	1	577	305.3	85.4	1906	45	58	117	109	84	160.97	7151	6336.5	2.8	10049.31
37	1/12/19 15:02:45	13728	1	602	303.1	83.5	1944	45	59	117	162	82	160.99	7148	6277.2	2.8	8655.688
38	1/12/19 21:23:45	13729	1	602	306.0	84.0	1797	45	60	118	125	85	160.93	7148	6433.7	2.9	9941.389
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43	1/14/19 6:23:45	13734	1	602	303.3	83.5	2041	45	65	117	140	80	160.99	7147	6148.1	2.9	9389.709
44	1/14/19 12:50:45	13735	1	602	303.7	83.9	2025	45	66	117	136	81	161.01	7147	6171.1	2.9	9540.422
45	1/14/19 19:23:45	13736	1	602	304.3	83.9	2013	45	67	118	135	82	161.83	7147	6187.4	3.0	9524.605
46	1/15/19 1:47:45	13737	1	602	305.9	83.6	2004	45	68	120	120	82	161.73	7146	6279.8	2.9	9932.086
47	1/15/19 8:09:45	13738	1	603	309.9	83.7	1977	45	69	121	121	82	161.88	7146	6287.2	2.9	9644.036
48	1/15/19 14:20:45	13738	1	602	312.1	83.6	1980	45	70	119	124	81	161.91	7147	6095.9	2.4	10440.04

Project Window - M20 (PLS) - Up to Dec '19

Number	Model	Type	A	N	R2X(cum)	R2Y(cum)	Q2(cum)	Date	Title	Hierarchical
17	M17	PLS	5	641	0.294	0.302	0.254	4/30/2020		
18	M18	PLS	10	641	0.526	0.299	0.241	4/30/2020		
19	M19	PLS	10	639	0.537	0.306	0.251	4/30/2020		
20	M20	PLS	6	7230	0.337	0.389	0.385	6/16/2020	Up to Dec '19	

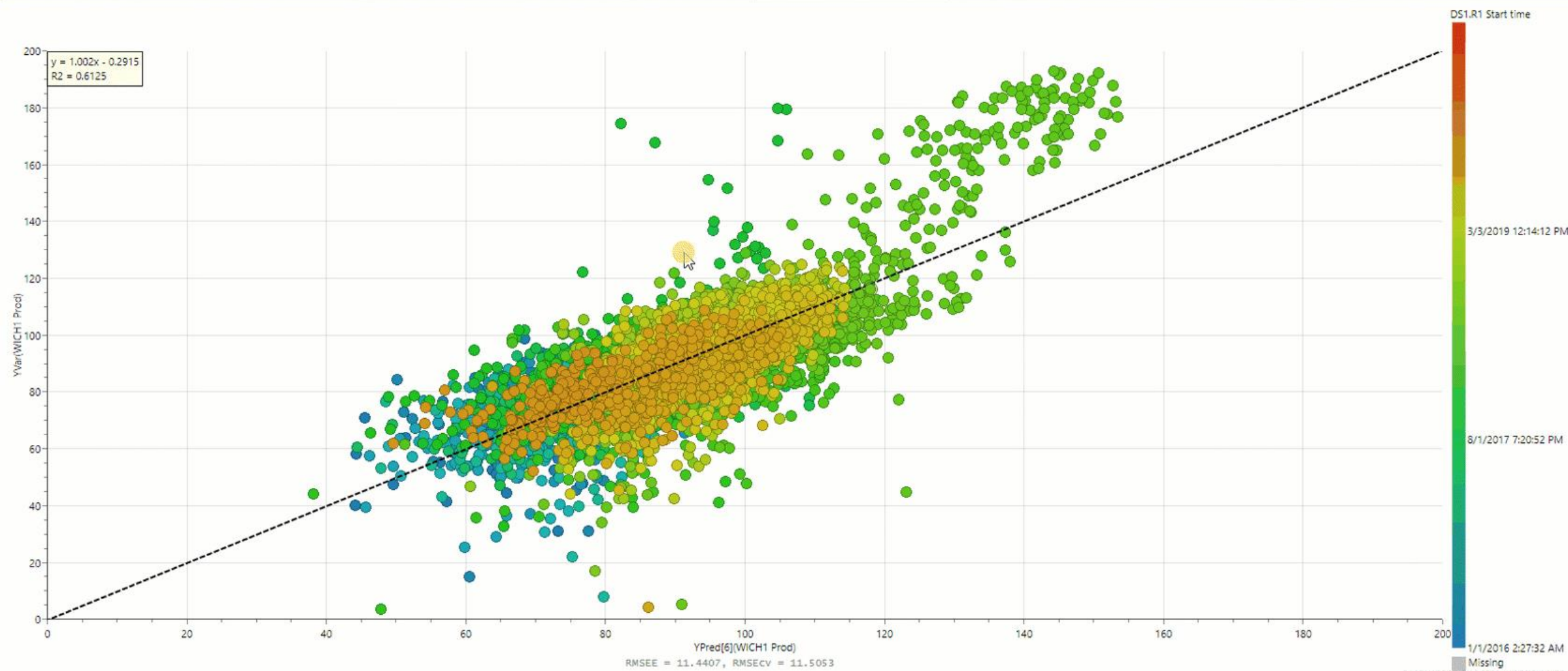
Observed vs. Predicted [M19] Loading Scatter Plot [M19] Score Scatter Plot [M19] Contribution Plot [M20] Observed vs. Predicted [M20] X Contribution Plot [M20] XVar Plot [M20] Contribution Plot [M20] XVar Plot [M20]



Project Window - M20 (PLS) - Up to Dec '19

Number	Model	Type	A	N	R2X(cum)	R2Y(cum)	Q2(cum)	Date	Title	Hierarchical
17	M17	PLS	5	641	0.294	0.302	0.254	4/30/2020		
18	M18	PLS	10	641	0.526	0.299	0.241	4/30/2020		
19	M19	PLS	10	639	0.537	0.306	0.251	4/30/2020		
20	M20	PLS	6	7230	0.337	0.389	0.385	6/16/2020	Up to Dec '19	

Observed vs. Predicted [M19]	Loading Scatter Plot [M19]	Score Scatter Plot [M19]	Contribution Plot [M20]	Observed vs. Predicted [M20] X	Contribution Plot [M20]	XVar Plot [M20]	Contribution Plot [M20]	XVar Plot [M20]
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File

Home

Data

Analyze

Predict

View

Tools

Marked items

List

Scatter

Line

Column

Plot XObs

Plot YObs

Exclude

Include

Class

Labels

Hide

Show all

Unlock column Layout

Format symbol

Format label

Create from marked items

Drill down

Modify model

Project Window - M20 (PLS) - Up to Dec '19

Number	Model	Type	A	N	R2X(cum)	R2Y(cum)	Q2(cum)	Date	Title	Hierarchical
17	M17	PLS	5	641	0.294	0.302	0.254	4/30/2020		
18	M18	PLS	10	641	0.526	0.299	0.241	4/30/2020		
19	M19	PLS	10	639	0.537	0.306	0.251	4/30/2020		
20	M20	PLS	6	7230	0.337	0.389	0.385	6/16/2020	Up to Dec '19	

Scatter Plot [M19]

Score Scatter Plot [M19]

Contribution Plot [M20]

Observed vs. Predicted [M20]

Contribution Plot [M20]

XVar Plot [M20]

Contribution Plot [M20]

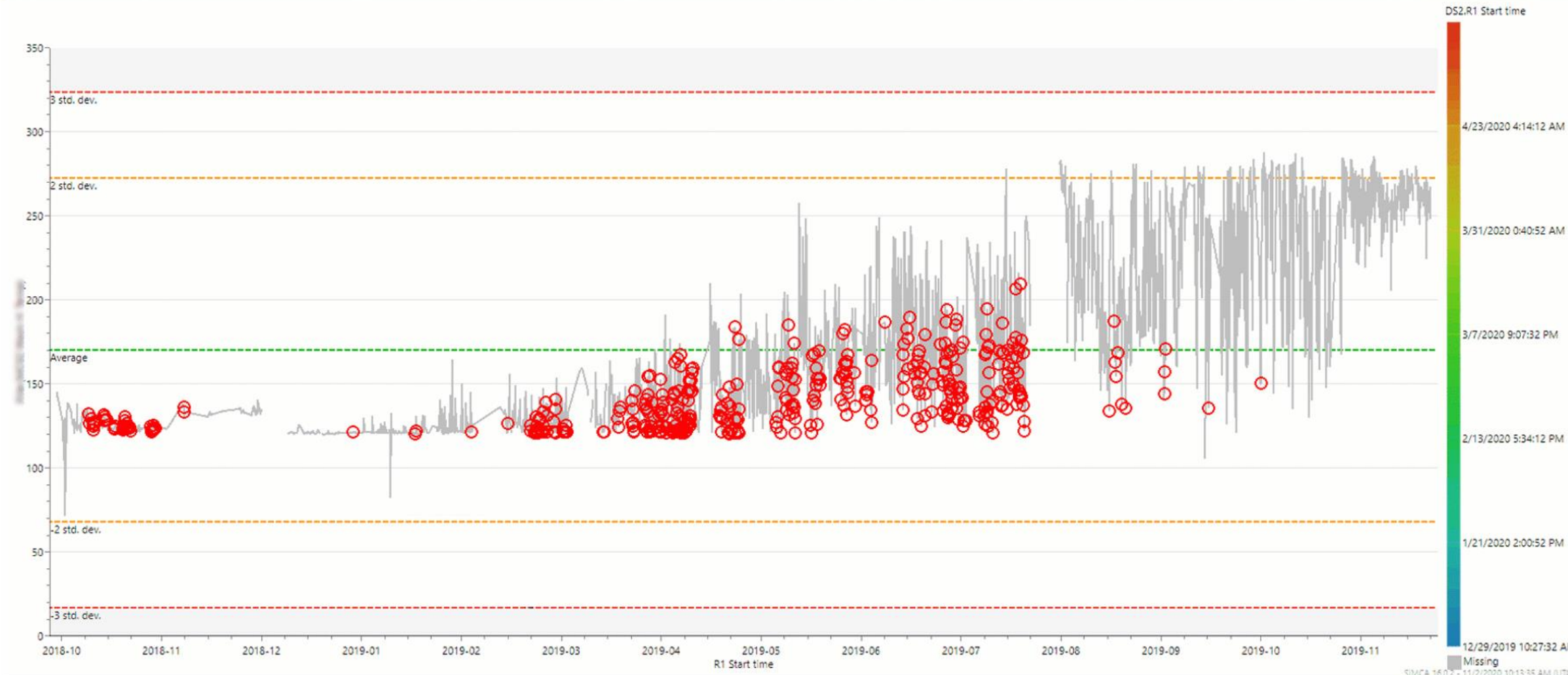
XVar Plot [M20]

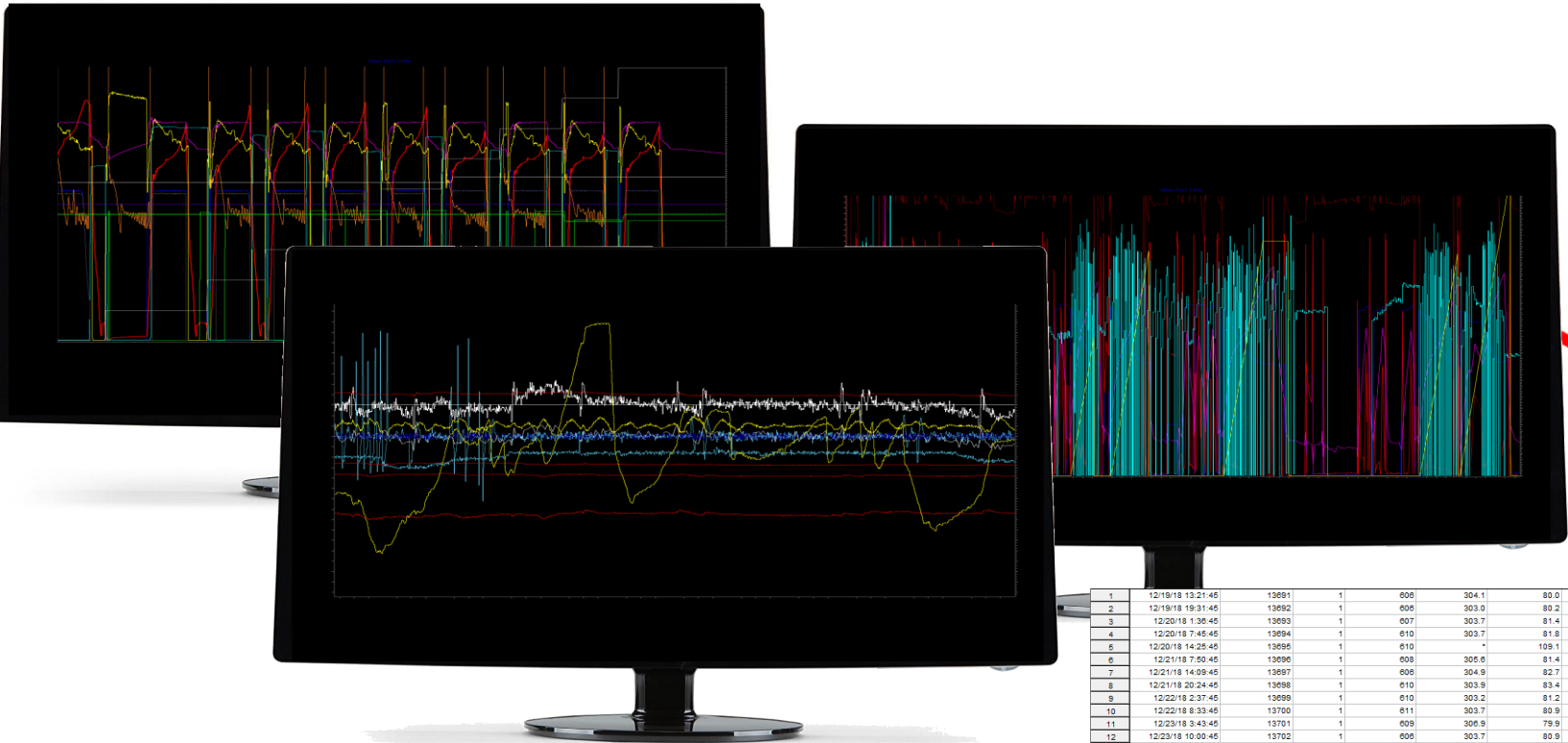
Contribution Plot [M20]

XVar Plot [M20]

Contribution Plot [M20]

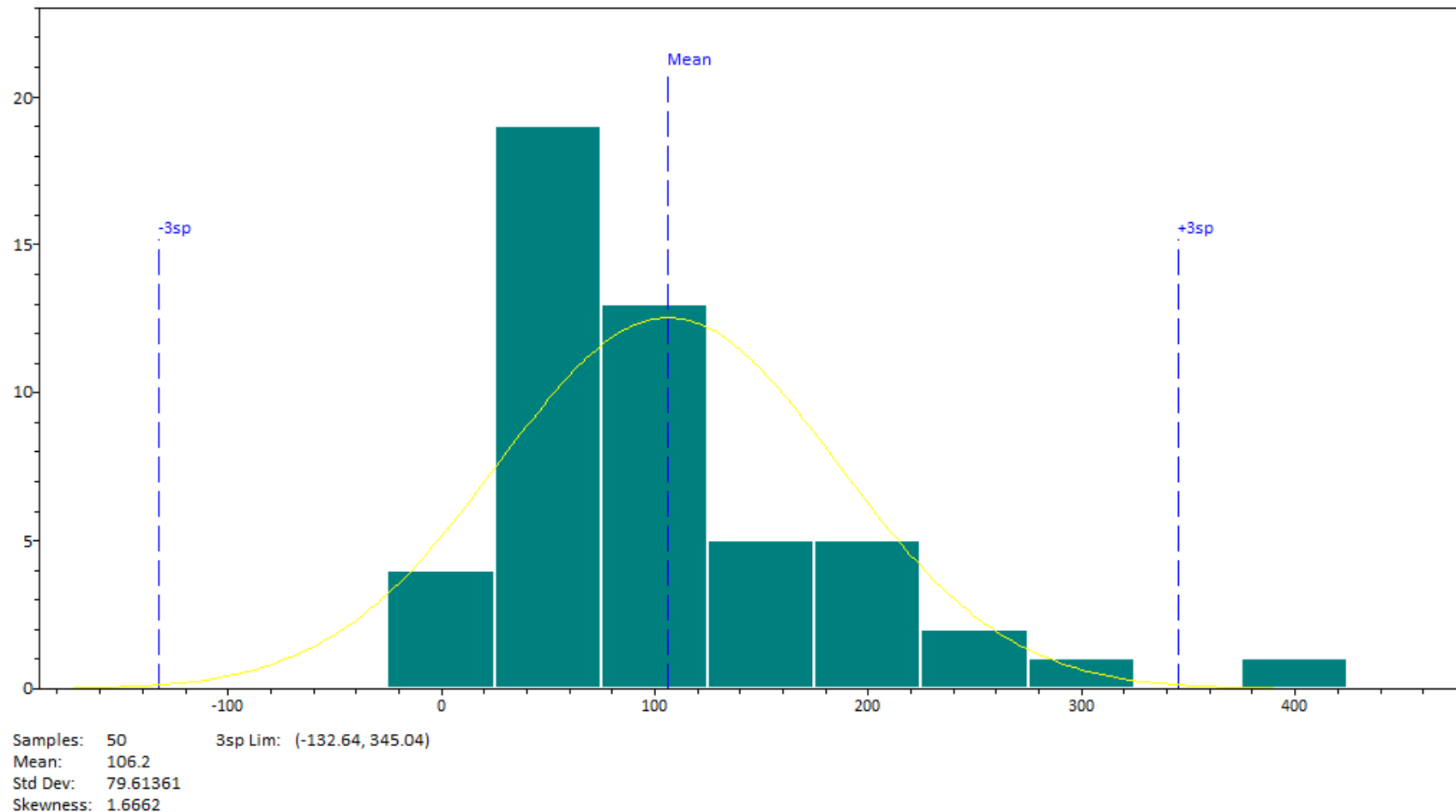
XVar Plot [M20]





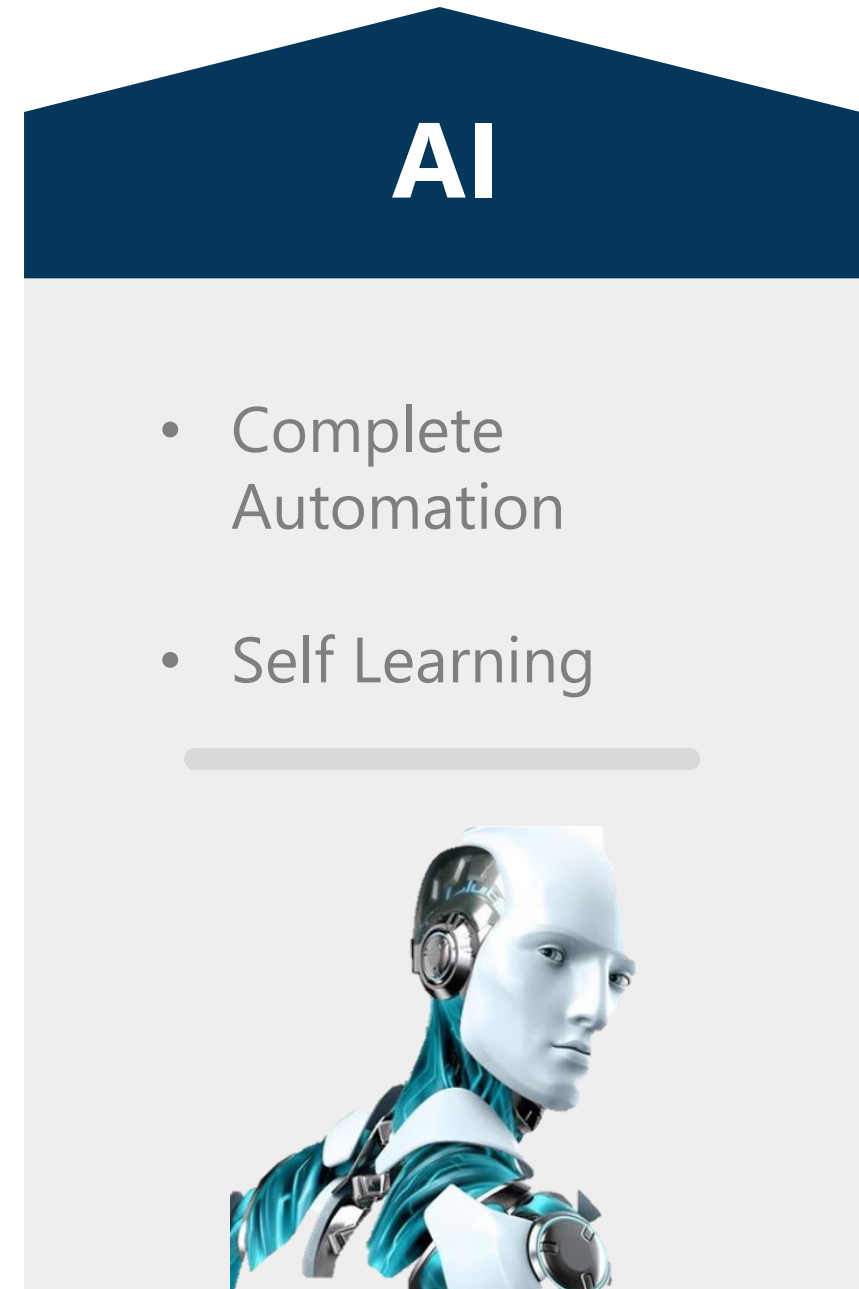
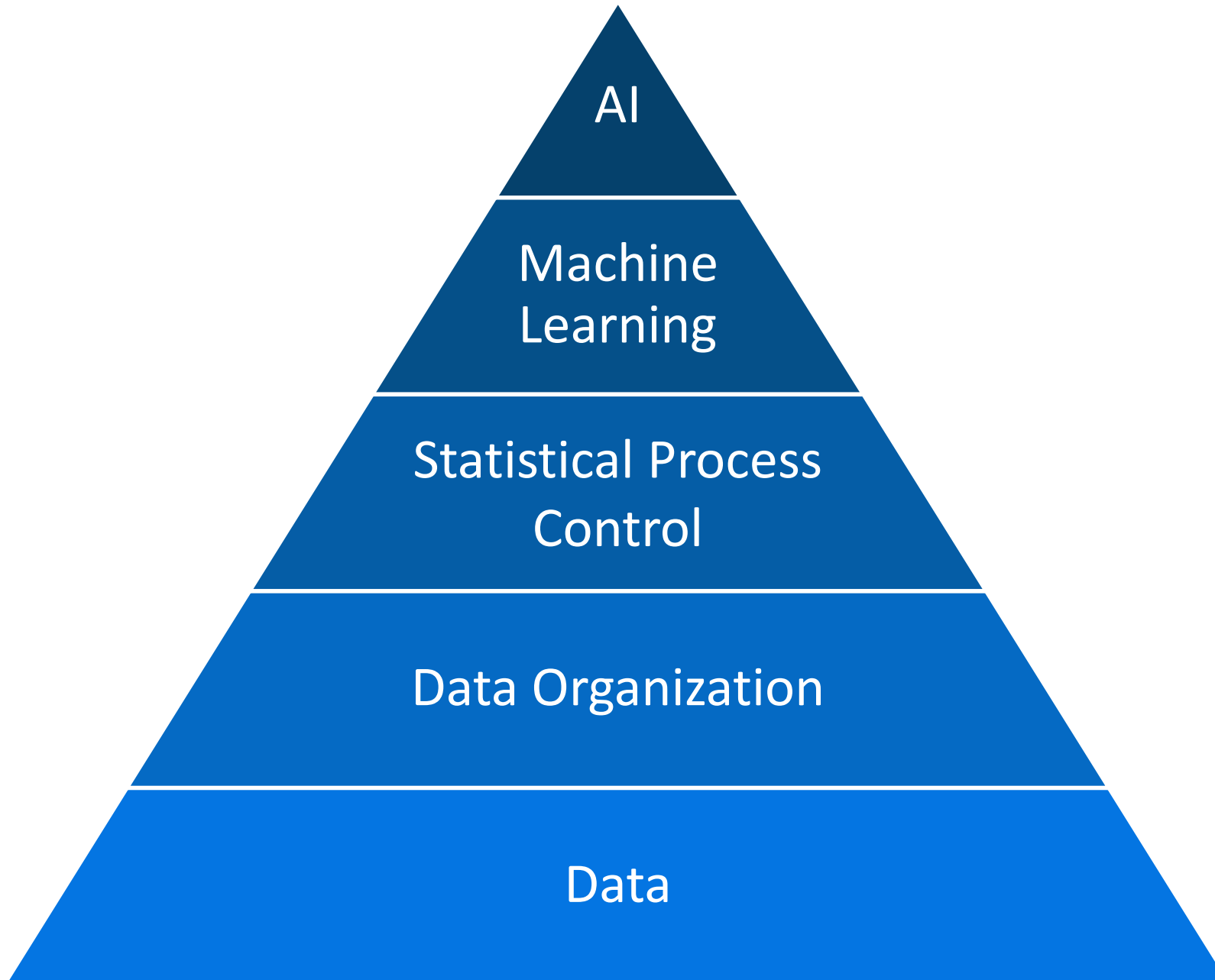
1	12/19/18 13:21:45	13691	1	606	304.1	80.0	2098	44.5	22	104	107	77	164.40	7149	6419.3	2.3	8847.334
2	12/19/18 19:31:45	13692	1	606	303.0	80.2	2048	44.5	23	101	136	77	164.01	7148	6390.6	2.3	8409.153
3	12/20/18 1:30:45	13693	1	607	303.7	81.4	2226	44.5	24	101	125	77	164.13	7149	6390.1	2.3	8478.928
4	12/20/18 7:45:45	13694	1	610	303.7	81.5	2316	44.5	25	98	132	77	164.01	7151	6327.4	2.3	8499.395
5	12/20/18 14:25:45	13695	1	610	*	109.1	2090	44.5	26	98	160	79	162.23	7150	6338.3	2.3	8611.953
6	12/21/18 7:50:45	13696	1	608	305.6	81.4	1227	45	27	108	148	80	162.42	7149	6447.5	2.3	8683.598
7	12/21/18 14:09:45	13697	1	606	304.9	82.7	2054	45	28	98	148	79	162.27	7151	6362.6	2.3	8832.448
8	12/21/18 20:24:45	13698	1	610	303.9	83.4	2061	45	29	97	144	80	162.08	7150	6406.9	2.2	7730.921
9	12/22/18 2:37:45	13699	1	610	303.2	81.2	-	45	30	97	87	80	162.21	7150	6440.3	2.2	8021.211
10	12/22/18 8:33:45	13700	1	611	303.7	80.9	2013	45	31	97	117	78	162.12	7150	6333.9	2.3	8285.421
11	12/23/18 3:43:45	13701	1	609	306.9	79.9	2140	45	32	107	87	80	162.38	7148	6525.2	2.3	7762.932
12	12/23/18 10:00:45	13702	1	606	303.7	80.9	2176	45	33	98	137	81	162.26	7149	6197.5	2.2	6291.746
13	12/23/18 16:50:45	13703	1	611	306.2	85.1	2064	45	34	98	137	82	162.29	7151	6414.4	2.2	7666.285
14	12/23/18 22:54:45	13704	1	*	311.6	81.9	2048	45	35	102	125	74	162.70	7152	6026.4	2.3	10093.03
15	12/24/18 7:31:45	13705	1	602	309.4	81.4	2090	45	36	94	280	71	162.48	7155	5982.3	2.4	11320.12
16	12/24/18 14:37:45	13706	1	645	309.5	84.2	2043	45	37	95	183	74	161.79	7157	5705.0	2.3	11832.73
17	12/24/18 20:33:45	13707	1	603	312.2	85.8	2088	45	38	99	105	79	162.27	7153	6245.2	2.2	9638.71
18	12/25/18 2:45:45	13708	1	603	309.8	82.2	2050	45	39	94	119	70	162.32	7156	5818.0	2.2	11451.3
19	12/25/18 10:40:45	13709	1	603	310.2	81.5	1877	45	40	96	244	72	162.21	7153	6043.8	3.0	11545.26
20	12/25/18 17:26:45	13710	1	602	312.4	85.1	2055	45	41	96	167	77	162.22	7154	6183.0	2.9	10347.01
21	12/26/18 0:00:45	13711	1	609	309.1	84.7	2022	45	42	96	168	80	158.78	7151	6091.4	2.8	8602.66
22	12/26/18 6:03:45	13712	1	609	309.7	83.9	2145	45	43	94	139	72	158.57	7158	5812.0	2.8	11900.13
23	12/26/18 12:55:45	13713	1	603	312.7	83.9	2022	46	44	99	173	79	162.23	7153	6170.2	2.8	9911.619
24	12/26/18 18:22:45	13714	1	605	307.8	85.4	2051	45	45	98	137	81	162.18	7150	6102.3	2.9	7056.47
25	12/27/18 1:04:45	13715	1	606	308.3	84.7	1971	45	46	100	111	81	162.20	7150	6211.3	2.9	7109.498
26	12/27/18 6:48:45	13716	1	606	308.8	83.8	2158	45	47	101	109	80	162.03	7149	6233.1	2.9	8123.546
27	12/27/18 12:44:45	13717	1	609	313.8	84.4	2019	45	48	106	112	80	161.58	7147	6333.8	2.9	8759.883
28	12/27/18 18:53:45	13718	1	603	307.8	84.7	1897	45	49	104	130	78	161.39	7149	6197.8	2.8	8932.923
29	12/28/18 0:59:45	13719	1	602	307.0	85.2	2097	45	50	104	128	79	161.53	7150	6237.0	2.9	9211.07
30	12/28/18 7:06:45	13720	1	602	309.8	85.0	2012	45	51	103	130	78	161.62	7151	6163.3	2.7	9938.528
31	12/28/18 16:17:45	13721	1	598	308.8	85.6	1937	45	52	118	288	85	161.21	7151	6004.8	2.7	9866.975
32	12/28/18 22:40:45	13722	1	597	312.8	86.3	1953	45	53	120	120	85	161.08	7151	6000.9	2.9	10469.81
33	12/29/18 5:20:45	13723	1	596	307.0	85.0	1852	45	54	117	130	83	161.17	7151	6356.3	2.7	9537.63
34	1/11/19 19:03:45	13725	3	595	307.9	86.4	2031	45	56	108	438	66	160.93	7148	6067.6	2.9	10104.2
35	1/12/19 2:10:45	13726	1	599	300.7	87.9	1907	45	57	119	166	88	160.92	7150	6326.3	2.8	7165.784
36	1/12/19 8:16:45	13727	1	577	305.3	85.4	1906	45	58	117	109	84	160.97	7151	6336.5	2.8	10049.31
37	1/12/19 15:02:45	13728	1	602	303.1	83.5	1944	45	59	117	162	82	160.99	7148	6277.2	2.8	8655.688
38	1/12/19 21:23:45	13729	1	602	306.0	84.0	1797	45	60	118	125	85	160.93	7148	6433.7	2.9	9941.389
39	1/13/19 4:11:45	13730	1	605	302.9	82.6	1735	45	61	119	155	83	160.85	7144	6283.0	2.9	8540.879
40	1/13/19 10:39:45	13731	1	602	303.4	83.5	2005	45	62	118	132	83	160.97	7147	6282.8	2.7	9694.854
41	1/13/19 17:10:45	13732	1	603	302.9	82.5	1946	45	63	116	124	80	160.97	7147	6046.4	2.9	9181.318
42	1/13/19 23:45:45	13733	1	602	304.9	83.1	2076	45	64	119	122	81	160.89	7145	6235.5	2.9	9758.116
43	1/14/19 6:23:45	13734	1	602	303.3	83.5	2041	45	65	117	140	80	160.99	7147	6148.1	2.9	9389.709
44	1/14/19 12:50:45	13735	1	602	303.7	83.9	2025	45	66	117	136	81	161.01	7147	6171.1	2.9	9540.422
45	1/14/19 19:23:45	13736	1	602	304.3	83.9	2013	45	67	118	135	82	161.83	7147	6187.4	3.0	9524.605
46	1/15/19 1:47:45	13737	1	602	305.9	83.6	2004	45	68	120	120	82	161.73	7146	6279.8	2.9	9932.086
47	1/15/19 8:09:45	13738	1	603	309.9	83.7	1977	45	69	121	121	82	161.88	7146	6287.2	2.9	9844.036
48	1/15/19 14:20:45	13738	1	602	312.1	83.6	1980	45	70	119	124	81	161.91	7147	6095.9	2.4	10440.04

Average Time Spent Daily – Manually Collecting, Organizing, Preparing Data



Avg Annual time spent, per person,
manually manipulating data

24,910
minutes annually

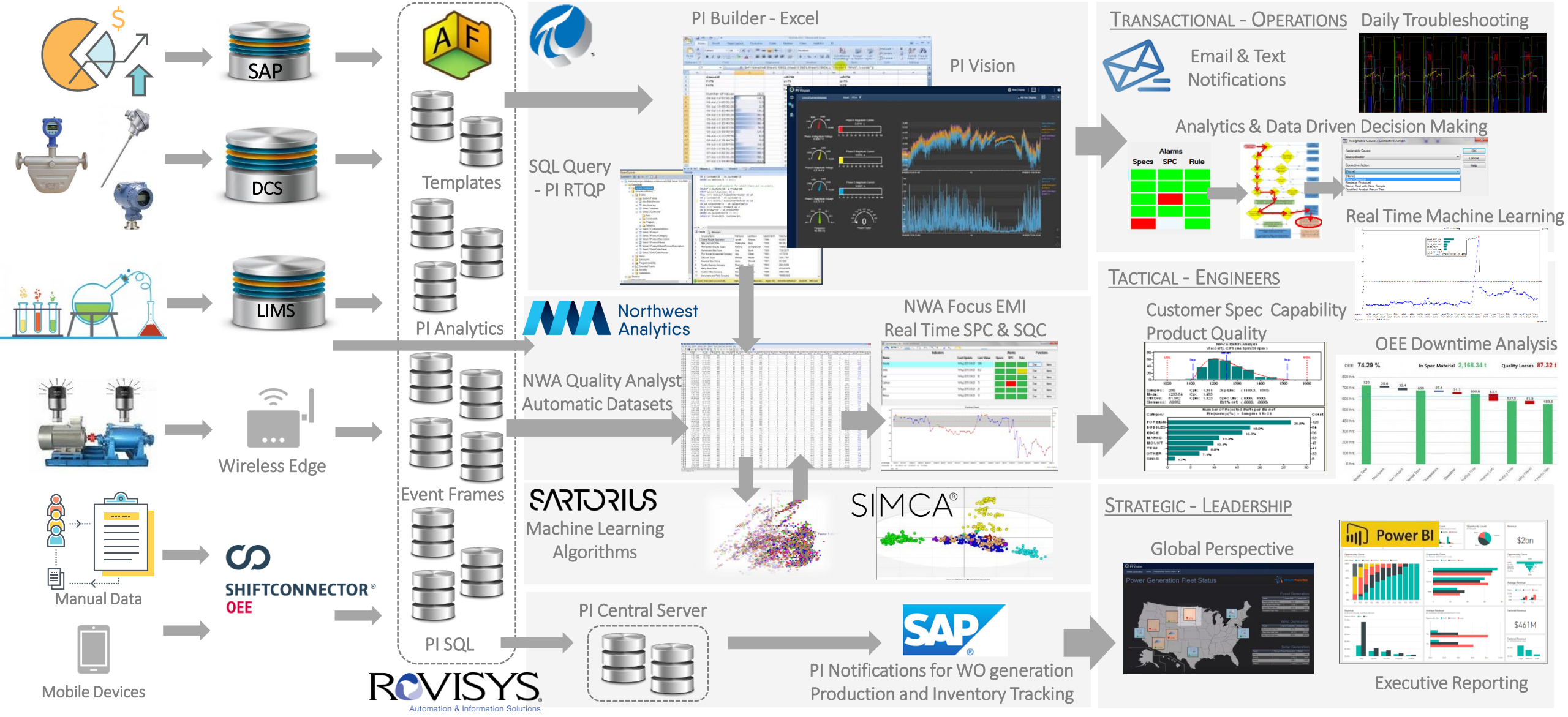


DATA SOURCES

AVEVA PI SYSTEM ASSET FRAMEWORK

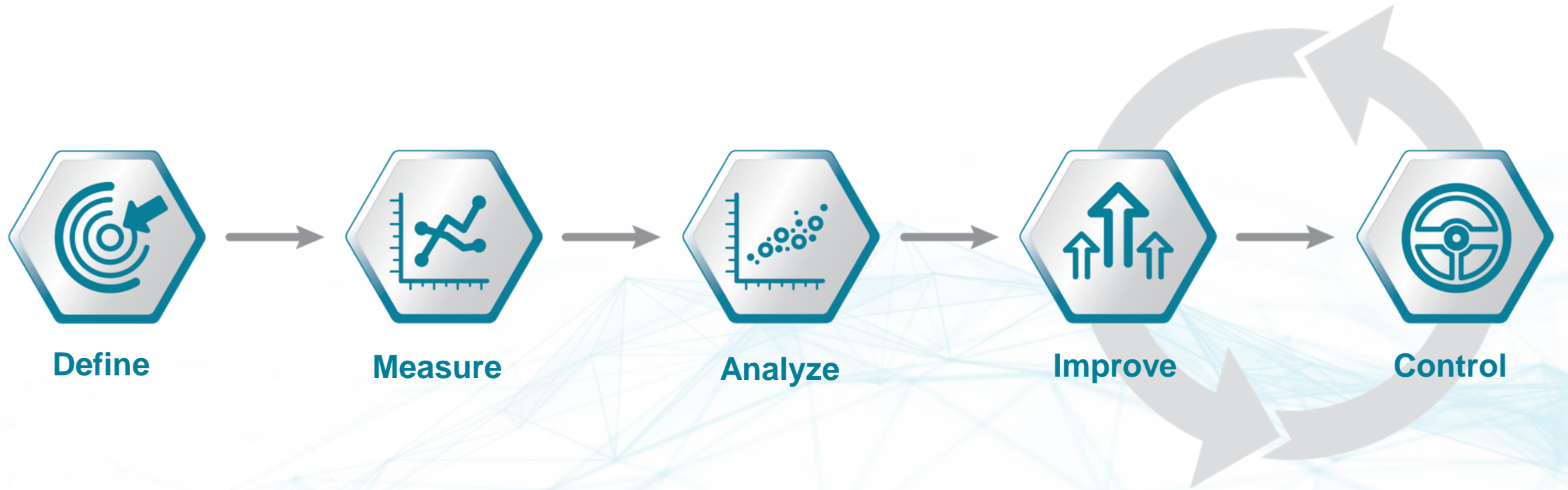
DATA ANALYTICS SUITE

USER ROLES





Six Sigma: Manual Version



Six Sigma: Automated



Define



Measure



Analyze

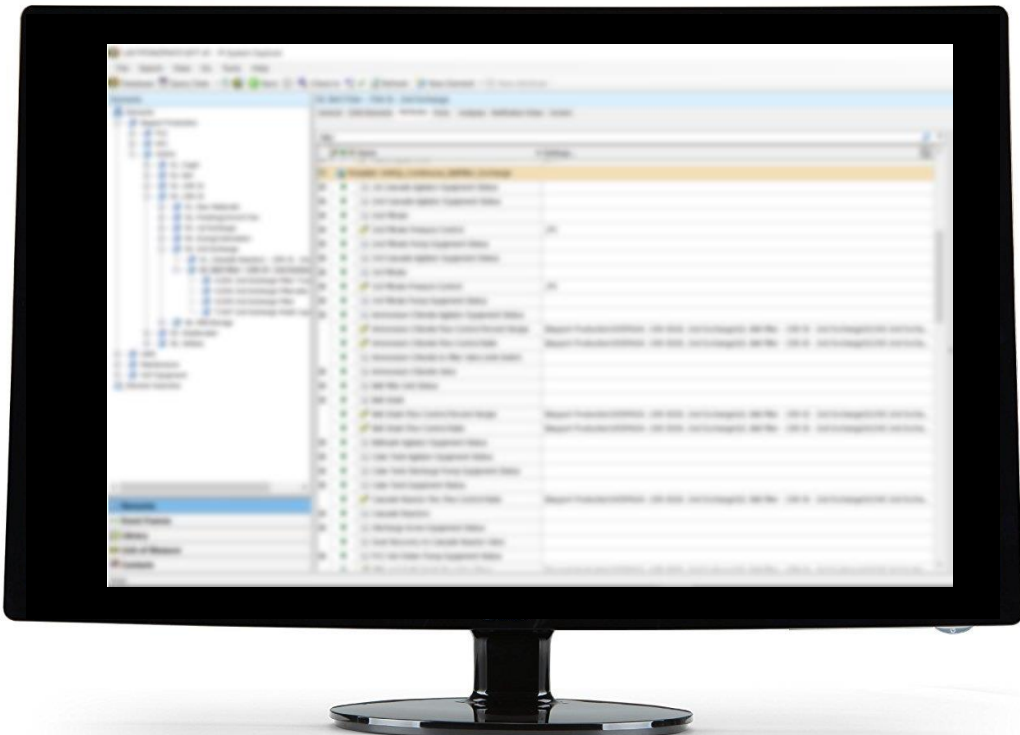
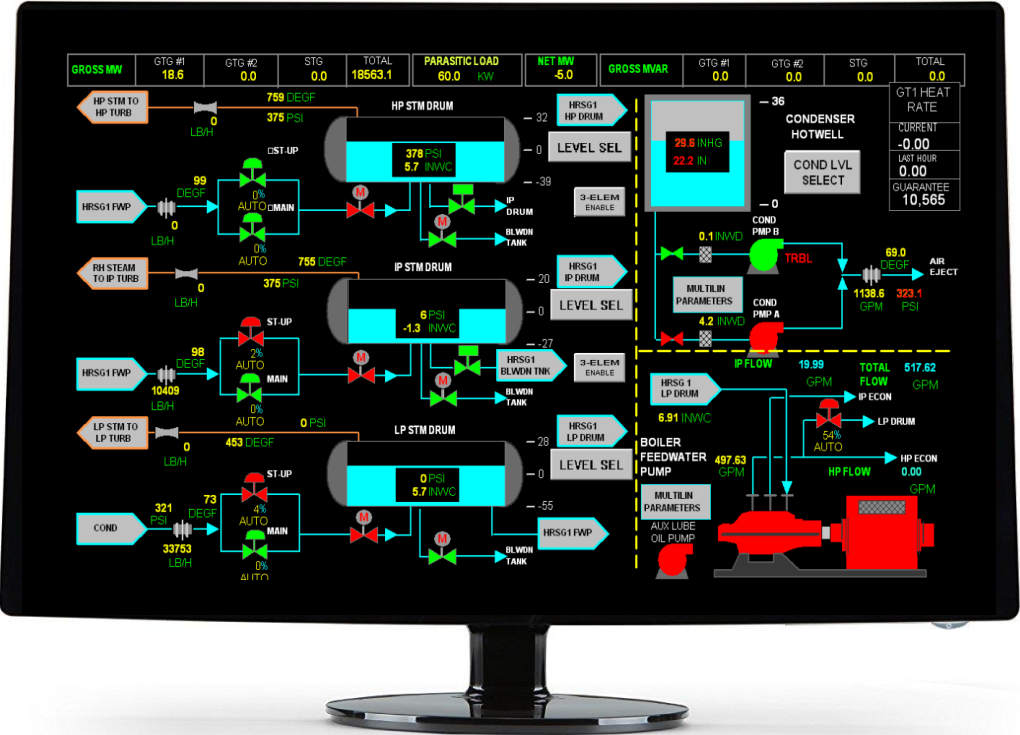


Improve

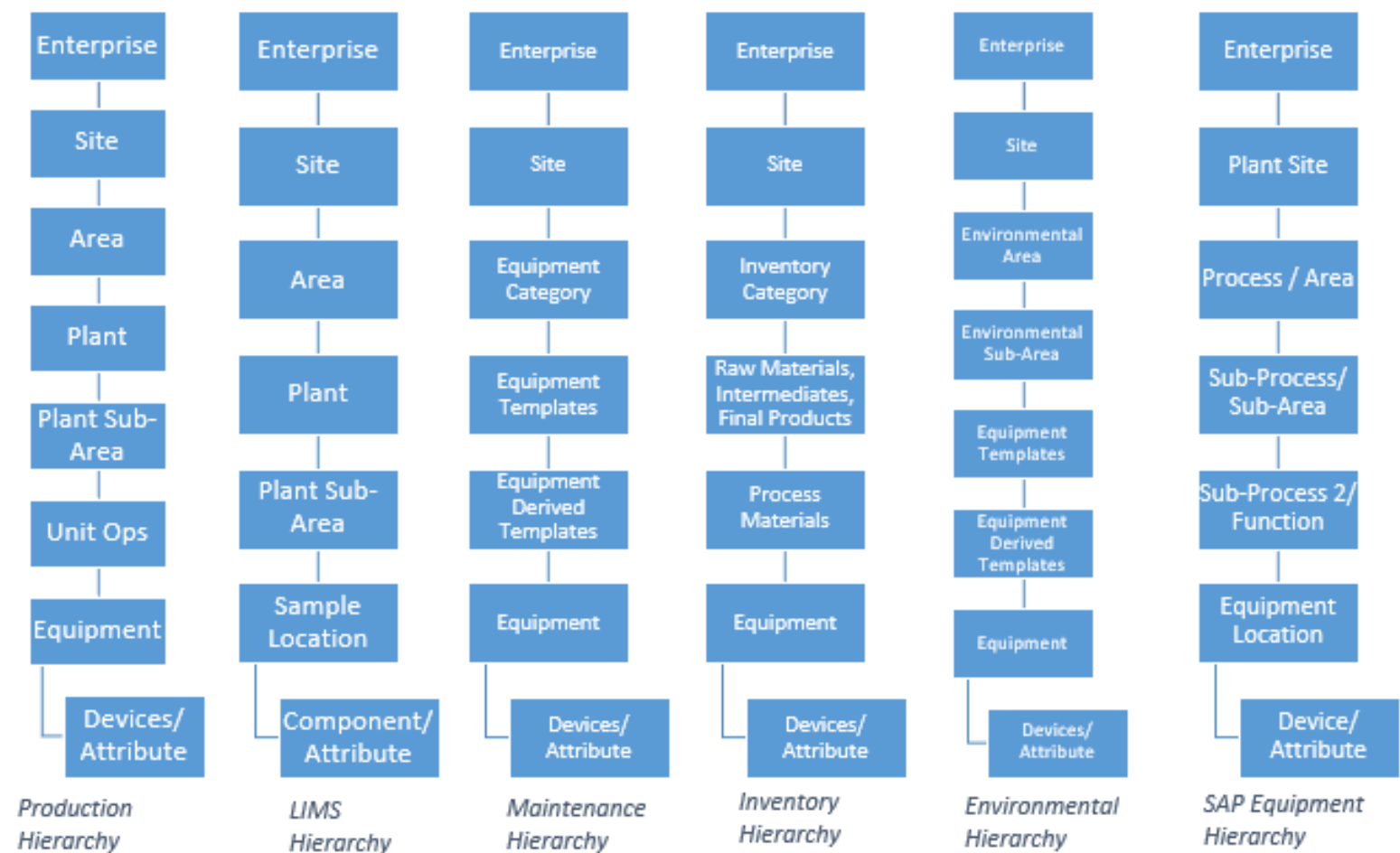


Control

DEFINE



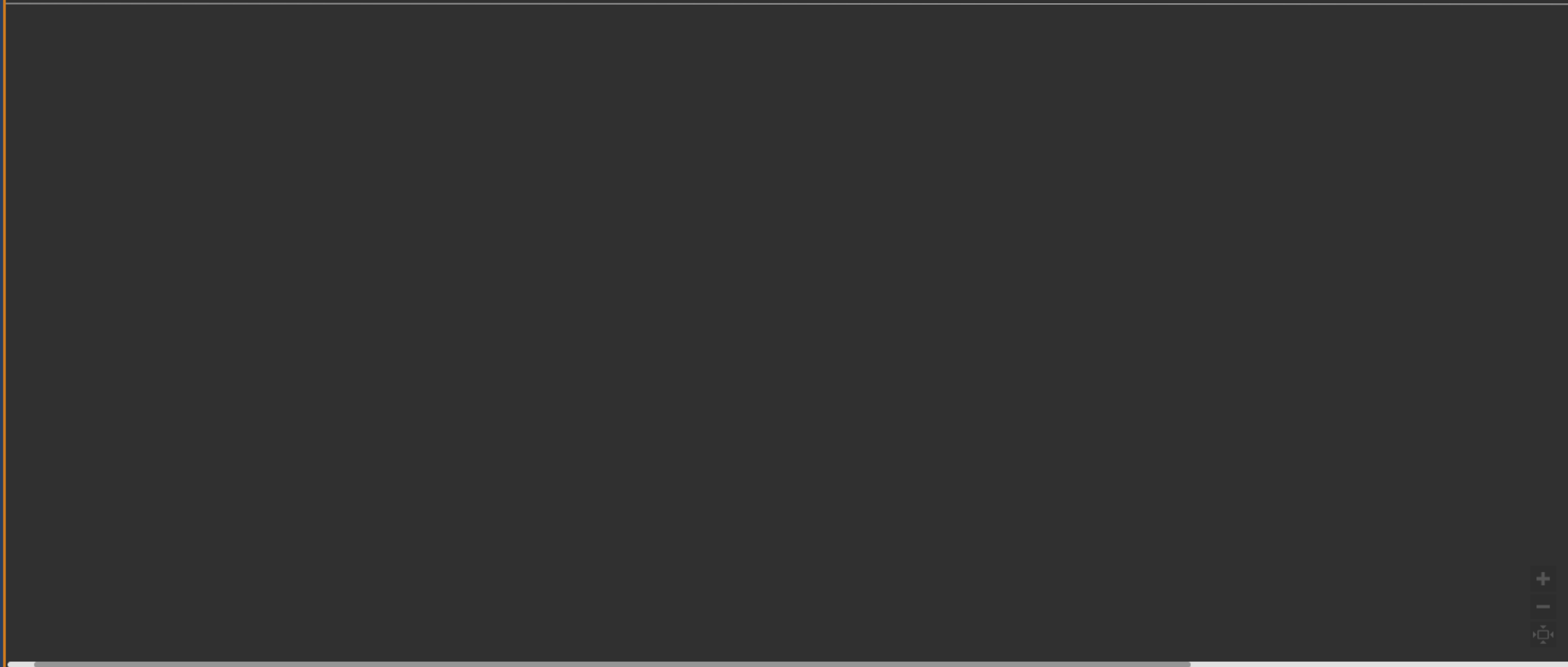
Global Asset Framework Hierarchy Standard





Area Link / Plant Link / Unit Op Name

Procedure Links





Area Link / Plant Link / Unit Op Name

Procedure Links

Equipment ###

CX2834

FU4854

FA8493

Feed UnitOp Link

AAXXXX

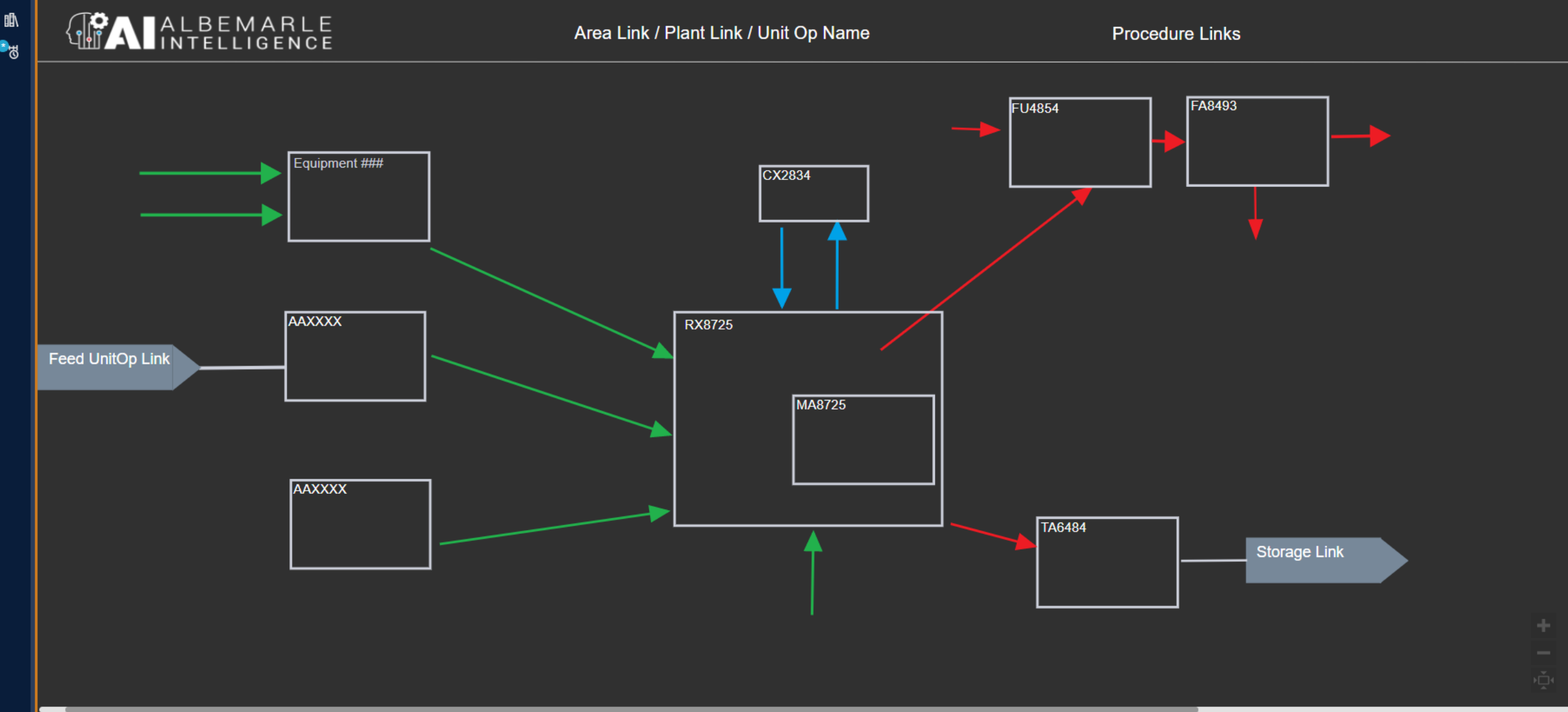
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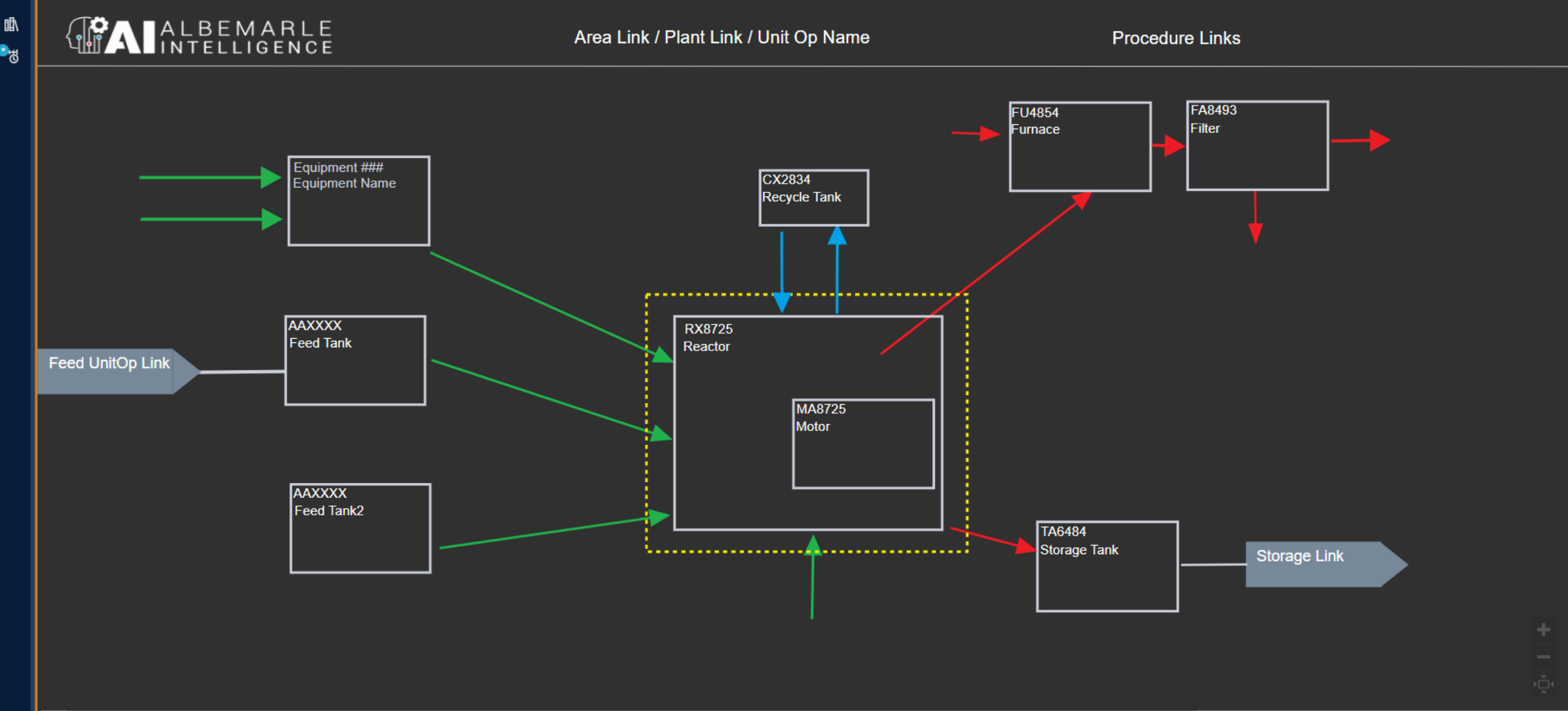
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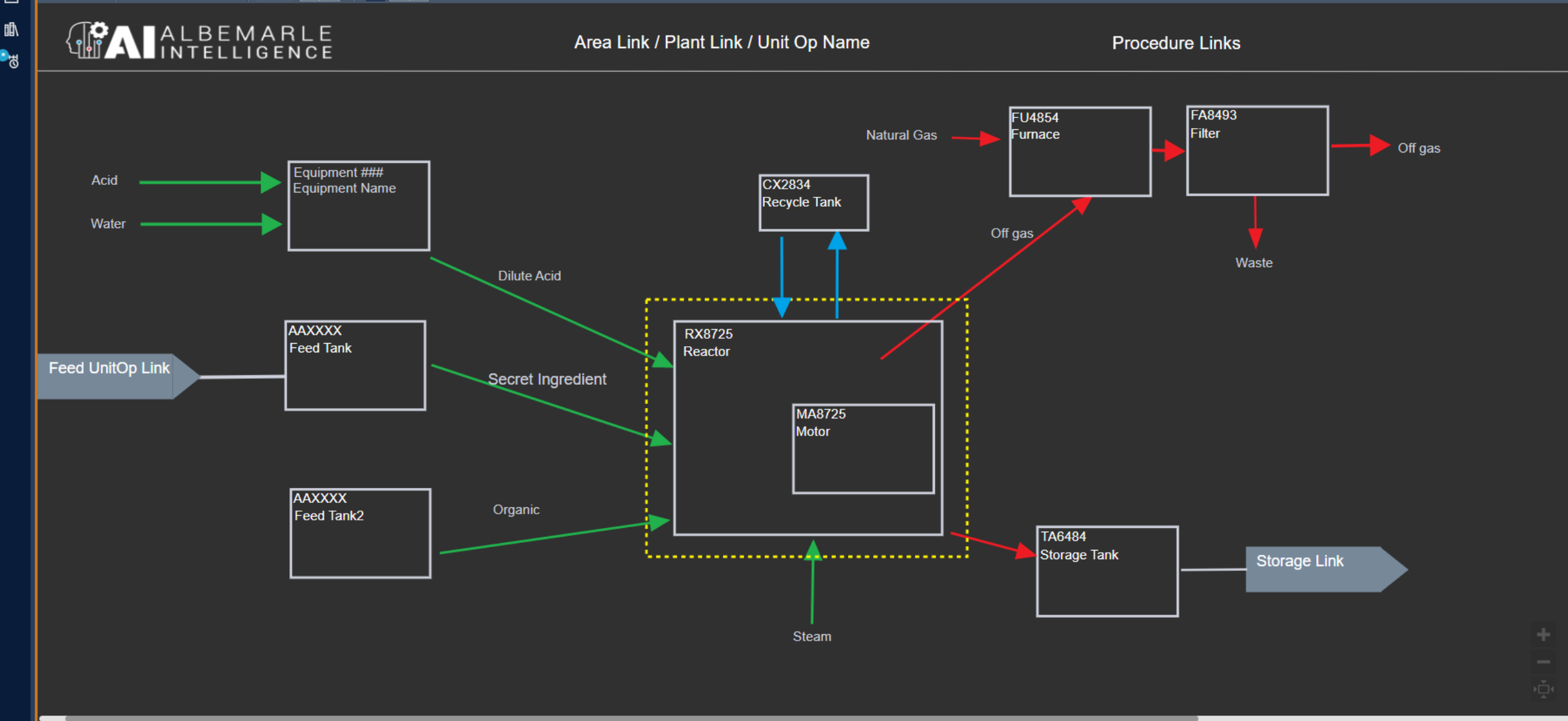
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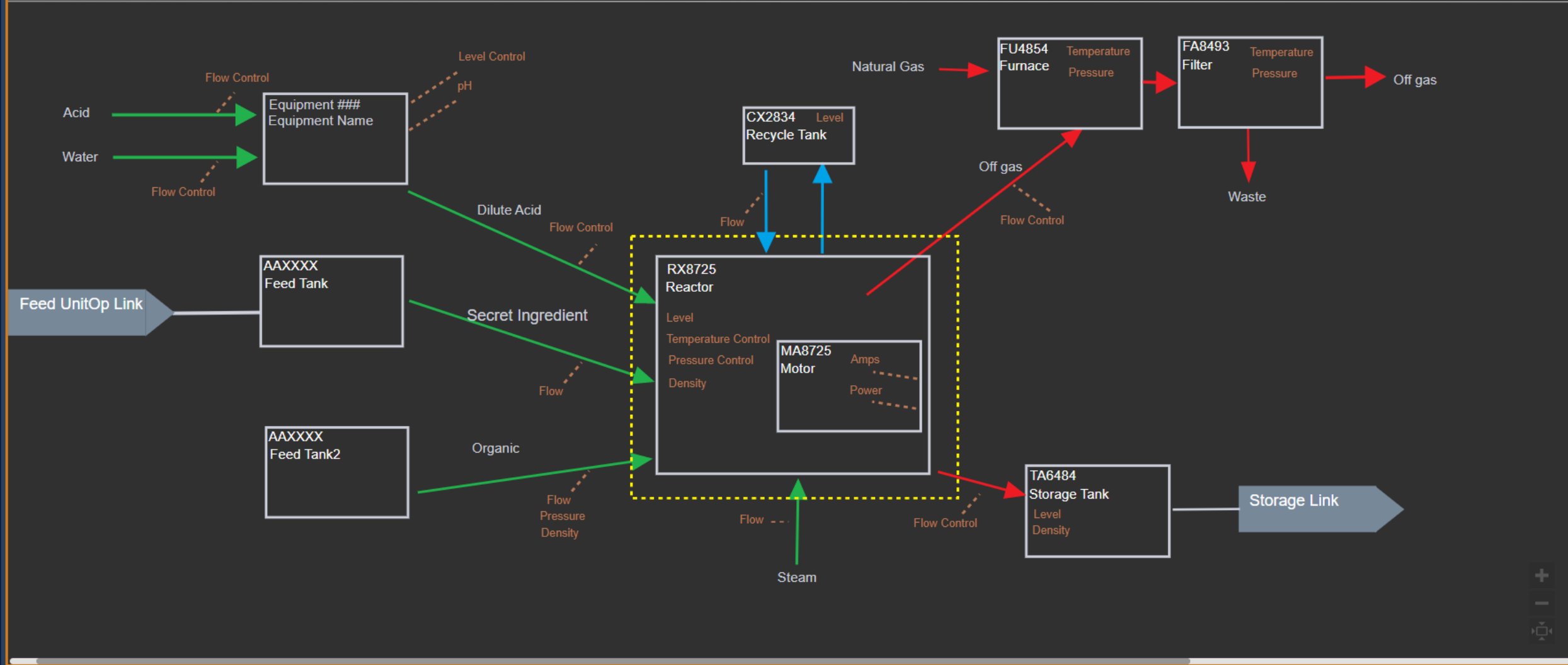
TA6484

Storage Link









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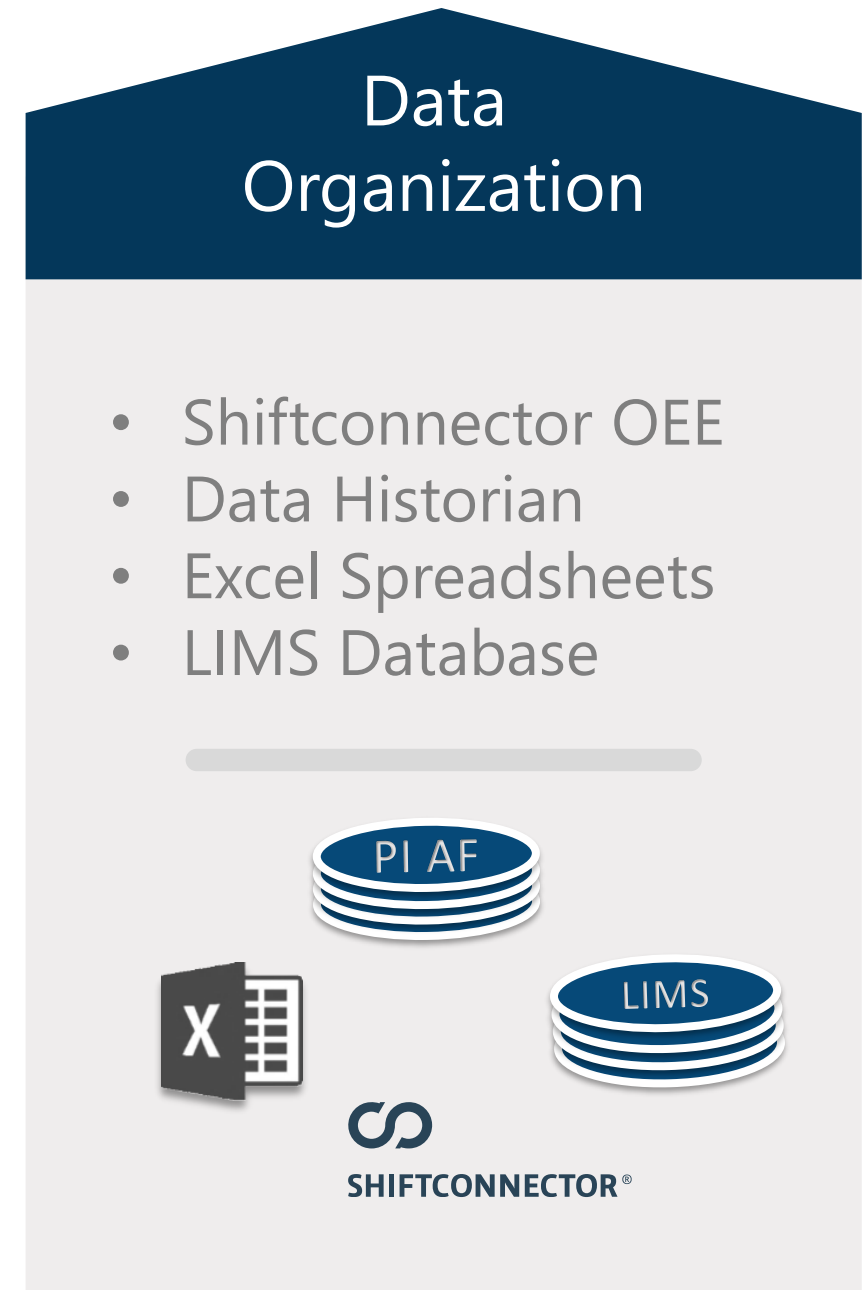
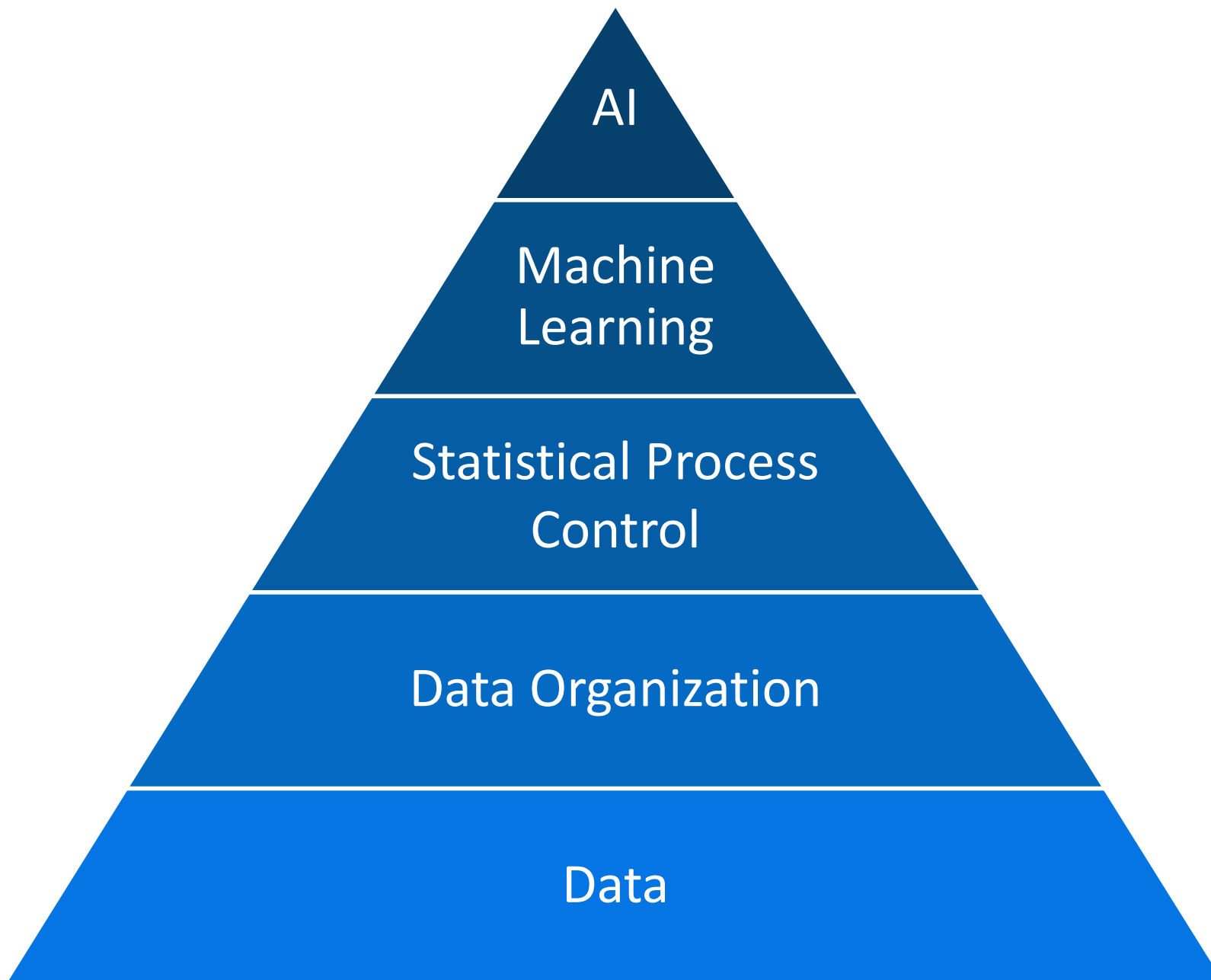
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LEADING INDEPENDENT PROVIDER OF COMPREHENSIVE AUTOMATION & INFORMATION SOLUTIONS

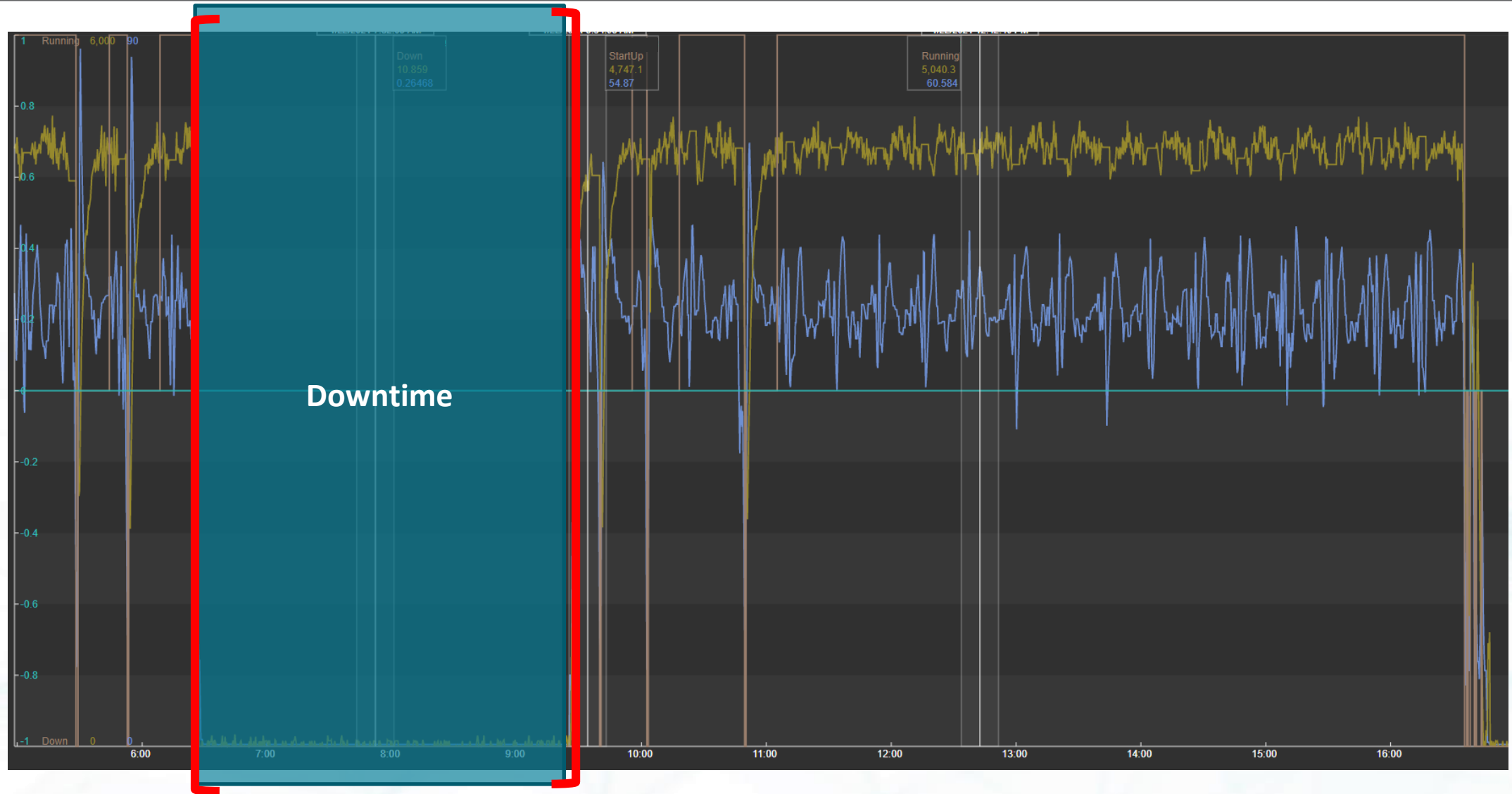
AVEVA
ENDORSED
System
Integrator

Endorsed Operate

ROVISYS
Automation & Information Solutions



Using Event Frames to capture Production Downtime



PI Event Frames Mapping to Shift Screen

Event Frame Search 1

Name	[00:02:53.398...	Duration	Start Time	End Time	Desc	Category	Template	Primary Element
20150325_092301		0:02:53.398	3/24/2015 10:23..	3/24/2015 10:...		OSIBatch	Procedure	
UP_BLEND:1-1		0:02:00.029	3/24/2015 10:23..	3/24/2015 10:...		OSIBatch	UnitProcedure	UM_BLEND_500
OP_CHARGE:1-1		0:01:00.015	3/24/2015 10:23..	3/24/2015 10:...		OSIBatch	Operation	UM_BLEND_500

1
Get event, e.g.
unit procedure

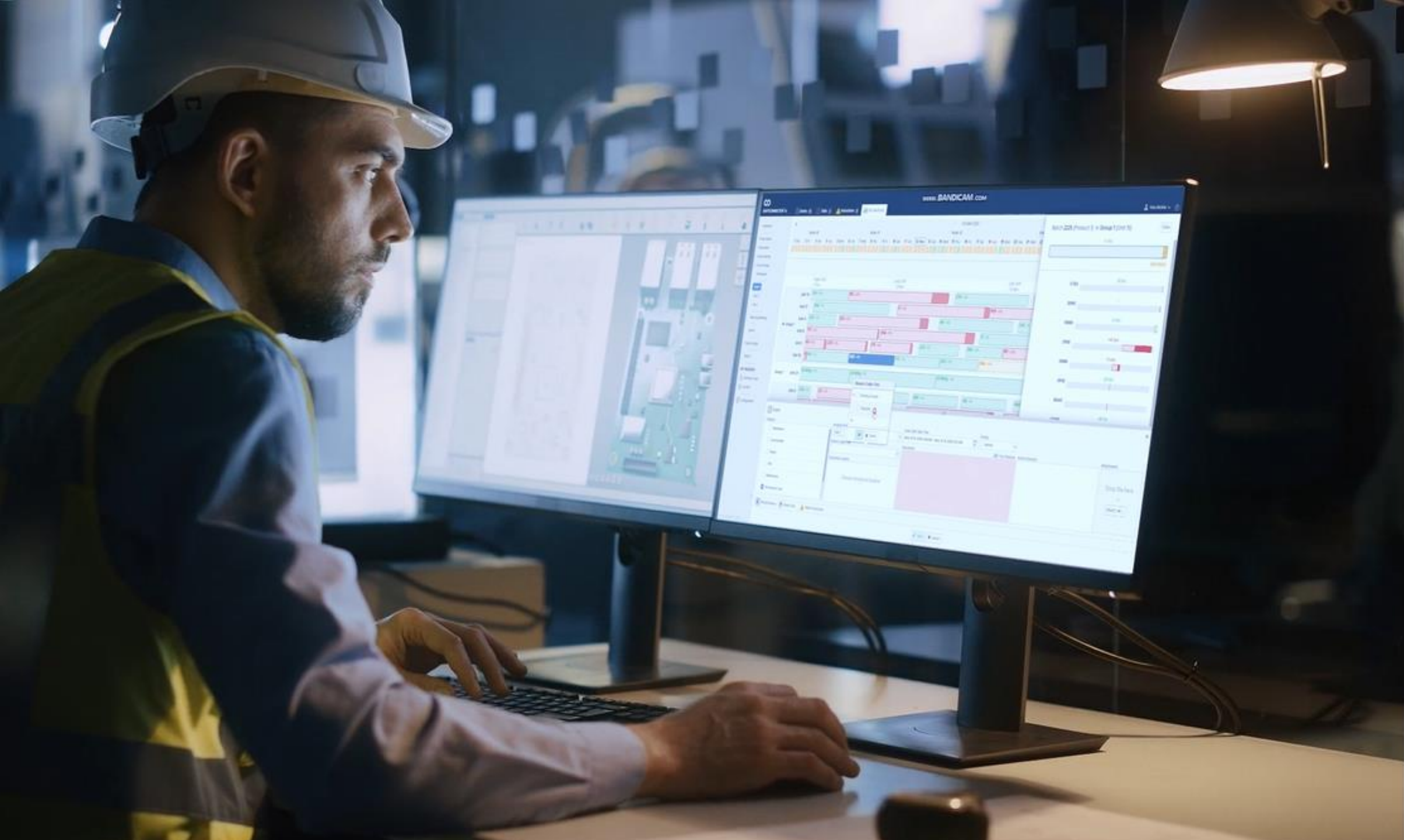
2
Get element
hierarchy level

3
Visualize in
Shiftconnector OEE

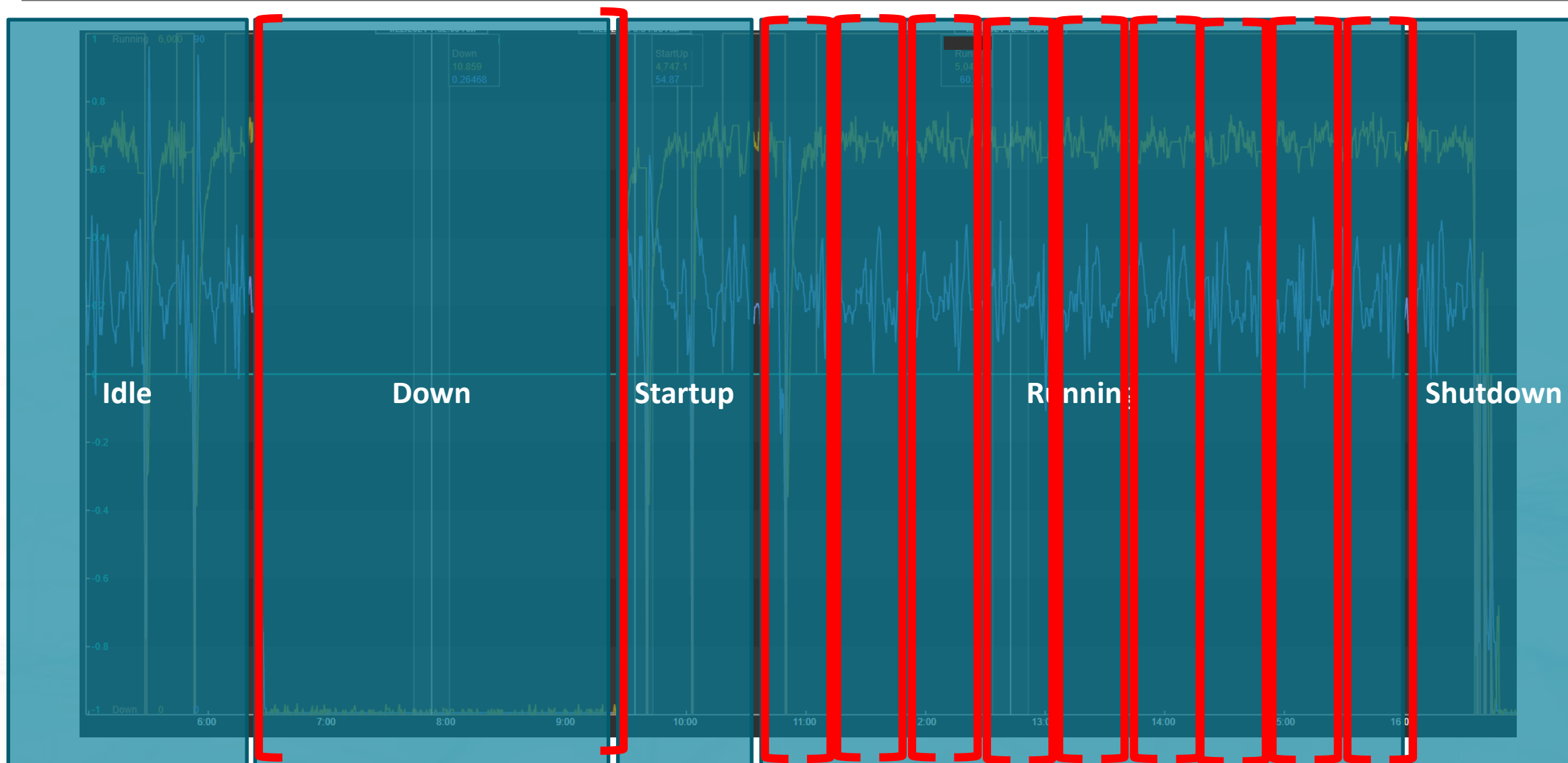


SHIFTCONNECTOR®

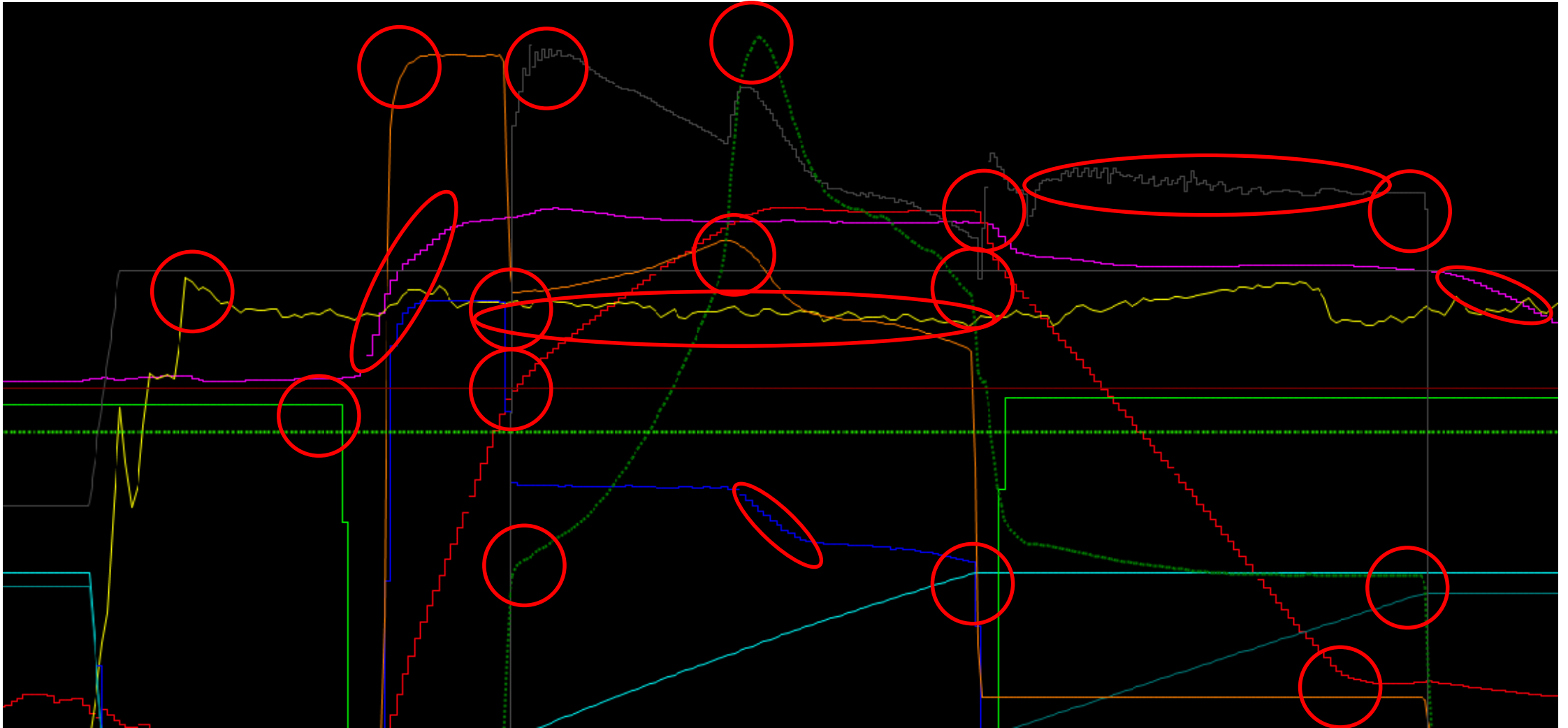
eschbach



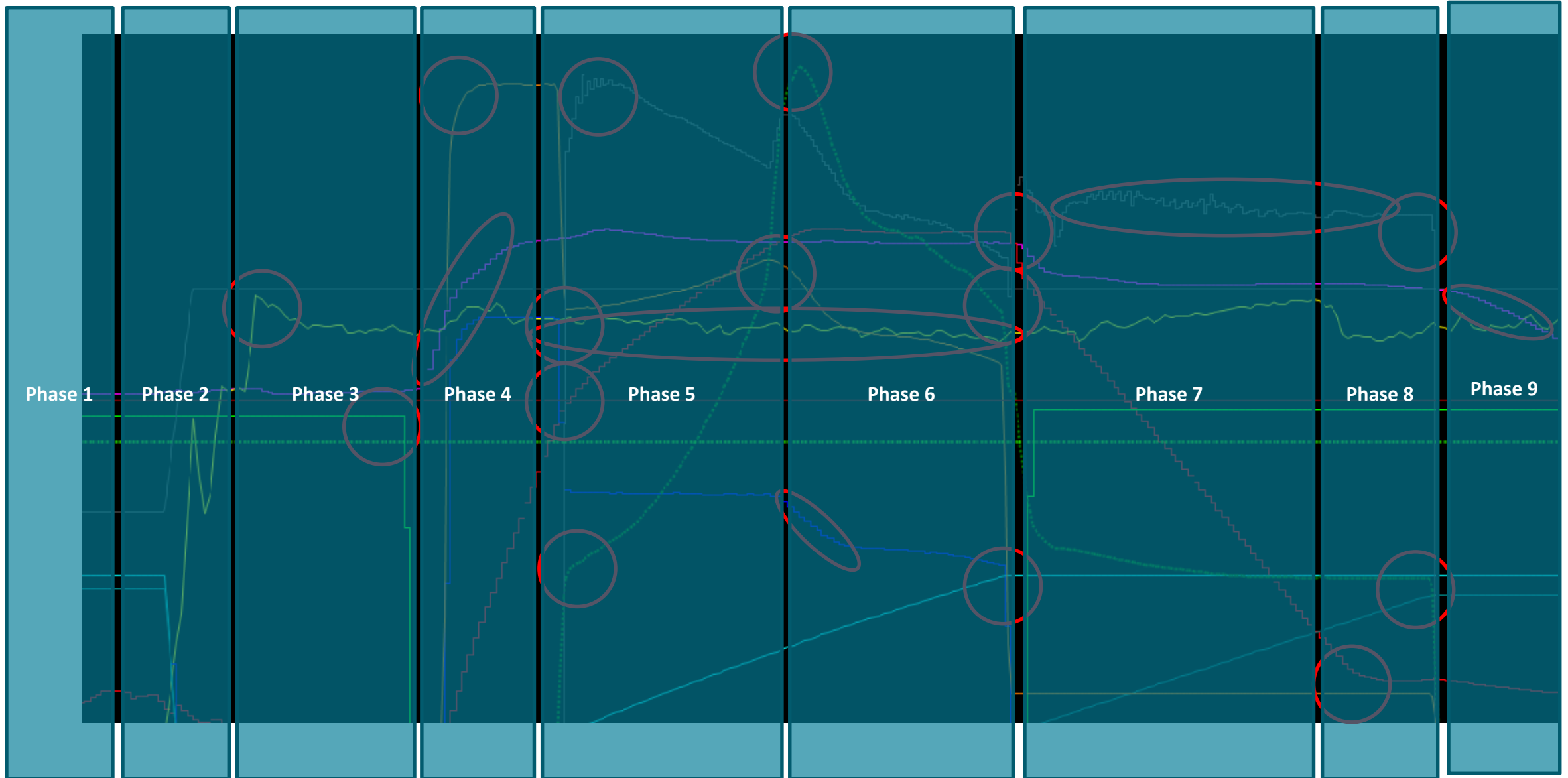
Dataset Theory – Continuous Unit Operation - Status Flag



Finding the Key Process Indicators & Inflection Points



PI Asset Framework Event Frames - Capturing Key Process Indicators



1/8/20 12:06 PM	10001	1	8,000	x	x	x	x	x	x	x	x	x
1/8/20 12:07 PM	10001	2	x	200	x	x	x	x	x	x	x	x
1/8/20 12:12 PM	10001	3	x	x	5000	x	x	x	x	x	x	x
1/8/20 12:19 PM	10001	3	x	x	x	315	x	x	x	x	x	x
1/8/20 2:20 PM	10001	5	x	x	x	x	120	x	x	x	x	x
1/8/20 2:56 PM	10001	5	x	x	x	x	x	600	x	x	x	x
1/8/20 3:06 PM	10001	5	x	x	x	x	x	x	12,000	x	x	x
1/8/20 3:11 PM	10001	6	x	x	x	x	x	x	x	2.13	x	x
1/8/20 3:14 PM	10001	8	x	x	x	x	x	x	x	x	25	x
1/8/20 3:19 PM	10001	9	x	x	x	x	x	x	x	x	x	12
1/8/20 3:20 PM	10002	1	8,000	x	x	x	x	x	x	x	x	x
1/8/20 3:21 PM	10002	2	x	200	x	x	x	x	x	x	x	x
1/8/20 3:26 PM	10002	3	x	x	5000	x	x	x	x	x	x	x
1/8/20 3:33 PM	10002	3	x	x	x	315	x	x	x	x	x	x
1/8/20 5:34 PM	10002	5	x	x	x	x	120	x	x	x	x	x
1/8/20 6:10 PM	10002	5	x	x	x	x	x	600	x	x	x	x
1/8/20 6:20 PM	10002	5	x	x	x	x	x	x	12,000	x	x	x
1/8/20 6:25 PM	10002	6	x	x	x	x	x	x	x	2.13	x	x
1/8/20 6:28 PM	10002	8	x	x	x	x	x	x	x	x	25	x
1/8/20 6:33 PM	10002	9	x	x	x	x	x	x	x	x	x	12
1/8/20 6:34 PM	10003	1	8,000	x	x	x	x	x	x	x	x	x
1/8/20 6:35 PM	10003	2	x	200	x	x	x	x	x	x	x	x
1/8/20 6:40 PM	10003	3	x	x	5000	x	x	x	x	x	x	x
1/8/20 6:47 PM	10003	3	x	x	x	315	x	x	x	x	x	x
1/8/20 8:48 PM	10003	5	x	x	x	x	120	x	x	x	x	x
1/8/20 9:24 PM	10003	5	x	x	x	x	x	600	x	x	x	x
1/8/20 9:34 PM	10003	5	x	x	x	x	x	x	12,000	x	x	x
1/8/20 9:39 PM	10003	6	x	x	x	x	x	x	x	2.13	x	x
1/8/20 9:42 PM	10003	8	x	x	x	x	x	x	x	x	25	x
1/8/20 9:47 PM	10003	9	x	x	x	x	x	x	x	x	x	12

1/8/20 12:06 PM	10001	1	8,000	x	x	x	x	x	x	x	x	x
1/8/20 12:07 PM	10001	2	x	200	x	x	x	x	x	x	x	x
1/8/20 12:12 PM	10001	3	x	x	5000	x	x	x	x	x	x	x
1/8/20 12:19 PM	10001	3	x	x	x	315	x	x	x	x	x	x
1/8/20 2:20 PM	10001	5	x	x	x	x	120	x	x	x	x	x
1/8/20 2:56 PM	10001	5	x	x	x	x	x	600	x	x	x	x
1/8/20 3:06 PM	10001	5	x	x	x	x	x	x	12,000	x	x	x
1/8/20 3:11 PM	10001	6	x	x	x	x	x	x	x	2.13	x	x
1/8/20 3:14 PM	10001	8	x	x	x	x	x	x	x	x	25	x
1/8/20 3:19 PM	10001	9	x	x	x	x	x	x	x	x	x	12
1/8/20 3:24 PM	10001		8,000	200	5000	315	120	600	12,000	2.13	25	12
1/8/20 3:20 PM	10002	1	8,000	x	x	x	x	x	x	x	x	x
1/8/20 3:21 PM	10002	2	x	200	x	x	x	x	x	x	x	x
1/8/20 3:26 PM	10002	3	x	x	5000	x	x	x	x	x	x	x
1/8/20 3:33 PM	10002	3	x	x	x	315	x	x	x	x	x	x
1/8/20 5:34 PM	10002	5	x	x	x	x	120	x	x	x	x	x
1/8/20 6:10 PM	10002	5	x	x	x	x	x	600	x	x	x	x
1/8/20 6:20 PM	10002	5	x	x	x	x	x	x	12,000	x	x	x
1/8/20 6:25 PM	10002	6	x	x	x	x	x	x	x	2.13	x	x
1/8/20 6:28 PM	10002	8	x	x	x	x	x	x	x	x	25	x
1/8/20 6:33 PM	10002	9	x	x	x	x	x	x	x	x	x	12
1/8/20 6:38 PM	10002		8,006	203	5005	315.2	121.3	600	12,002	2.15	24	12.2
1/8/20 6:34 PM	10003	1	8,000	x	x	x	x	x	x	x	x	x
1/8/20 6:35 PM	10003	2	x	200	x	x	x	x	x	x	x	x
1/8/20 6:40 PM	10003	3	x	x	5000	x	x	x	x	x	x	x
1/8/20 6:47 PM	10003	3	x	x	x	315	x	x	x	x	x	x
1/8/20 8:48 PM	10003	5	x	x	x	x	120	x	x	x	x	x
1/8/20 9:24 PM	10003	5	x	x	x	x	x	600	x	x	x	x
1/8/20 9:34 PM	10003	5	x	x	x	x	x	x	12,000	x	x	x
1/8/20 9:39 PM	10003	6	x	x	x	x	x	x	x	2.13	x	x
1/8/20 9:42 PM	10003	8	x	x	x	x	x	x	x	x	25	x
1/8/20 9:47 PM	10003	9	x	x	x	x	x	x	x	x	x	12
1/8/20 9:52 PM	10003		8,003	201	5004	315.7	119	599	12,024	2.17	25.5	12.5

1/8/20 12:06 PM	10001	1												
1/8/20 12:07 PM	10001	2												
1/8/20 12:12 PM	10001	3												
1/8/20 12:19 PM	10001	3												
1/8/20 2:20 PM	10001	5												
1/8/20 2:56 PM	10001	5												
1/8/20 3:06 PM	10001	5												
1/8/20 3:11 PM	10001	6												
1/8/20 3:14 PM	10001	8												
1/8/20 3:19 PM	10001	9												
1/8/20 3:24 PM	10001		8,000	200	5000	315	120	600	12,000	2.13	25	12		
1/8/20 3:20 PM	10002	1												
1/8/20 3:21 PM	10002	2												
1/8/20 3:26 PM	10002	3												
1/8/20 3:33 PM	10002	3												
1/8/20 5:34 PM	10002	5												
1/8/20 6:10 PM	10002	5												
1/8/20 6:20 PM	10002	5												
1/8/20 6:25 PM	10002	6												
1/8/20 6:28 PM	10002	8												
1/8/20 6:33 PM	10002	9												
1/8/20 6:38 PM	10002		8,006	203	5005	315.2	121.3	600	12,002	2.15	24	12.2		
1/8/20 6:34 PM	10003	1												
1/8/20 6:35 PM	10003	2												
1/8/20 6:40 PM	10003	3												
1/8/20 6:47 PM	10003	3												
1/8/20 8:48 PM	10003	5												
1/8/20 9:24 PM	10003	5												
1/8/20 9:34 PM	10003	5												
1/8/20 9:39 PM	10003	6												
1/8/20 9:42 PM	10003	8												
1/8/20 9:47 PM	10003	9												
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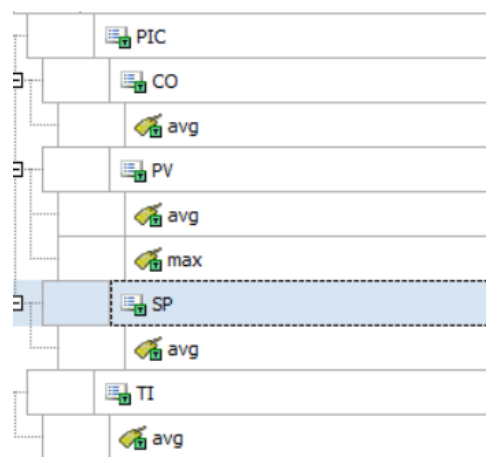
1/8/20 3:24 PM	10001		8,000	200	5000	315	120	600	12,000	2.13	25	12
1/8/20 6:38 PM	10002		8,006	203	5005	315.2	121.3	600	12,002	2.15	24	12.2
1/8/20 9:52 PM	10003		8,003	201	5004	315.7	119	599	12,024	2.17	25.5	12.5

1	12/19/18 13:21:45	13691	1	606	304.1	80.0	2098	44.5	22	104	107	77	164.46	7149	6419.3	2.3	8847.334
2	12/19/18 19:31:45	13692	1	606	303.0	80.2	2048	44.5	23	101	136	77	164.01	7148	6380.6	2.3	8409.153
3	12/20/18 1:36:45	13693	1	607	303.7	81.4	2226	44.5	24	101	125	77	164.13	7149	6386.1	2.3	8478.928
4	12/20/18 7:45:45	13694	1	610	303.7	81.8	2316	44.5	25	98	132	77	164.01	7151	6327.4	2.3	8499.395
5	12/20/18 14:25:45	13695	1	610	*	109.1	2060	44.5	26	98	160	79	162.23	7150	6338.3	2.3	8611.963
6	12/21/18 7:50:45	13696	1	608	305.6	81.4	1227	45	27	108	148	80	162.42	7149	6447.5	2.3	8683.598
7	12/21/18 14:09:45	13697	1	606	304.9	82.7	2054	45	28	98	146	79	162.27	7151	6362.6	2.3	8832.448
8	12/21/18 20:24:45	13698	1	610	303.9	83.4	2061	45	29	97	144	80	162.08	7150	6406.9	2.2	7730.021
9	12/22/18 2:37:45	13699	1	610	303.2	81.2	*	45	30	97	67	80	162.21	7150	6440.3	2.2	8021.211
10	12/22/18 8:33:45	13700	1	611	303.7	80.9	2013	45	31	97	117	78	162.12	7150	6323.9	2.3	8285.421
11	12/23/18 3:43:45	13701	1	609	306.9	79.9	2140	45	32	107	67	80	162.38	7148	6525.2	2.3	7762.582
12	12/23/18 10:00:45	13702	1	606	303.7	80.9	2176	45	33	98	137	81	162.26	7149	6197.5	2.2	6291.748
13	12/23/18 16:50:45	13703	1	611	306.2	85.1	2064	45	34	96	137	82	162.29	7151	6414.4	2.2	7566.285
14	12/23/18 22:54:45	13704	1	*	311.6	81.9	2048	45	35	102	125	74	162.70	7152	6028.4	2.3	10093.03
15	12/24/18 7:31:45	13705	1	602	309.4	81.4	2090	45	36	94	286	71	162.48	7155	5982.3	2.4	11320.12
16	12/24/18 14:37:45	13706	1	545	309.5	84.2	2043	45	37	95	183	74	161.79	7157	5706.0	2.3	11832.73
17	12/24/18 20:33:45	13707	1	603	312.2	85.8	2068	45	38	99	105	79	162.27	7153	6245.2	2.2	9536.7
18	12/25/18 2:45:45	13708	1	603	309.8	82.2	2050	45	39	94	119	70	162.32	7156	5818.0	2.2	11451.3
19	12/25/18 10:40:45	13709	1	603	310.2	81.5	1877	45	40	96	244	72	162.21	7153	6043.8	3.0	11545.26
20	12/25/18 17:26:45	13710	1	602	312.4	85.1	2055	45	41	96	167	77	162.22	7154	6183.0	2.9	10347.01
21	12/26/18 0:00:45	13711	1	609	309.1	84.7	2022	45	42	96	168	80	158.78	7151	6091.4	2.8	8602.66
22	12/26/18 6:03:45	13712	1	569	309.7	83.9	2146	46	43	94	139	72	158.57	7158	5812.0	2.8	11360.13
23	12/26/18 12:55:45	13713	1	603	312.7	83.9	2022	46	44	99	173	79	162.28	7153	6170.2	2.8	9911.619
24	12/26/18 19:22:45	13714	1	605	307.8	85.4	2051	45	45	98	137	81	162.18	7150	6102.3	2.9	7056.47
25	12/27/18 1:04:45	13715	1	606	308.3	84.7	1971	45	46	100	111	81	162.26	7150	6211.3	2.9	7109.498
26	12/27/18 6:48:45	13716	1	606	308.8	83.8	2158	45	47	101	109	80	162.03	7149	6233.1	2.9	8123.546
27	12/27/18 12:44:45	13717	1	609	313.8	84.4	2019	45	48	106	112	80	161.58	7147	6333.8	2.9	8759.883
28	12/27/18 18:53:45	13718	1	603	307.8	84.7	1897	45	49	104	130	78	161.39	7149	6197.8	2.8	8932.923
29	12/28/18 0:59:45	13719	1	602	307.0	85.2	2097	45	50	104	128	79	161.53	7150	6237.0	2.9	9011.07
30	12/28/18 7:06:45	13720	1	602	309.8	85.0	2012	45	51	103	130	78	161.62	7151	6163.3	2.7	9939.528
31	12/28/18 16:17:45	13721	1	598	308.8	85.6	1937	45	52	118	288	85	161.21	7151	6504.8	2.7	9986.975
32	12/28/18 22:40:45	13722	1	597	312.8	86.3	1953	45	53	120	120	85	161.08	7151	6600.9	2.9	10469.81
33	12/29/18 5:20:45	13723	1	596	307.0	85.0	1852	45	54	117	130	83	161.17	7151	6356.3	2.7	9537.63
34	1/11/19 19:03:45	13725	3	565	307.9	86.4	2031	45	56	108	438	56	160.93	7148	6567.6	2.9	10104.2
35	1/12/19 2:10:45	13726	1	569	300.7	87.9	1967	45	57	118	166	86	160.92	7150	6329.3	2.8	7185.784
36	1/12/19 8:16:45	13727	1	577	305.3	85.4	1966	45	58	117	109	84	160.97	7151	6336.5	2.8	10049.31
37	1/12/19 15:02:45	13728	1	602	303.1	83.5	1944	45	59	117	152	82	160.99	7148	6277.2	2.8	8655.688
38	1/12/19 21:23:45	13729	1	602	306.0	84.0	1797	45	60	118	125	85	160.93	7148	6433.7	2.9	9941.389
39	1/13/19 4:11:45	13730	1	605	302.9	82.6	1735	45	61	119	156	83	160.85	7144	6283.6	2.9	8946.879
40	1/13/19 10:39:45	13731	1	602	303.4	83.5	2006	45	62	118	132	83	160.97	7147	6282.8	2.7	9694.854
41	1/13/19 17:18:45	13732	1	603	302.9	82.5	1946	45	63	116	124	80	160.97	7147	6046.4	2.9	9181.318
42	1/13/19 23:45:45	13733	1	602	304.9	83.1	2076	45	64	119	122	81	160.89	7145	6235.5	2.9	9758.116
43	1/14/19 6:23:45	13734	1	602	303.3	83.5	2041	45	65	117	140	80	160.99	7147	6148.1	2.9	9389.709
44	1/14/19 12:50:45	13735	1	602	303.7	83.9	2025	45	66	117	136	81	161.01	7147	6171.1	2.9	9540.422
45	1/14/19 19:23:45	13736	1	602	304.3	83.9	2013	45	67	118	135	82	161.83	7147	6187.4	3.0	9524.605
46	1/15/19 1:47:45	13737	1	602	305.9	83.6	2004	45	68	120	120	82	161.73	7146	6279.8	2.9	9932.086
47	1/15/19 8:09:45	13738	1	603	309.9	83.7	1977	45	69	121	121	82	161.88	7146	6287.2	2.9	9844.636
48	1/15/19 14:26:45	13739	1	602	312.1	83.6	1980	45	70	119	124	81	161.91	7147	6095.9	2.4	10440.04

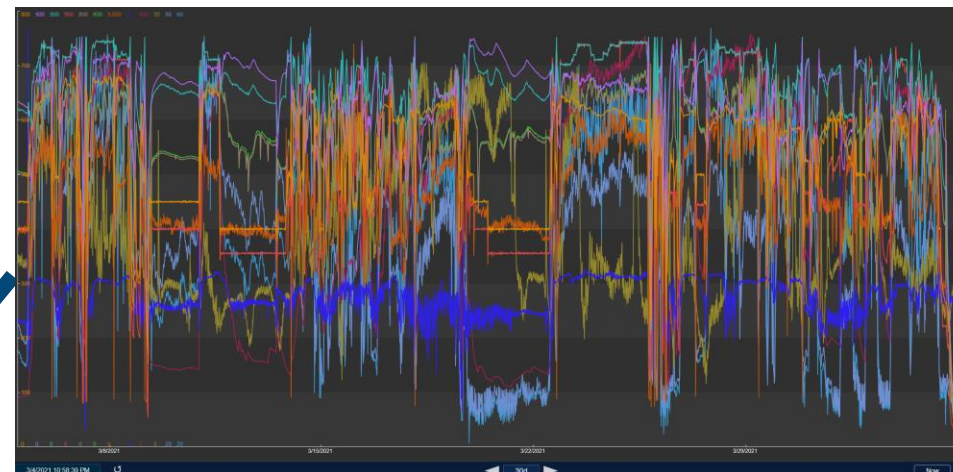
Scaling Event Frames as an Analytics Engine

- Event Frames created to be triggered when unit is down, starting up, or running at steady state.
- PI Vision utilized when deciding which attributes to capture and what summary analytics were needed for best analysis of calciner performance
- Query to align EF on an hourly basis onto a single row.
- Filter Dataset by Relational Fields:
 - Product
 - Recipe
 - Campaign
 - Unit Operation
 - Shift
 - Status Flag
 - Weather
- LIMS Laboratory data can be merged with PI Process data to predict production rate and quality issues

PI Builder – Automated Event Frame & Output Analytic Generator
Capture Key Process Indicators

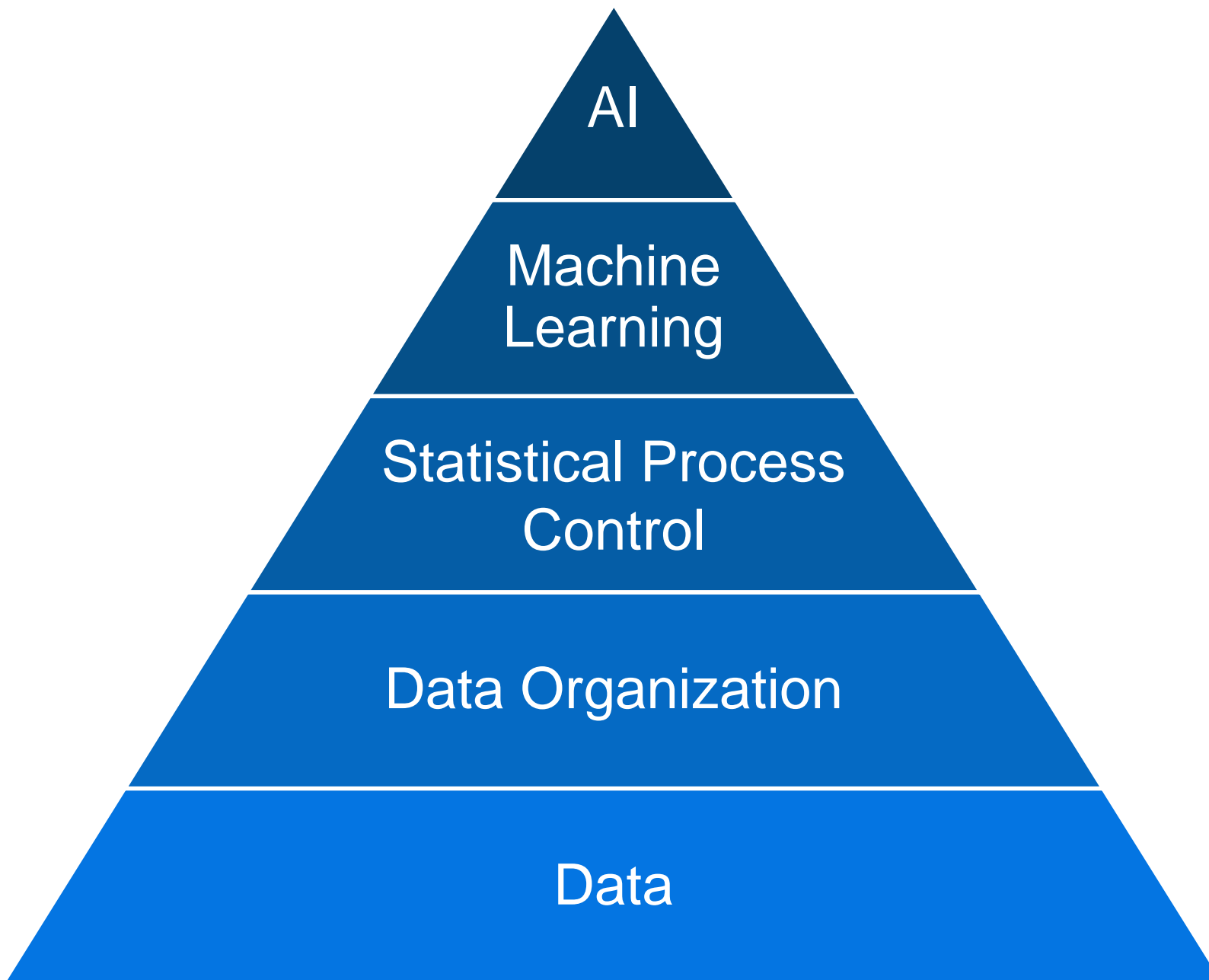


PI Vision – Time Series Trend




Time Series Data converted to NWA Automated Dataset

Running	0.3718942	2.909119	216.495738900325	-0.1321941	383.8147
StartUp	-0.4279914	-0.2840576	322.860671633938	0.1736194	63.82583
Running	-0.4223962	-0.3425598	305.745576461575	0.1763347	62.06646
Shutdown	-0.4734771	-0.324707	298.052300682118	0.1772715	61.86706
Running	0.2159671	0.4127502	220.930605507834	-0.1006555	313.9682
Down	-0.5094602	-0.2527466	284.357069405793	0.1859251	60.79785
StartUp	-0.5613872	-0.3166433	278.476235698077	0.2133375	68.21075
Running	-0.5736619	-0.4169922	284.672640178253	0.2123941	73.50066
Running	-1.567335	0.441864	137.47848703637	-0.1426007	371.2763
Running	-0.5626348	8.453369E-03	302.569833874908	0.2008539	71.44946
Running	-1.412884	0.4262085	102.067914653533	-0.1506102	391.2102
Running	-0.5321657	-0.1895752	360.876072756626	0.2073481	70.59
Running	0.4135617	0.4399414	93.1583761218026	-0.1361288	355.4965
Running	-0.539593	-0.2280273	405.759095291282	0.2009507	73.90455
Running	0.4200543	0.4533997	88.5530691171617	-0.1277233	384.5705
Running	-0.5278784	-0.1741943	414.219982169718	0.196907	75.8298
Running	0.4203337	0.4443359	86.7404389593375	-0.1268579	388.081
Running	-0.5972258	-0.2887268	408.247929732666	0.1513973	124.4997
Running	0.4149729	0.4399414	84.805173803336	-0.1262336	389.712
Running	-0.5588144	-0.2571411	414.147331062345	0.213384	71.81898
Running	0.4115643	0.441864	84.9105852121235	-0.1293062	392.6315
Running	-0.5406891	-0.131073	435.808046336968	0.2040336	69.80434
Running	-0.174948	0.419342	86.0640458073636	-0.1368737	400.9058
Running	-0.5188184	-0.2796631	400.786887646635	0.237986	80.87172
Running	0.2648312	0.9035645	142.866938346426	-0.133588	368.343
Running	-0.5269991	-0.2887268	425.40655445341	0.2053514	80.04122
Running	0.4027434	0.6423645	171.854726951085	-0.1557973	370.0322
Running	-0.5193281	-0.2077026	443.191644130461	0.2043966	81.53143
Running	0.5225884	1.459473	212.481242306819	-0.1425536	389.6417
Running	-0.5414297	-0.3021851	456.241302642243	0.1967892	83.35027
Running	0.5620538	1.268311	258.128296187607	-0.1338389	391.7454



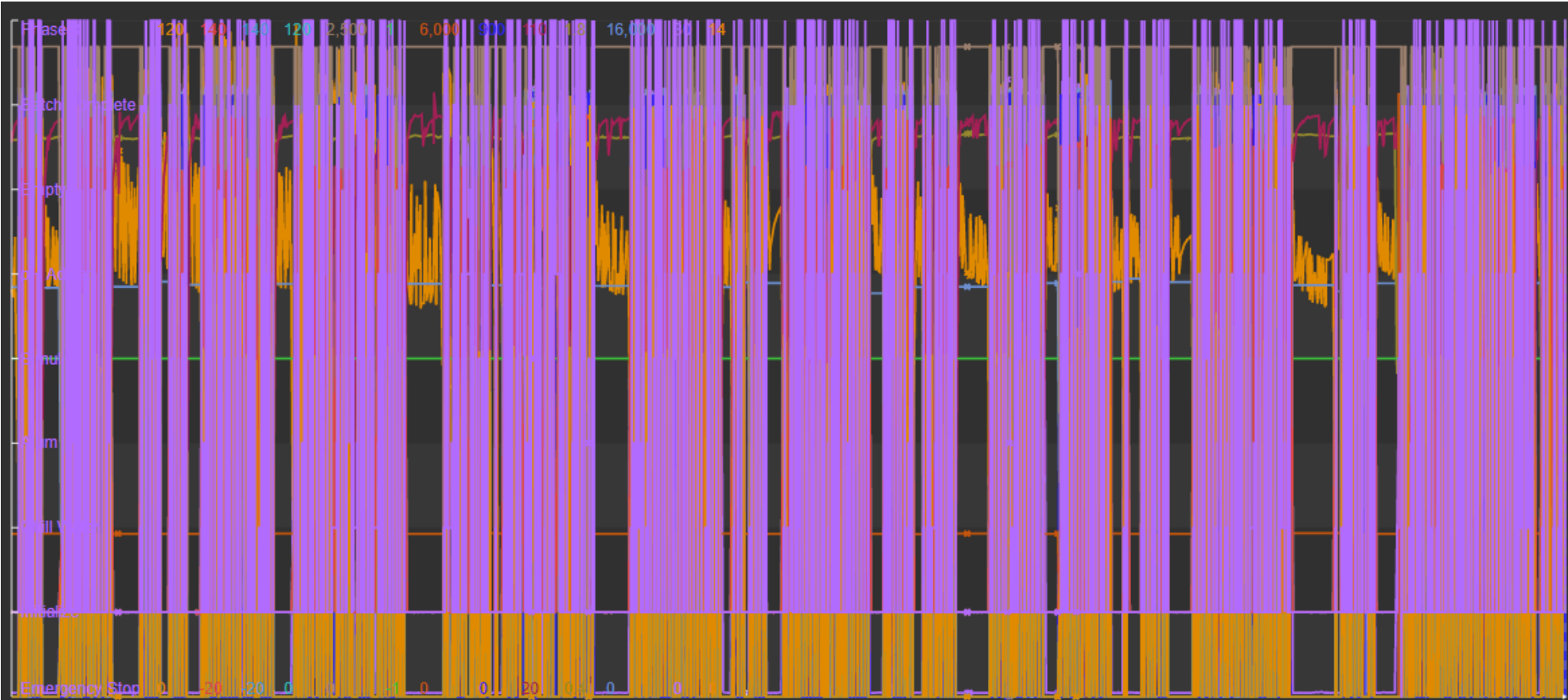
Statistical Process Control

- SPC
- Eliminating Noise
- Focus on What Matters

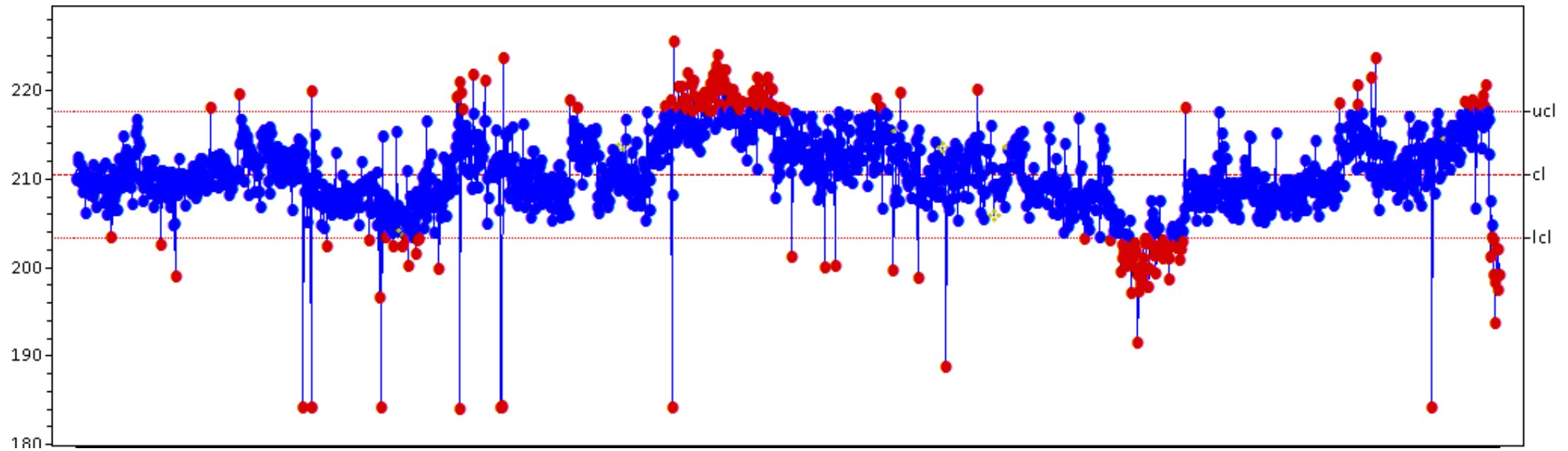


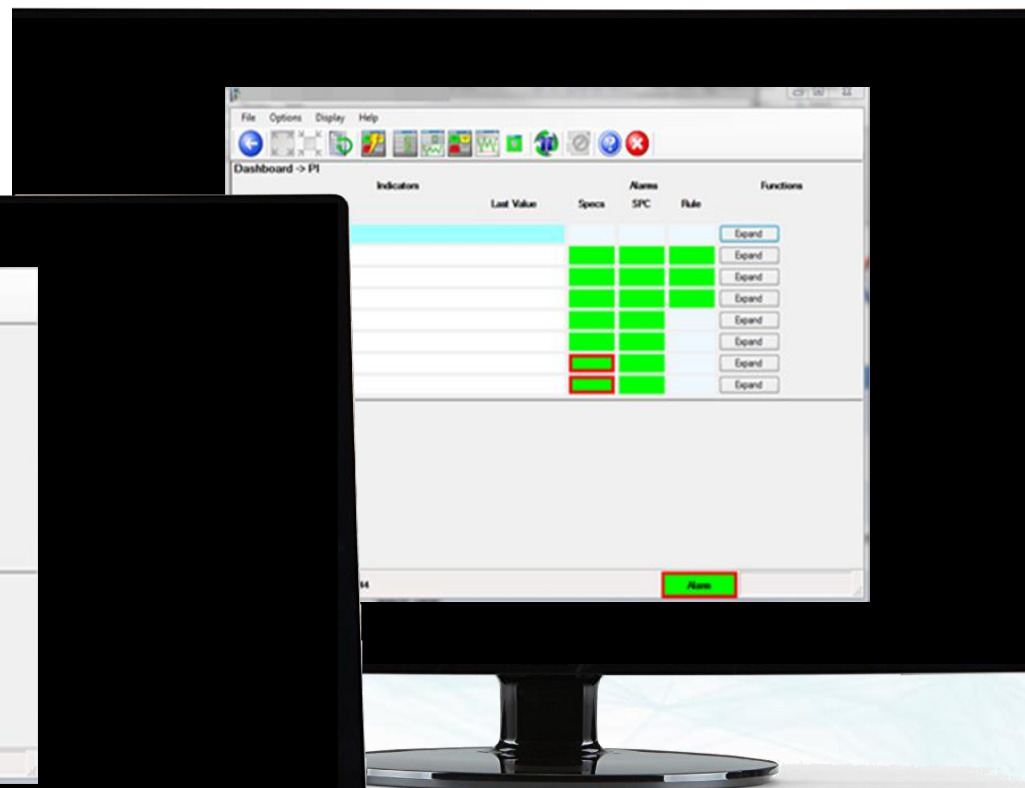
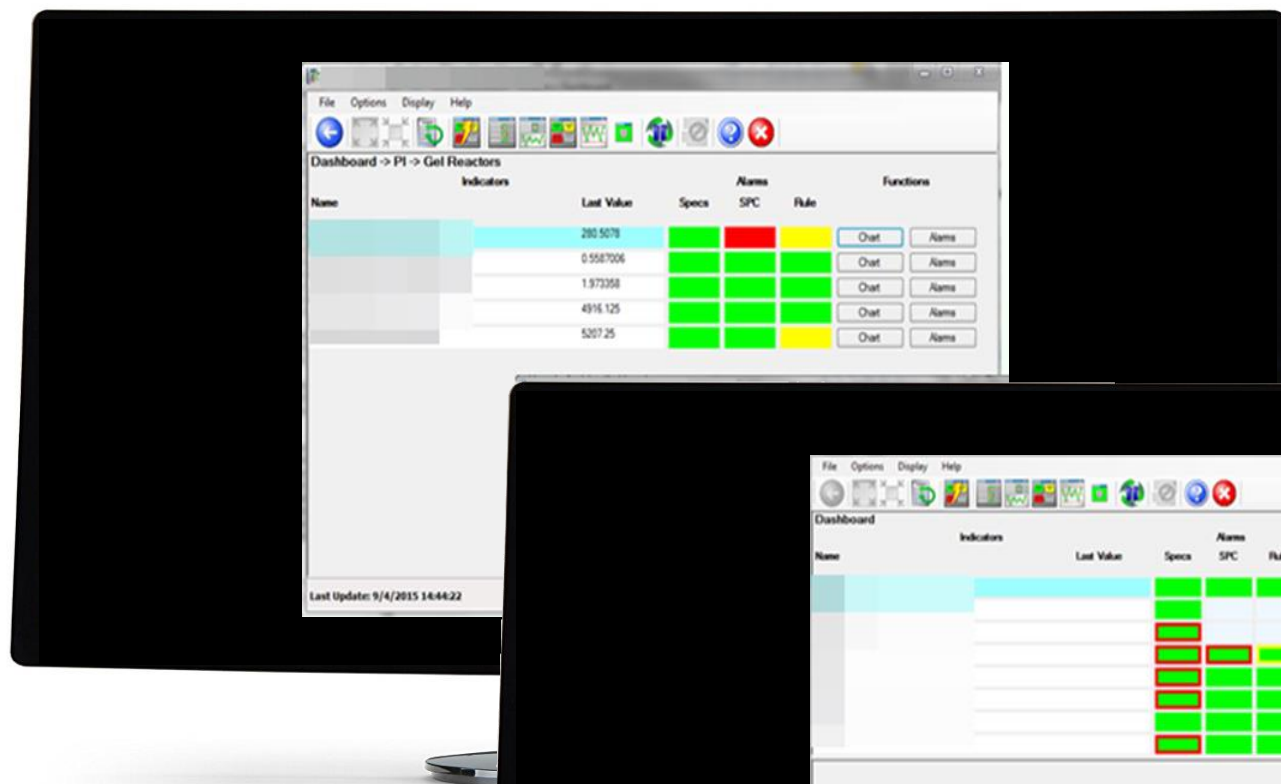
The Northwest Analytics logo features a stylized 'M' made of blue and dark blue geometric shapes. Below the logo is a line graph with data points connected by a blue line. The graph has three horizontal control limits: USL (Upper Specification Limit), ucl (Upper Control Limit), and cl (Center Line). Two data points are highlighted with yellow callouts: one at ROW: 45 DATETIME: 6/31/14 11:50:08 and another at ROW: 58 DATETIME: 6/20/14 16:31:18.

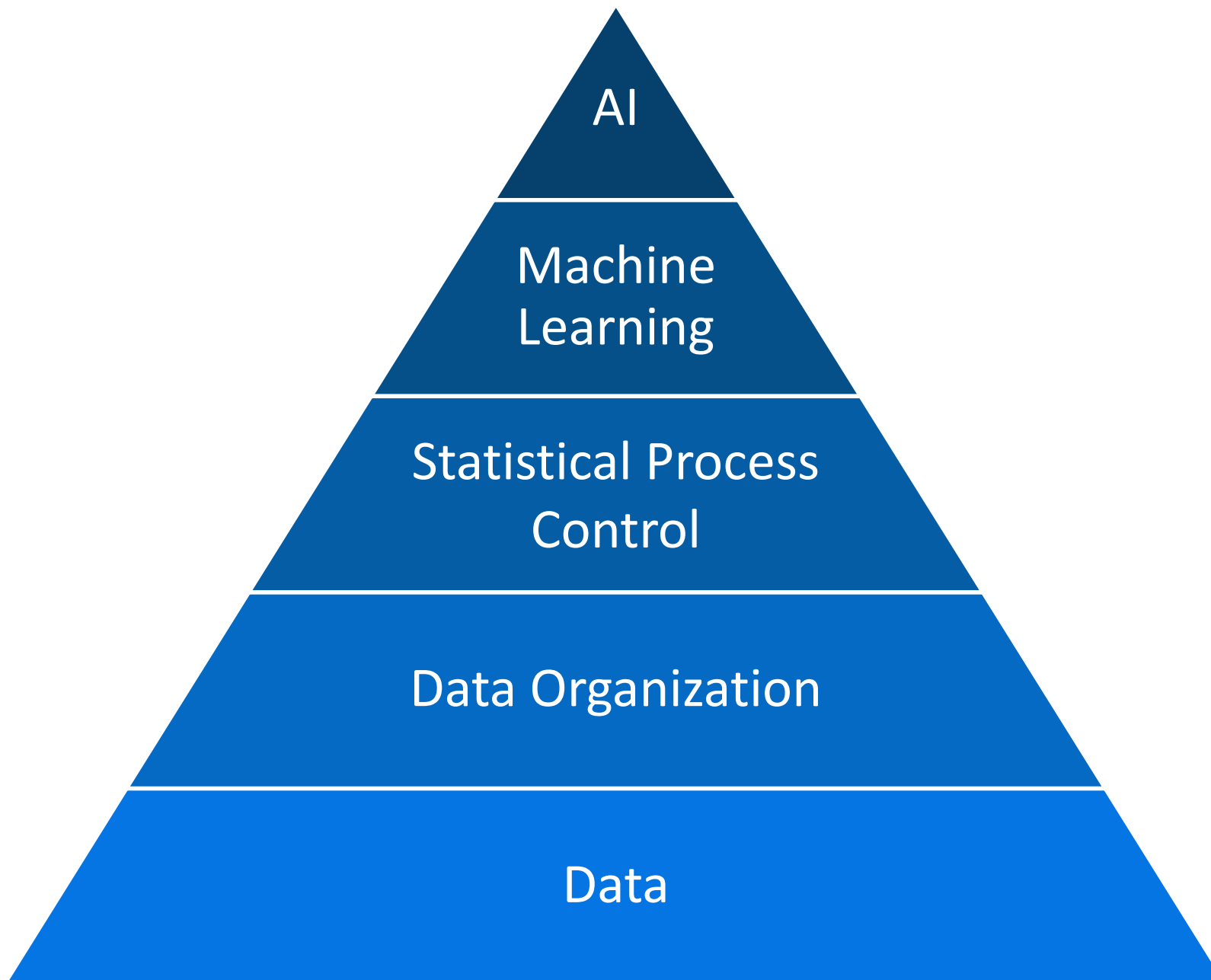
3 Month PI Vision Trend – No Event Frames



3 Month Statistical Analysis – w/ Event Frames

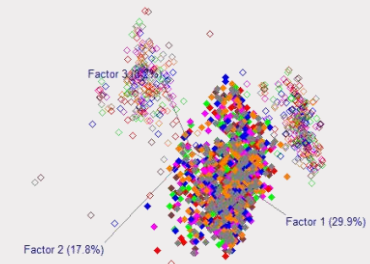




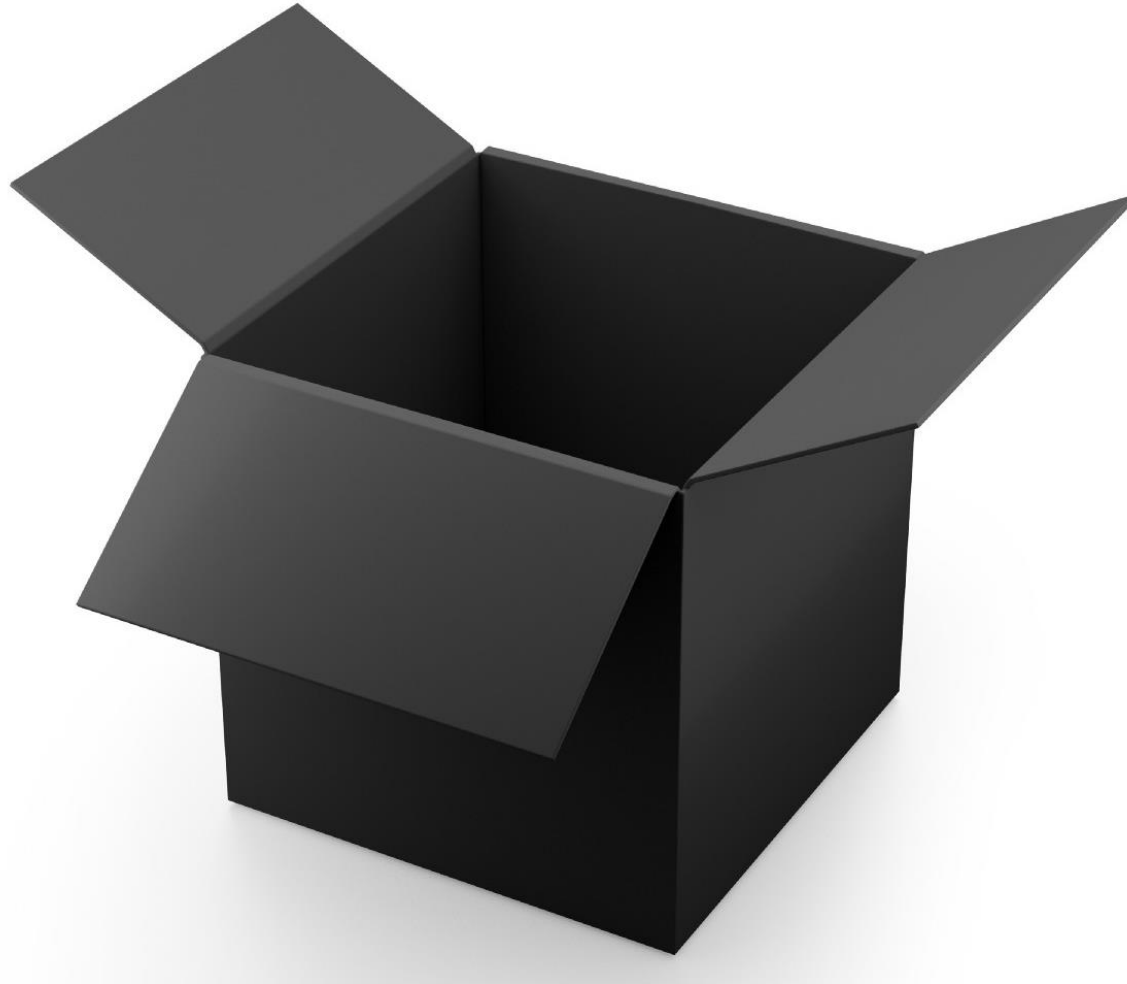


Machine Learning

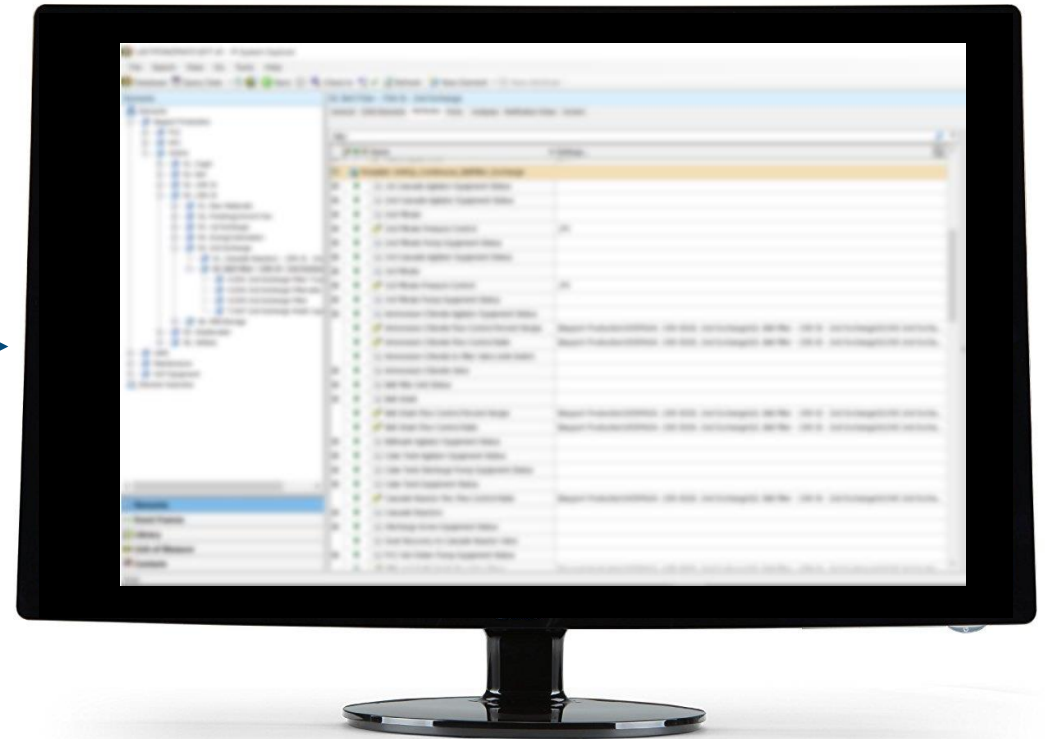
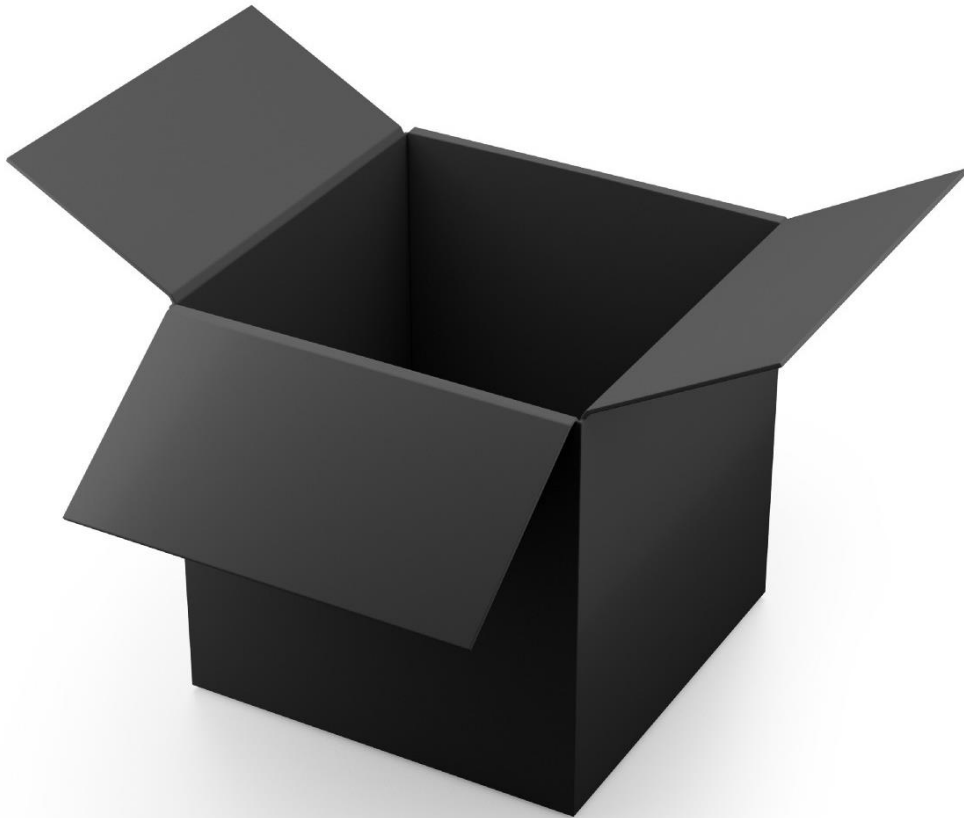
- Multi-dimensional Models
- Discovering Unknown Correlations
- “Signals Between the Signals”



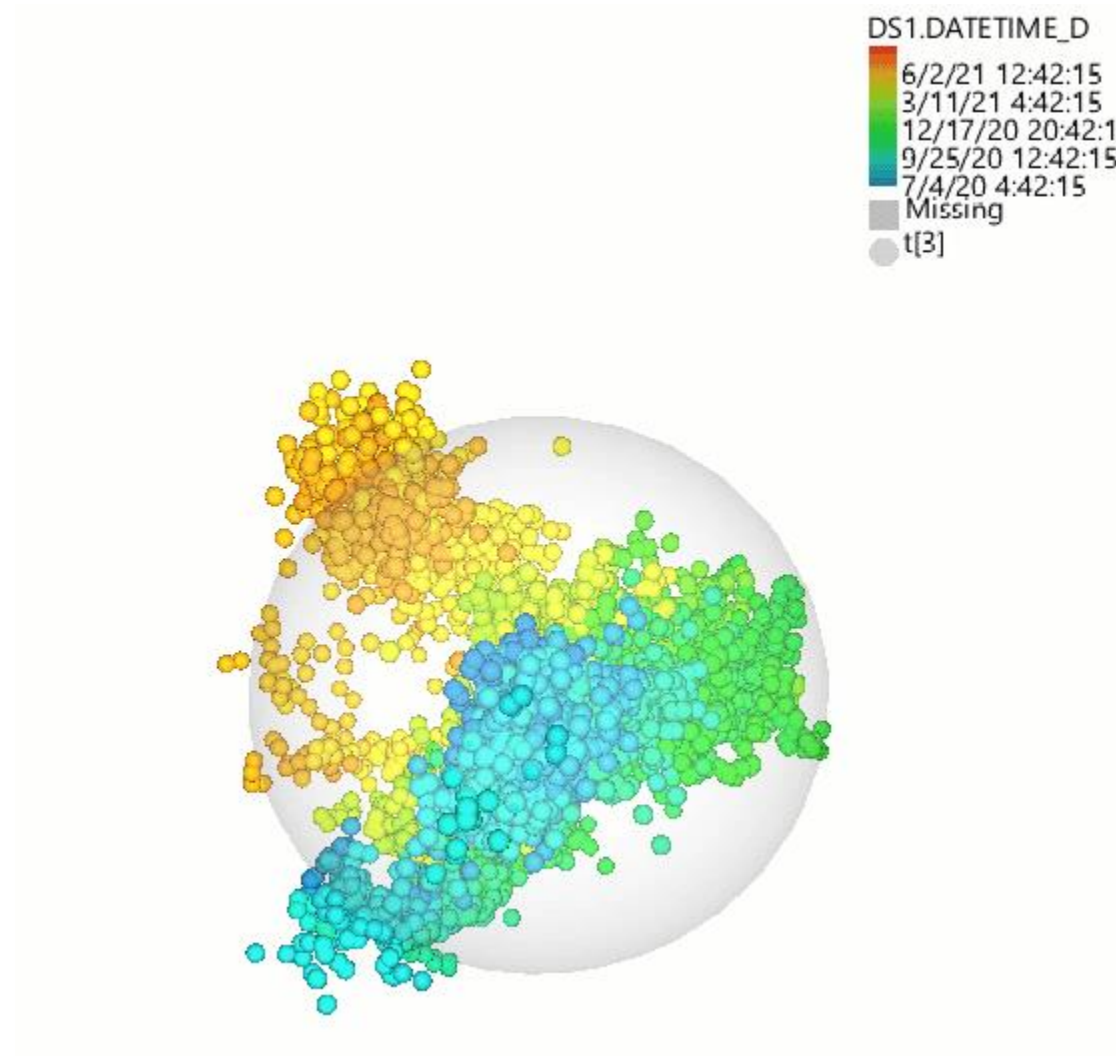
The “Black Box” Unit Operation

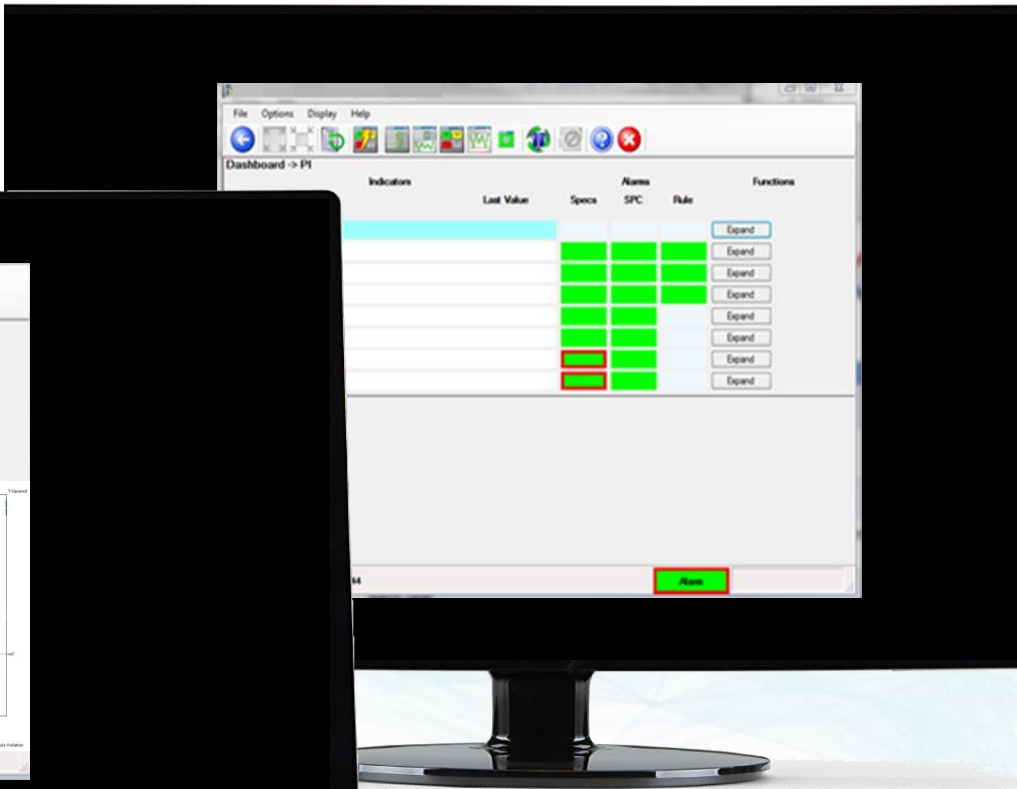
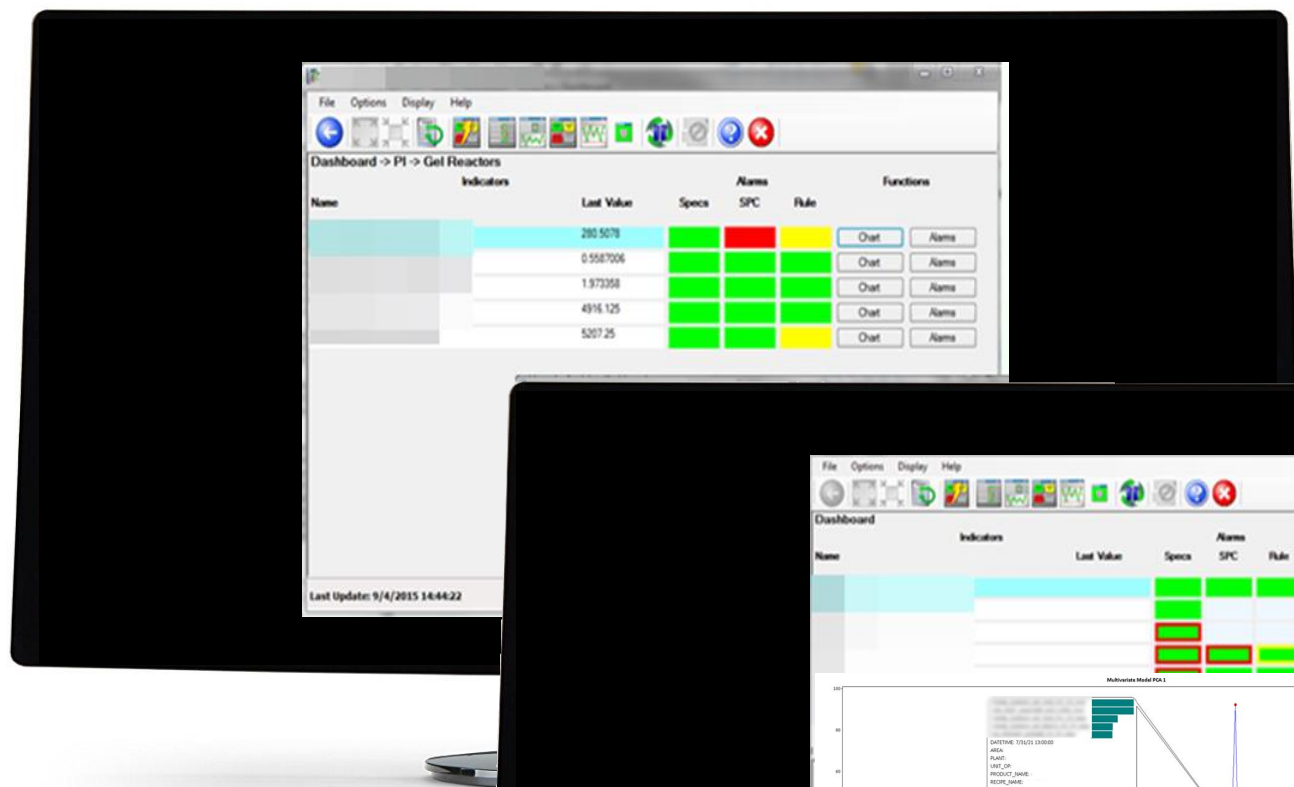


DEFINE



Dissecting the “Black Box” with Machine Learning





SARTORIUS SIMCA®

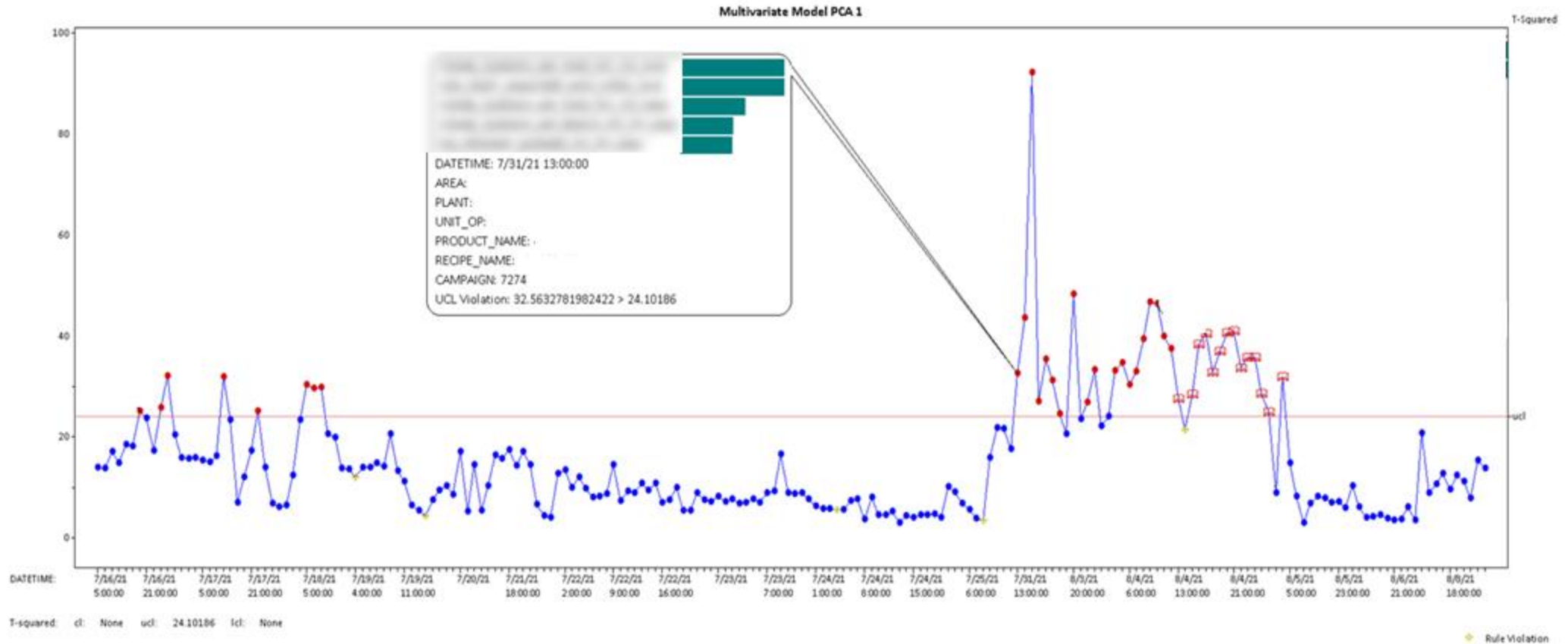
Northwest
Analytics

ALBEMARLE®

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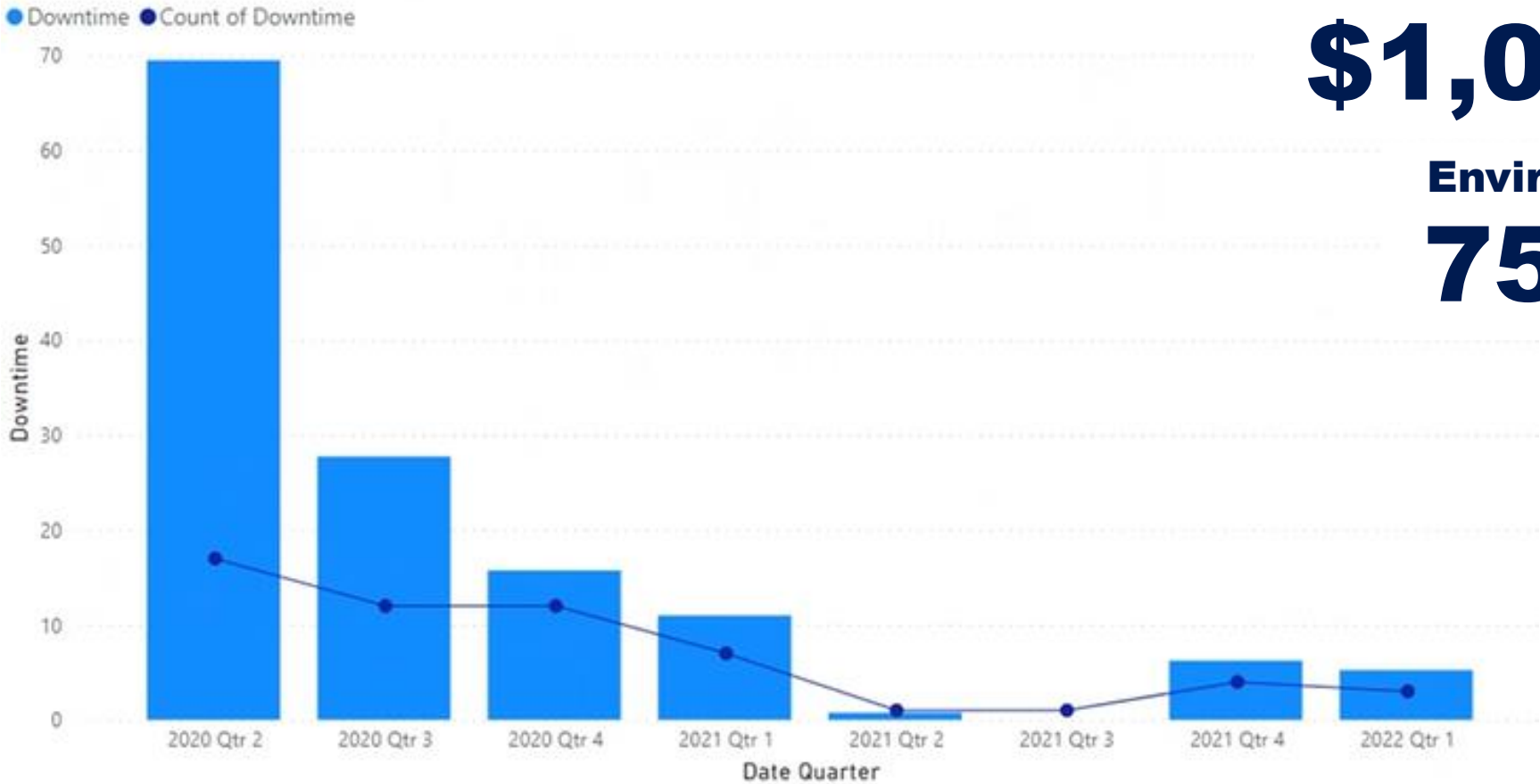
ALBEMARLE INTELLIGENCE

Real-Time Machine Learning



The “Black Box” Real-Time Machine Learning Model

Downtime and Count of Downtime by Year and Quarter



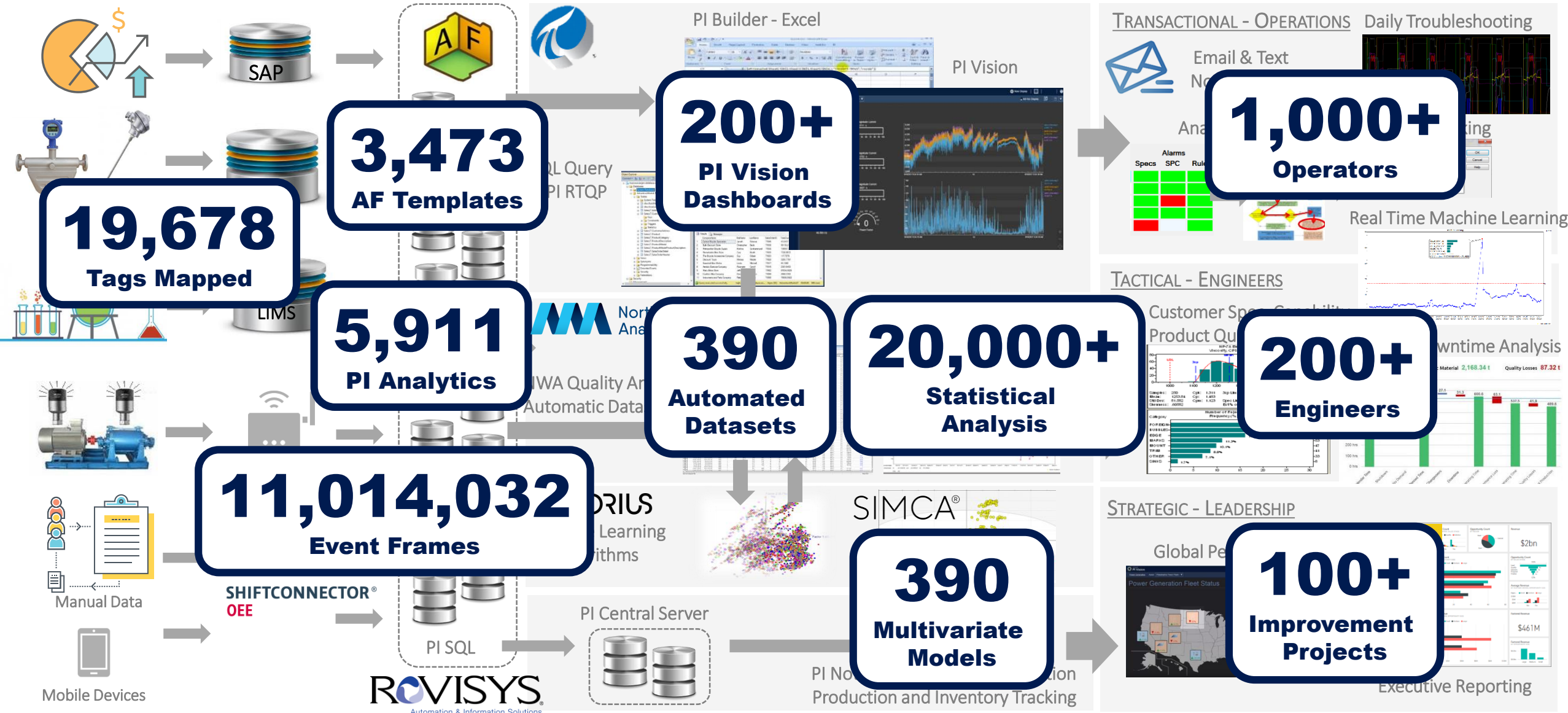
OEE Improvements
\$1,000,000/yr
Environmental Incidents
75% reduction

DATA SOURCES

AVEVA PI ASSET FRAMEWORK

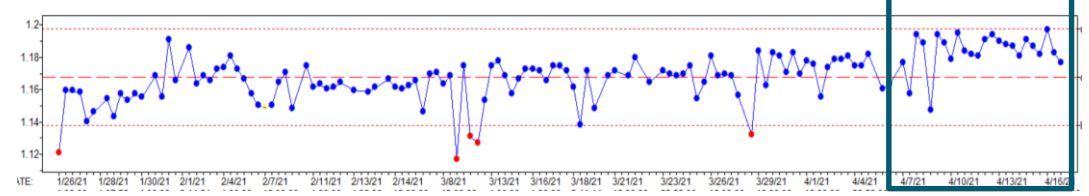
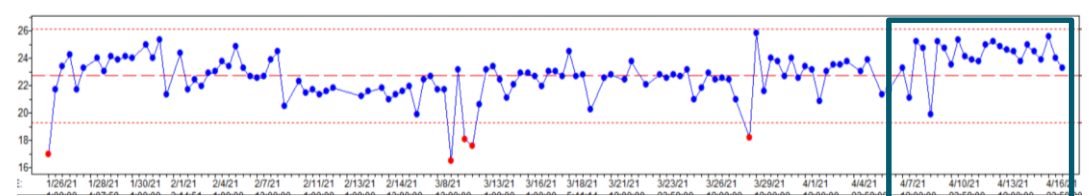
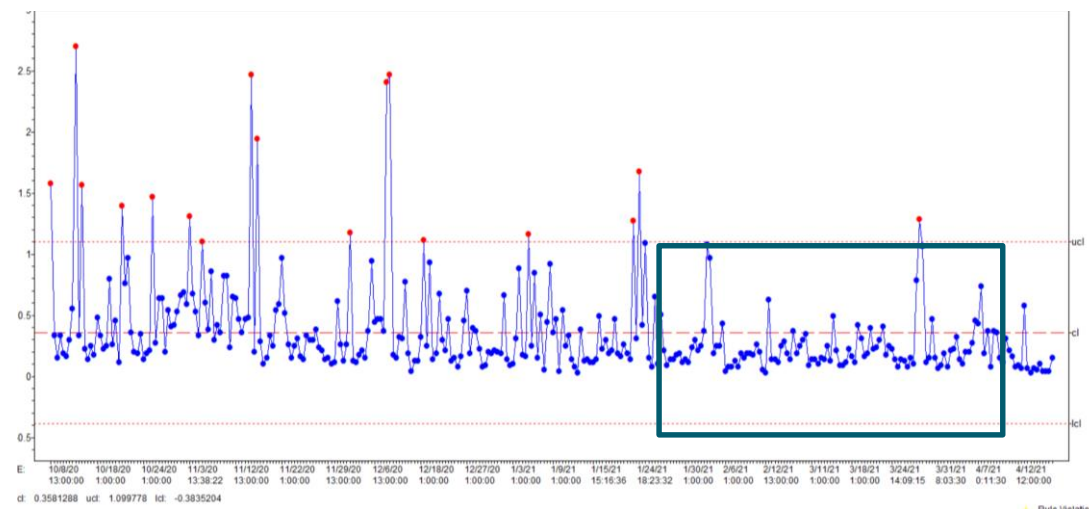
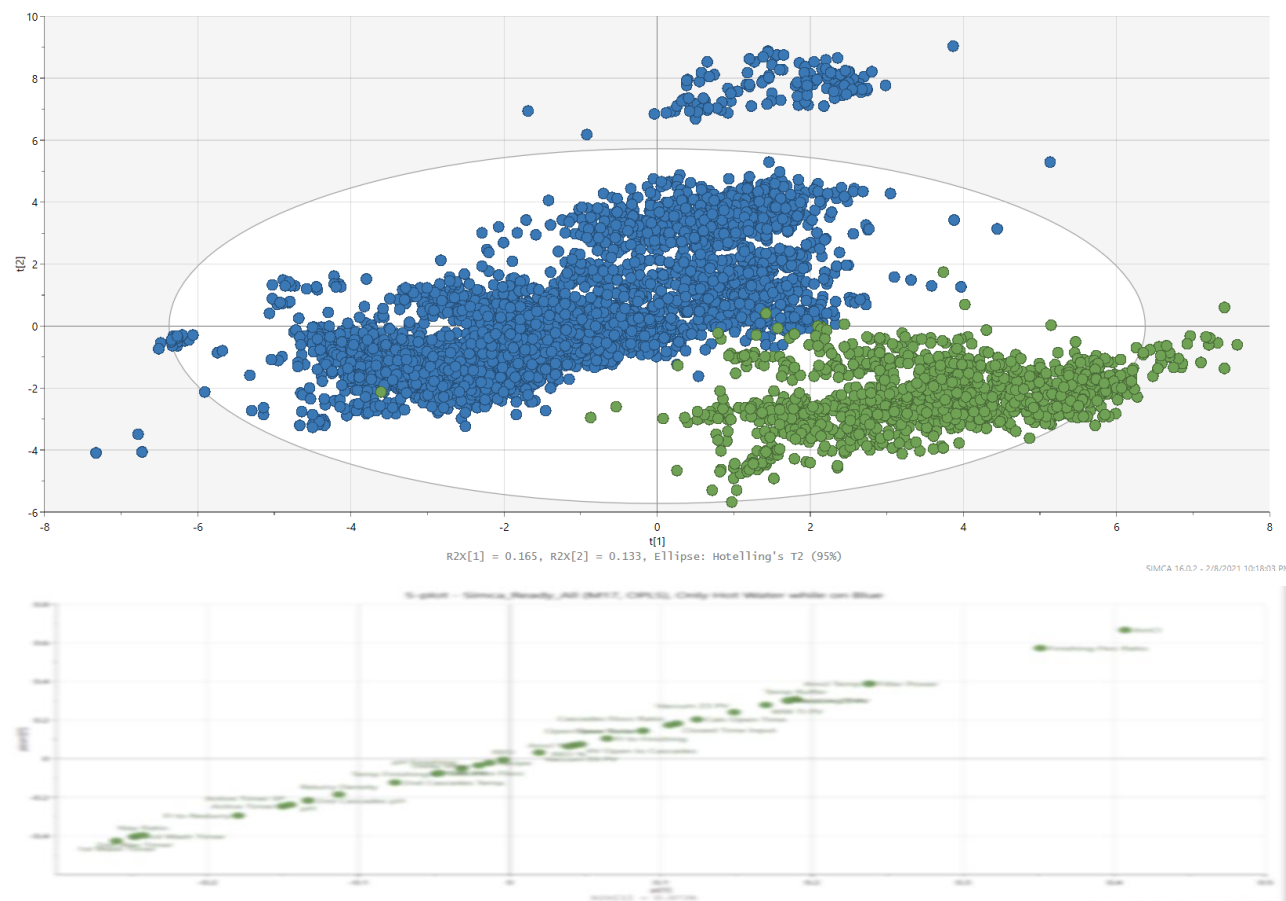
DATA ANALYTICS SUITE

USER ROLES



Albemarle Intelligence – Engineer Improvement Project

Capacity & Quality Improvements
\$450,000/yr



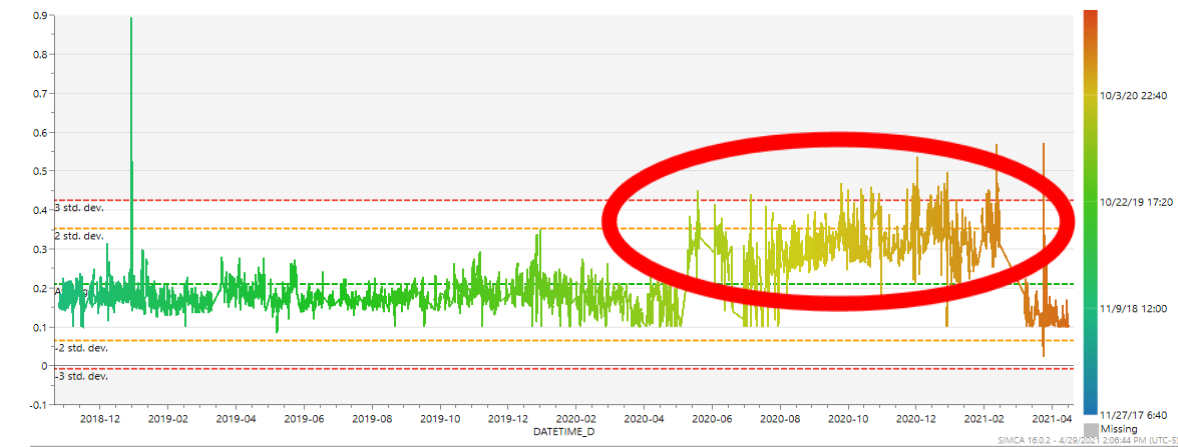
Downtime Reduction & Environmental Improvements

ucf

DATE/TIME: 4/5/21 4/6/21 4/8/21 4/10/21 4/12/21 4/14/21 4/16/21 4/18/21 4/20/21 4/22/21 4/24/21 4/26/21 4/28/21 5/1/21 5/3/21 5/5/21 5/7/21 5/9/21 5/10/21

T-squared: cl: None ucl: 24.79157 lcl: None

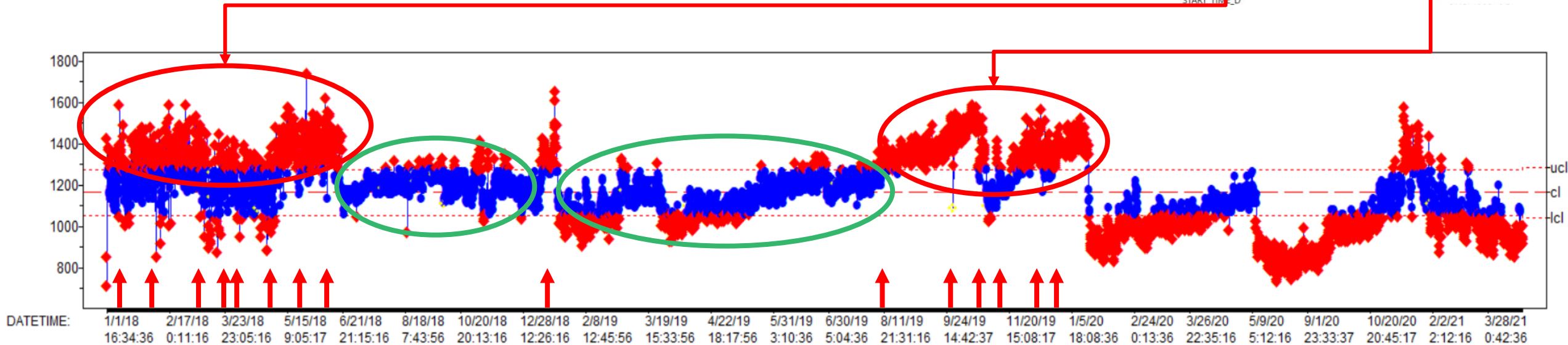
Rule Violation



Albemarle Intelligence – Engineer Improvement Project

Maintenance Equipment Reliability Improvement

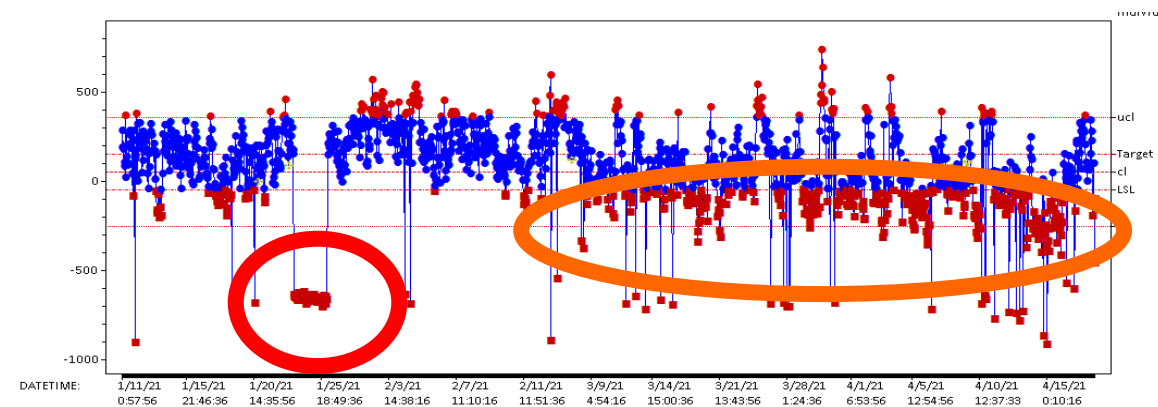
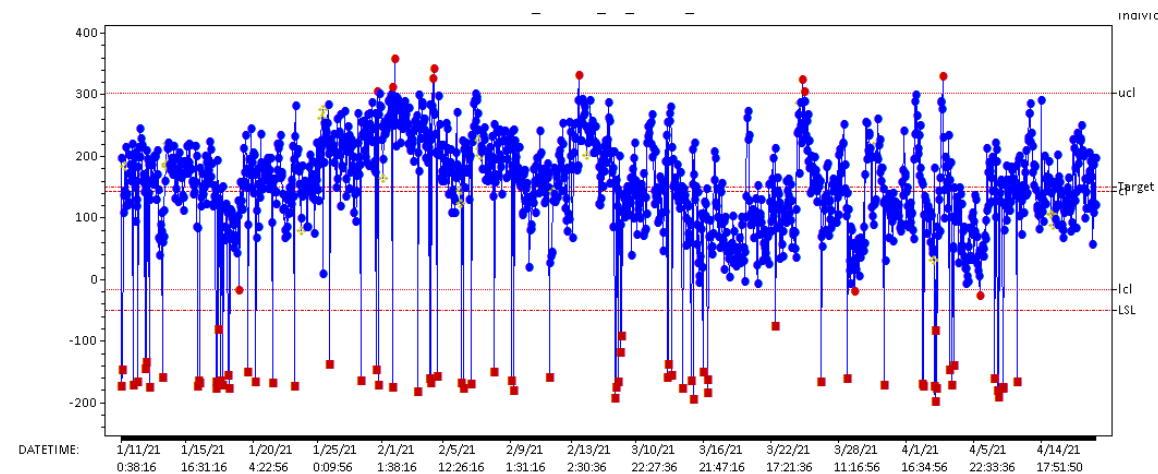
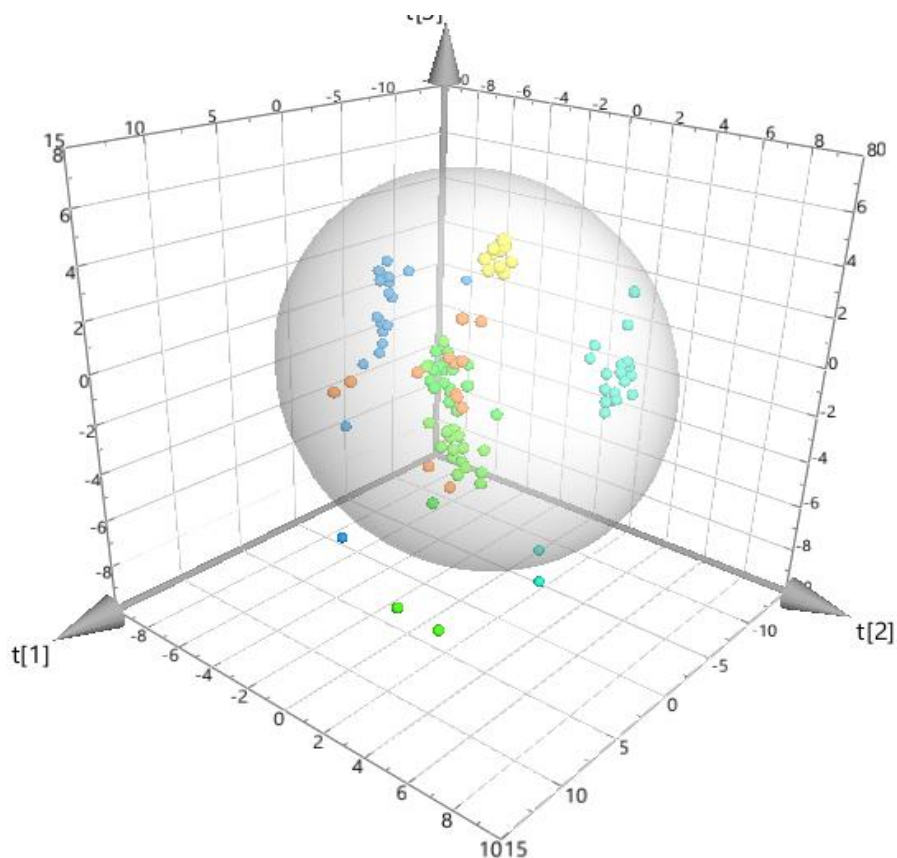
\$220,000/yr



Albemarle Intelligence – Engineer Improvement Project

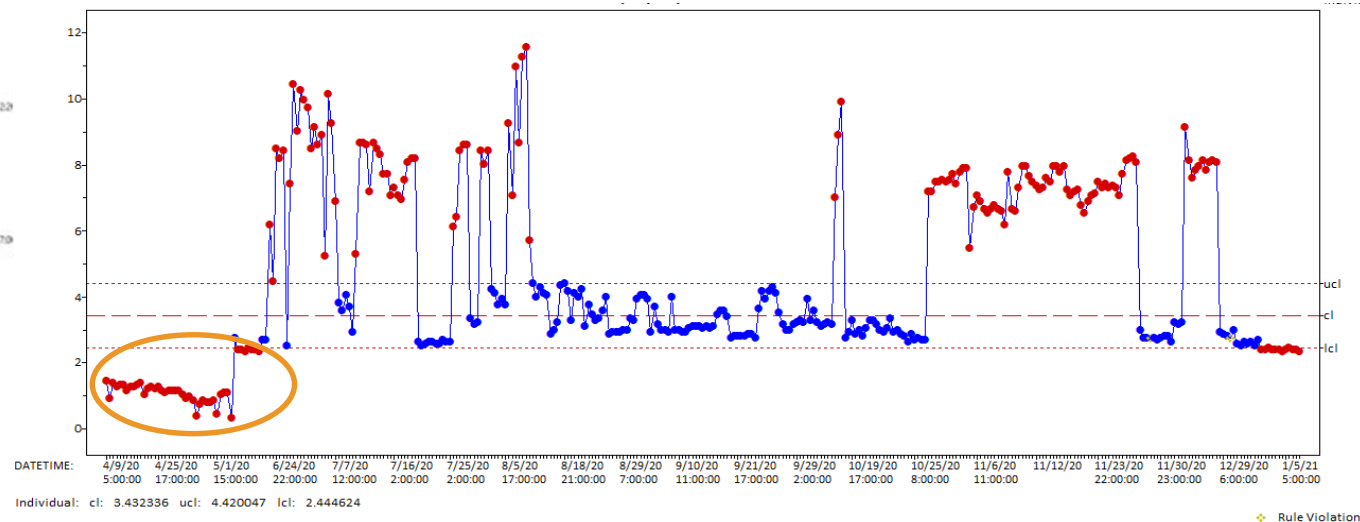
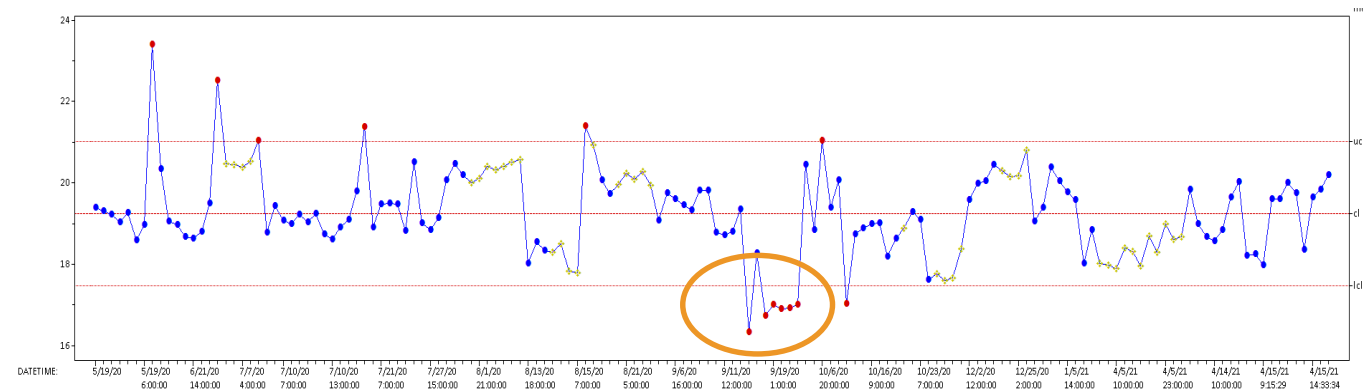
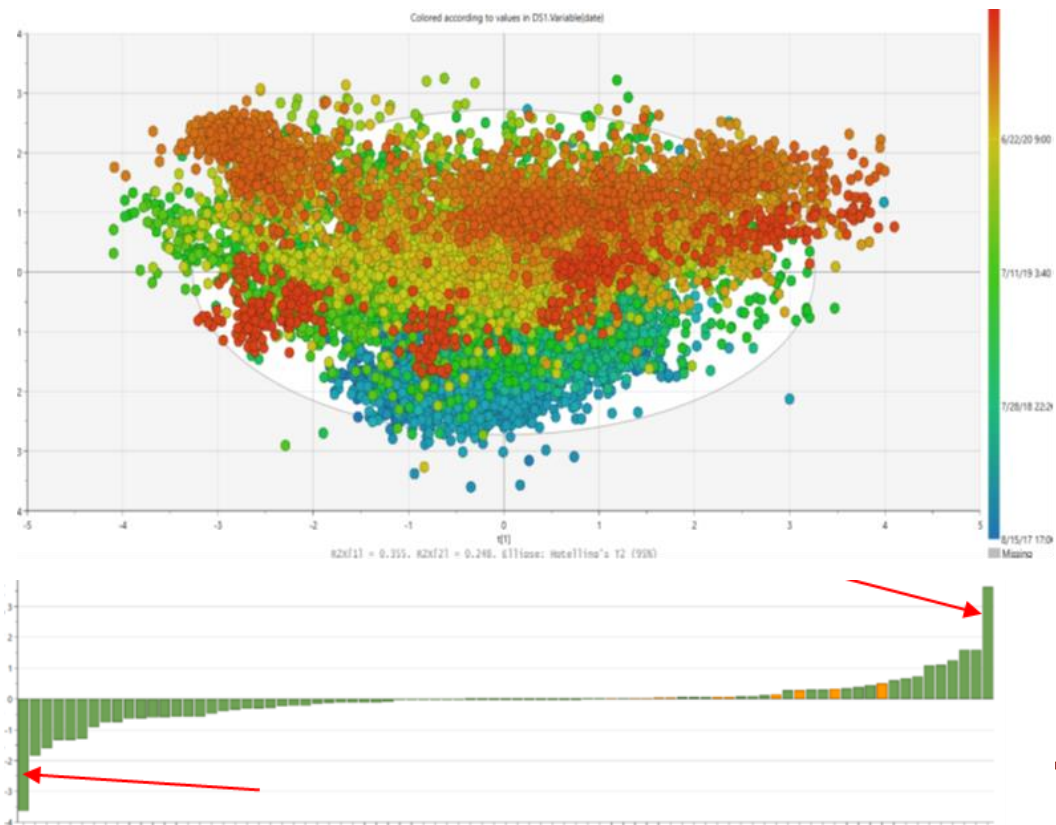
**Raw Material Utilization, Quality, and
Customer Satisfaction Improvements**

\$150,000/yr



Albemarle Intelligence – Engineer Improvement Project

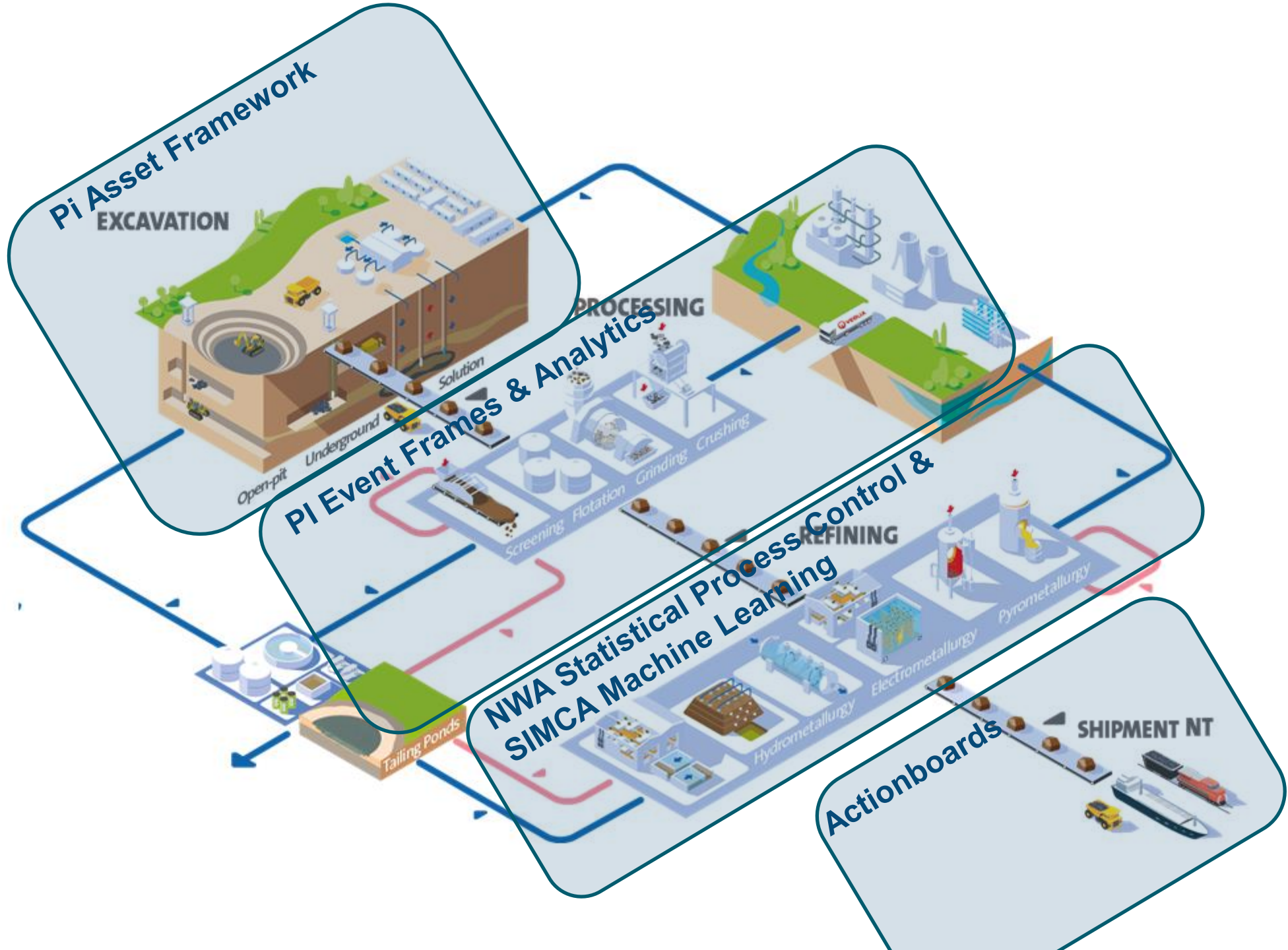
Quality and Rate Improvements
\$840,000/yr















Automated Information

Analytics Innovation

Actionable Insight



AUTOMATIZACIÓN DE LA INFORMACIÓN

ANALÍTICA CON INNOVACIÓN

ACCIONES INFORMADAS



Personal de Albemarle,
Empoderados por la Tecnología,
Liberando el Valor de la Información



雅保智能

自动信息

分析创新

切实可行的洞察



雅保人，
技术赋能，
释放信息的价值



**ALBEMARLE PEOPLE,
empowered by technology,
unlocking the value of information.**

World Class Chemical Manufacturing



Challenge

Scaling Machine Learning & AI across a global enterprise, within a Specialty Chemical Company with thousands of unique chemical processes and data sources

Solution

Deployed the latest AVEVA PI System technology including PI AF, PI Event Frames, PI Analytics, Northwest Analytics SPC, and Sartorius SIMCA Multivariate Analysis

Benefits

Beyond \$10,000,000 annual improvements via increased production, operational efficiency, improved raw material utilization, improved quality, improved equipment reliability, significantly accelerated 'Time to Value' for Advanced Analytics & Machine Learning projects



Jonathan Alexander

Manufacturing AI & Advanced Analytics Manager

- Albemarle
- jonathan.alexander@albemarle.com

[illegible]