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An *OmniVariate* Approach to Semiconductor Reliability

Reliability & Quality Improvement for Aerospace and Automotive Applications

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November 17, 2022

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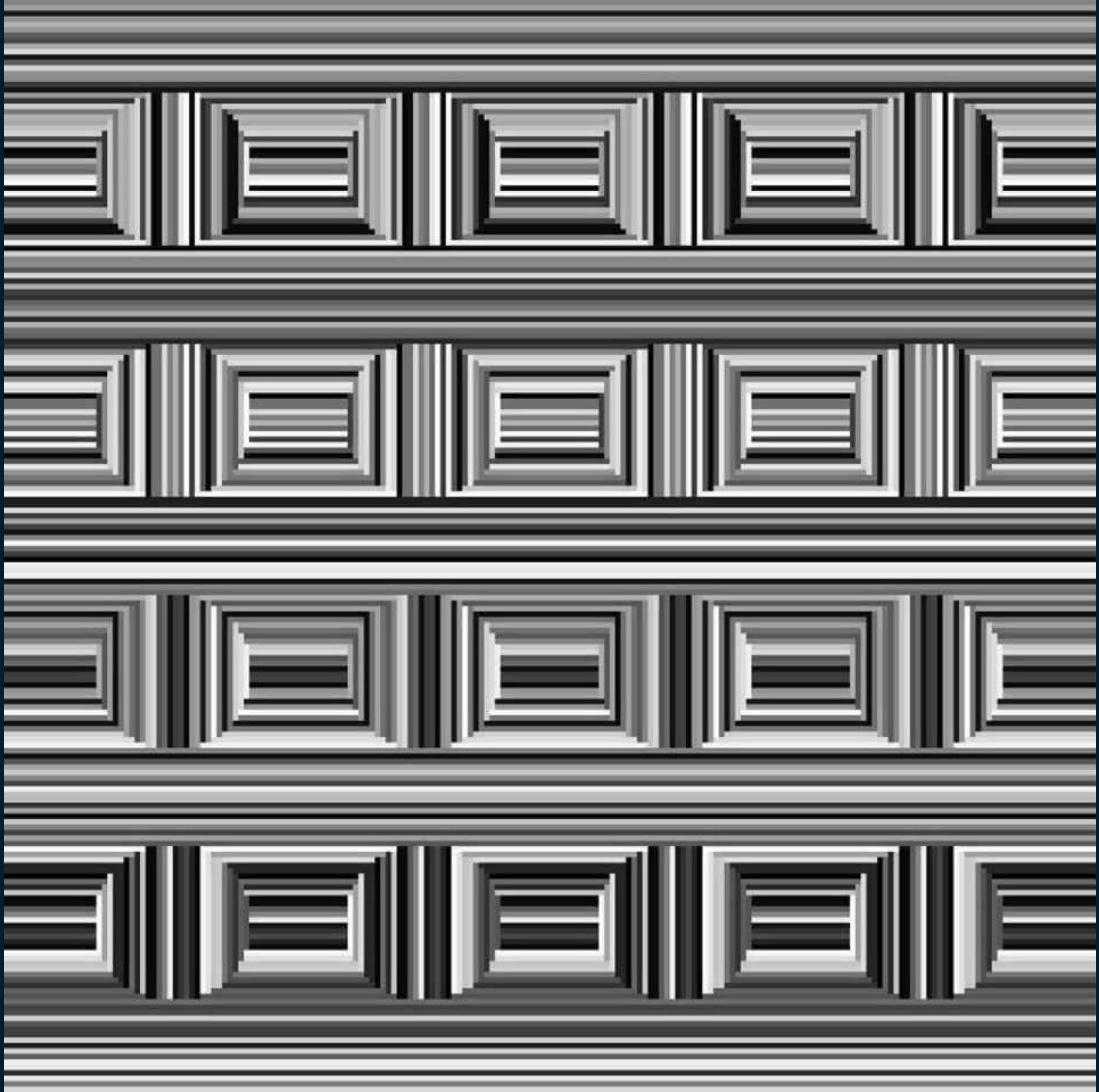
Abstract

As the number and complexity of electronic parts increases with every vehicle, the demands for reliability continually increase. This is even more acute when deploying advanced materials such as SiC and GaN to address the ever more stringent demands for electric powertrains.

An advanced statistical screening approach is proposed for the purpose of identification of electronic parts that have an elevated risk of field failure. A comparison is made between the proposed Omnivariate approach, industry-standard DPAT, and more commonly recognized multivariate methods such as Mahalanobis Distance and Hoteling T^2, which tend to provide less useful information as the number of monitored parameters exceeds a few hundred.

A few examples from known RMA devices on Silicon CMOS manufacturing are used for demonstration.



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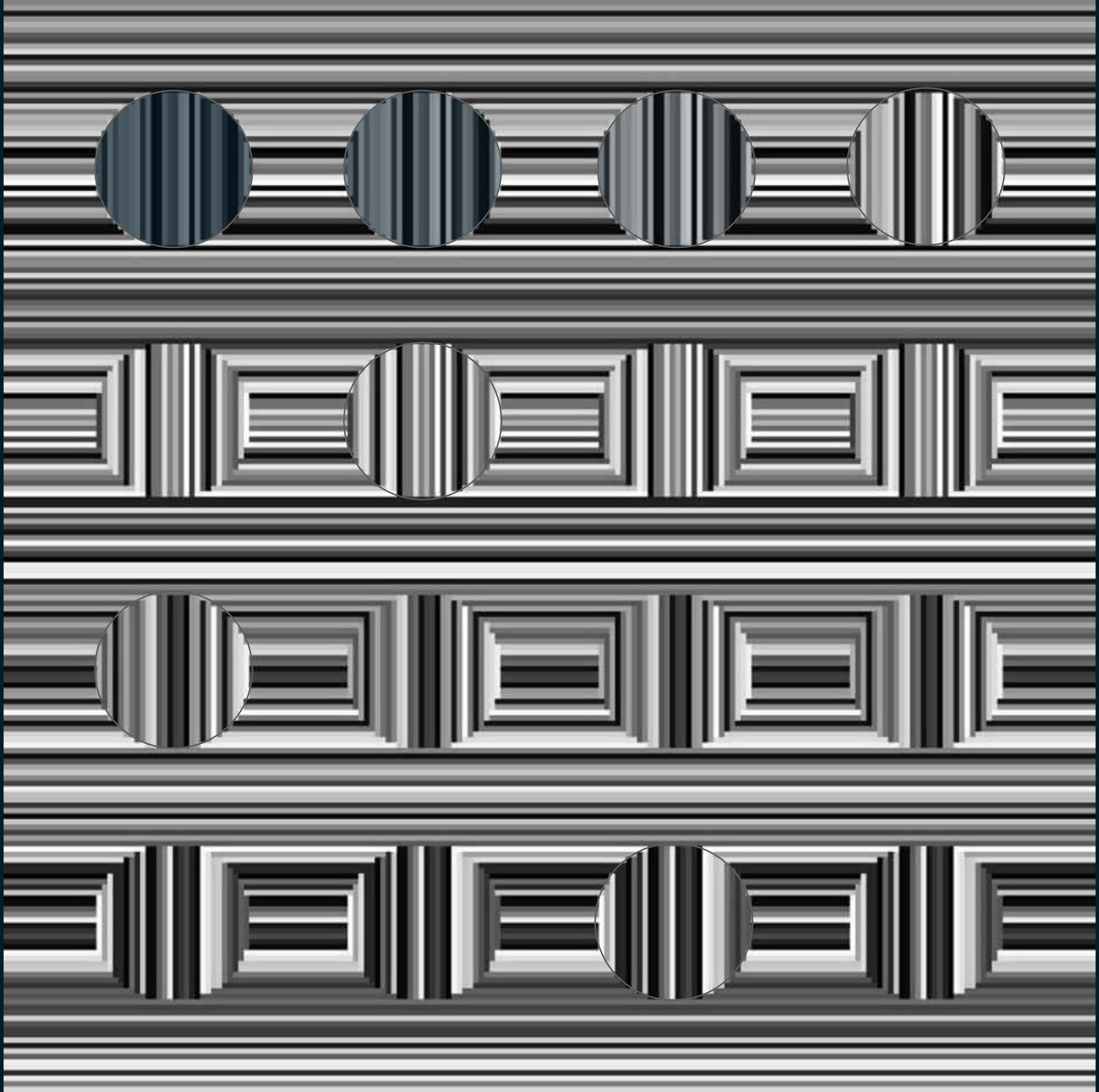

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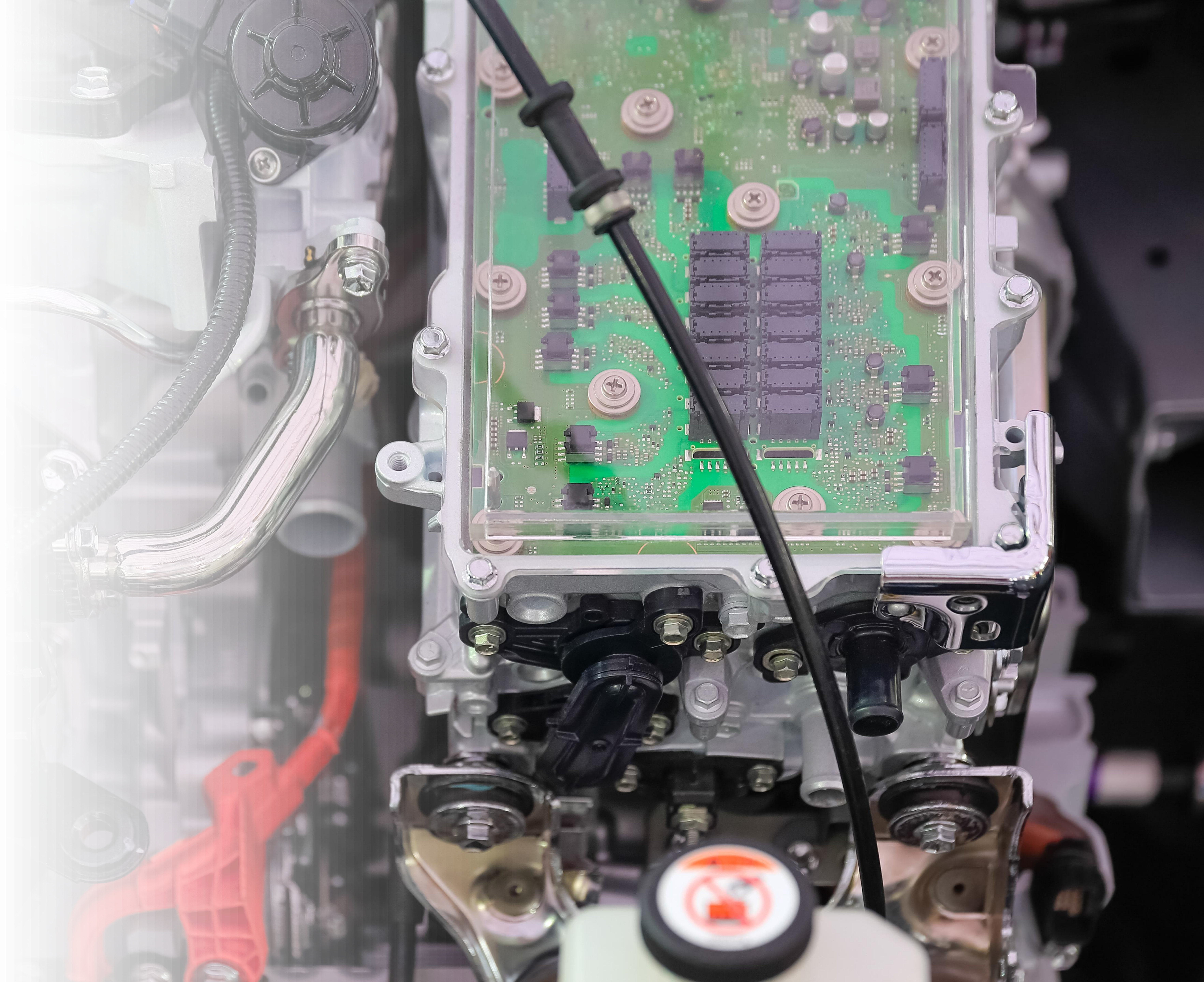
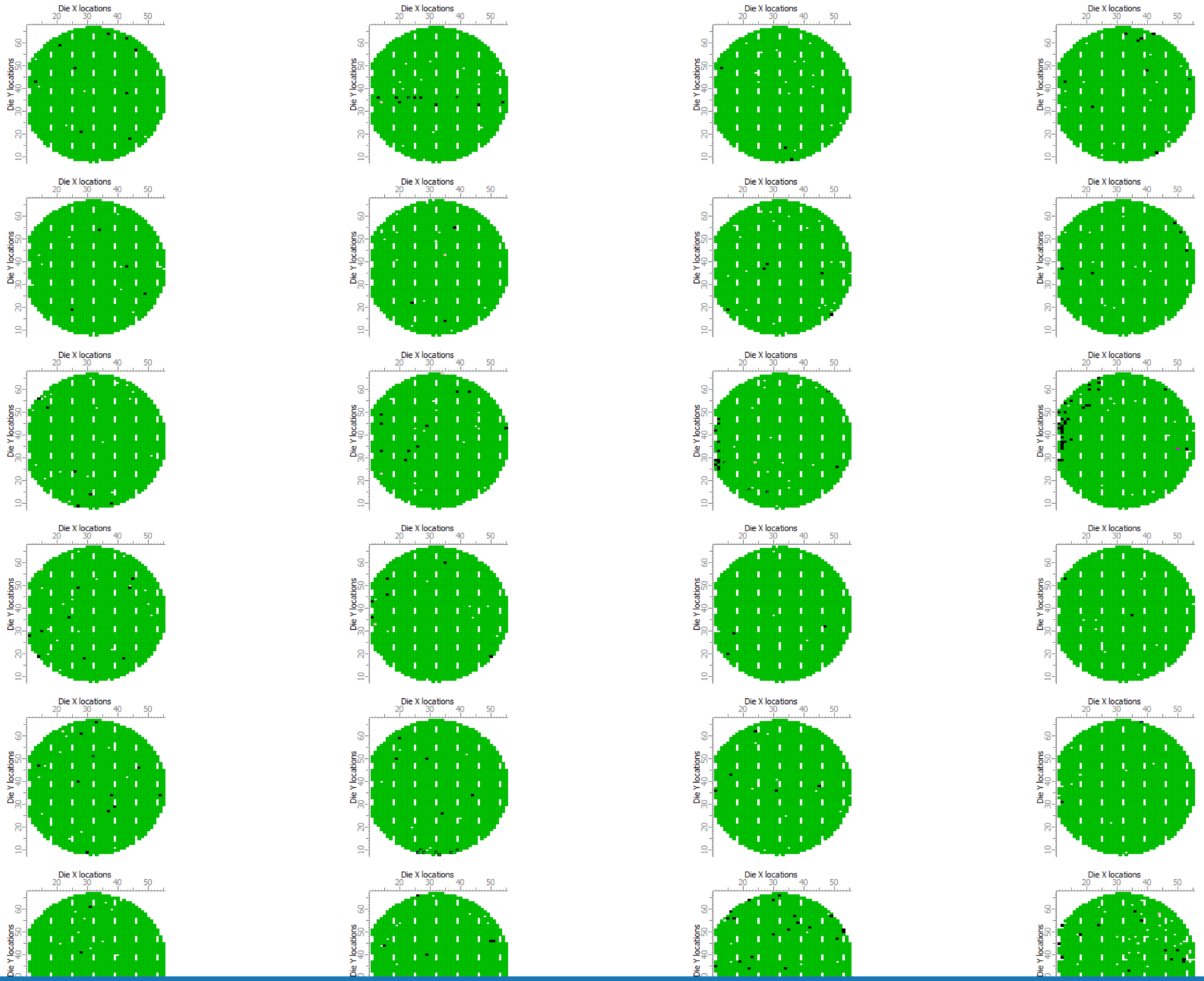
- Once upon a time in Vokalia...

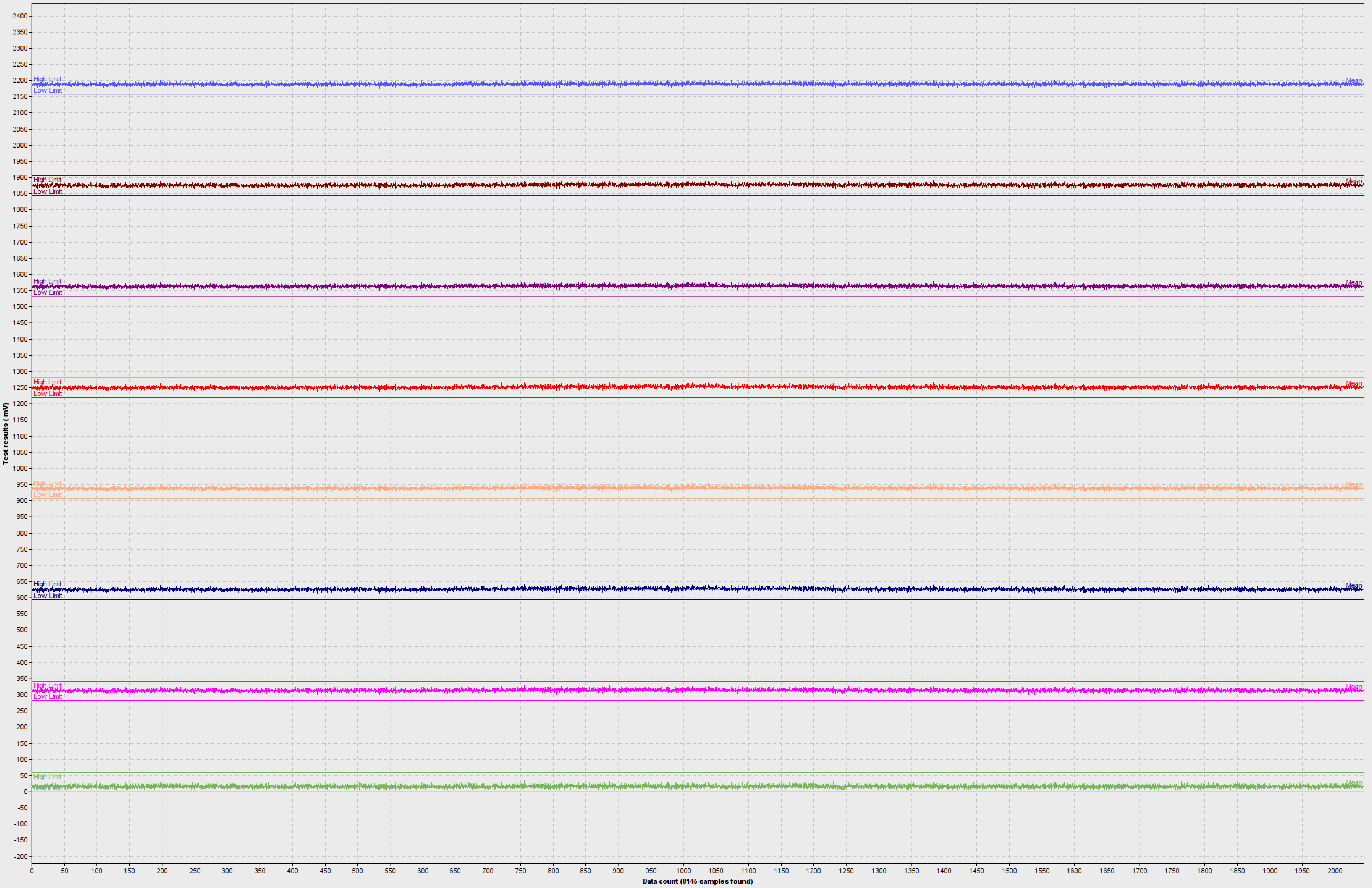
- 50 RMA
- Devices.

- 1 Angry Customer



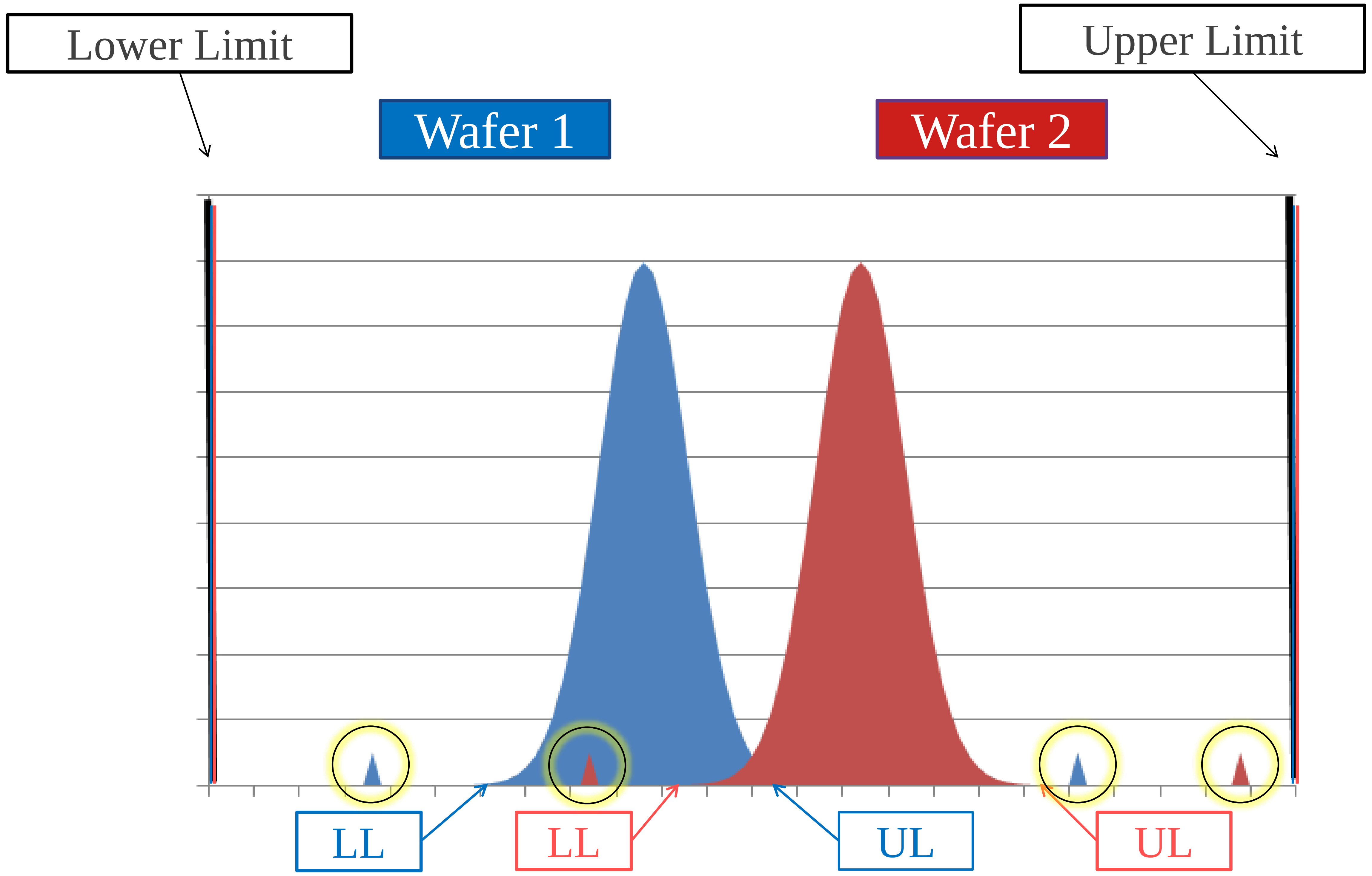
Test	Name	Type	Low L.	High L.	Shape	Source	Execs	Fails	Fails %	Flow ID	Mean	Sigma	3xSigma	Min	Max	Cpk	Cpl	Cpu	Yield	Skew	Kurtosis	P2.5%	P50% - Median	P97.5%	IQR	IQR SD
400		P	0.0 V	60 mV	Unknown	Samples	100281	3	0.00 %	1	15.957 mV	14.2497 mV	42.749 mV	5.493 mV	2.4973 V	0.3733	0.3733	1.03	100.00 %	156.592	27185.6	8.0785 mV	15.783 mV	24.8755 mV	6.3295 mV	4.69199 mV
401		P	0.2825 V	0.3425 V	Gaussian	Samples	100281	3	0.00 %	2	314.435 mV	12.458 mV	37.3739 mV	299.443 mV	2.49731 V	0.7509	0.8545	0.7509	100.00 %	159.271	27809.3	307.119 mV	314.371 mV	321.621 mV	4.97848 mV	3.6905 mV
402		P	0.595 V	0.655 V	Gaussian	Samples	100281	3	0.00 %	3	627 mV	10.8791 mV	32.6372 mV	611.158 mV	2.49709 V	0.8579	0.9805	0.8579	100.00 %	150.205	25718.8	619.507 mV	626.936 mV	634.472 mV	5.13101 mV	3.80356 mV
403		P	0.9075 V	0.9675 V	Gaussian	Samples	100281	3	0.00 %	4	939.539 mV	9.31381 mV	27.9414 mV	923.24 mV	2.4974 V	1.00	1.15	1.00	100.00 %	137.997	22970.1	931.97 mV	939.479 mV	947.087 mV	5.19753 mV	3.85287 mV
404		P	1.22 V	1.28 V	Gaussian	Samples	100281	4	0.00 %	5	1.25181 V	7.79812 mV	23.3944 mV	1.23599 V	2.49718 V	1.20	1.36	1.20	100.00 %	119.706	19002.9	1.24418 V	1.25177 V	1.25936 V	5.20802 mV	3.86065 mV
405		P	1.5325 V	1.5925 V	Gaussian	Samples	100281	4	0.00 %	6	1.5644 V	6.34684 mV	19.0405 mV	1.54764 V	2.49731 V	1.48	1.68	1.48	100.00 %	92.7933	13530.6	1.55685 V	1.56438 V	1.57185 V	5.16701 mV	3.83025 mV
406		P	1.845 V	1.905 V	Gaussian	Samples	100281	3	0.00 %	7	1.87661 V	5.02956 mV	15.0887 mV	1.85955 V	2.49742 V	1.88	2.09	1.88	100.00 %	54.2322	6613.72	1.86919 V	1.87659 V	1.88391 V	5.06592 mV	3.75531 mV
407		P	2.1575 V	2.2175 V	Gaussian	Samples	100281	3	0.00 %	8	2.18921 V	4.01594 mV	12.0478 mV	2.17249 V	2.49742 V	2.35	2.63	2.35	100.00 %	12.5527	941.553	2.18197 V	2.18921 V	2.19631 V	4.94695 mV	3.66712 mV
408		P	2.47 V	2.53 V	Gaussian	Samples	100281	0	0.00 %	9	2.50088 V	3.87857 mV	11.6357 mV	2.48285 V	2.5177 V	2.50	2.65	2.50	100.00 %	-0.0261686	0.0265532	2.49323 V	2.5009 V	2.50842 V	5.25117 mV	3.89264 mV
409		P	2.7825 V	2.8425 V	Gaussian	Samples	100281	3	0.00 %	10	2.81362 V	4.18855 mV	12.5656 mV	2.48504 V	2.82919 V	2.30	2.48	2.30	100.00 %	-13.8451	1068.88	2.80612 V	2.81365 V	2.82099 V	5.14007 mV	3.81028 mV
410		P	3.095 V	3.155 V	Gaussian	Samples	100281	3	0.00 %	11	3.12585 V	5.1235 mV	15.3705 mV	2.48502 V	3.14171 V	1.90	2.01	1.90	100.00 %	-57.1826	7094.56	3.11844 V	3.12589 V	3.13315 V	5.07593 mV	3.76274 mV
411		P	3.4075 V	3.4675 V	Gaussian	Samples	100281	4	0.00 %	12	3.43854 V	6.40188 mV	19.2056 mV	2.48477 V	3.45444 V	1.51	1.62	1.51	100.00 %	-97.3443	14423	3.43115 V	3.43858 V	3.44582 V	5.04899 mV	3.74277 mV
412		P	3.72 V	3.78 V	Gaussian	Samples	100281	4	0.00 %	13	3.75081 V	7.844 mV	23.532 mV	2.48499 V	3.76679 V	1.24	1.31	1.24	100.00 %	-124.25	19970.4	3.74343 V	3.75087 V	3.75811 V	5.02396 mV	3.72421 mV
413		P	4.0325 V	4.0925 V	Gaussian	Samples	100281	4	0.00 %	14	4.06362 V	9.37727 mV	28.1318 mV	2.48492 V	4.07976 V	1.03	1.11	1.03	100.00 %	-141.394	23726.8	4.05633 V	4.0637 V	4.07091 V	4.99916 mV	3.70583 mV
414		P	4.345 V	4.405 V	Gaussian	Samples	100281	4	0.00 %	15	4.37602 V	10.9556 mV	32.8668 mV	2.48466 V	4.39169 V	0.8816	0.9439	0.8816	100.00 %	-152.653	26279.1	4.36878 V	4.3761 V	4.38325 V	4.95005 mV	3.66942 mV
415		P	4.6575 V	4.7175 V	Gaussian	Samples	100281	6	0.01 %	16	4.68901 V	14.3586 mV	43.0758 mV	2.48475 V	4.70495 V	0.6613	0.7316	0.6613	99.99 %	-143.167	21915	4.68195 V	4.68912 V	4.69615 V	4.87232 mV	3.6118 mV
Test	Name	Type	Low L.	High L.	Shape	Source	Execs	Fails	Fails %	Flow ID	Mean	Sigma	3xSigma	Min	Max	Cpk	Cpl	Cpu	Yield	Skew	Kurtosis	P2.5%	P50% - Median	P97.5%	IQR	IQR SD
416		P	4.62 V	4.69 V	Unknown	Samples	100281	5	0.00 %	17	4.67306 V	26.562 mV	79.6861 mV	-599 uV	4.68142 V	0.2126	0.6658	0.2126	100.00 %	-168.656	29139.5	4.6696 V	4.67329 V	4.6765 V	2.388 mV	1.7702 mV
417		P	-3.0 LSB	3.0 LSB	Bi-Modal (clear modes)	Samples	100281	10	0.01 %	18	-99.4087 mLSB	5.42086 LSB	16.2626 LSB	-1.67579 KLSB	7.69336 LSB	0.1784	0.1784	0.1906	99.99 %	-294.702	91057.3	-1.62668 LSB	-664.589 mLSB	1.61205 LSB	2.00597 LSB	1.487 LSB
418		P	-6.0 LSB	6.0 LSB	Bi-Modal (clear modes)	Samples	100281	7	0.01 %	19	-653.591 mLSB	5.52377 LSB	16.5713 LSB	-9.62881 LSB	1.67579 KLSB	0.3226	0.3226	0.4015	99.99 %	278.928	84611	-2.86343 LSB	-1.1848 LSB	2.19948 LSB	2.68483 LSB	1.99024 LSB
419		P	-25.0 LSB	25.0 LSB	Bi-Modal (clear modes)	Samples	100281	5	0.00 %	20	1.60475 LSB	10.5458 LSB	31.6373 LSB	-38.751 LSB	1.78979 KLSB	0.7395	0.8409	0.7395	100.00 %	144.328	24389.2	-6.0801 LSB	2.40804 LSB	8.37468 LSB	6.53394 LSB	4.84354 LSB
430		P	0.606 V	0.646 V	Gaussian	Samples	100268	0	0.00 %	21	626.945 mV	3.8123 mV	11.4369 mV	611.158 mV	643.302 mV	1.67	1.83	1.67	100.00 %	0.0219976	0.0317781	619.507 mV	626.936 mV	634.471 mV	5.13053 mV	3.80321 mV
431		P	0.623 V	0.67 V	Gaussian	Samples	100268	0	0.00 %	22	646.457 mV	3.82561 mV	11.4768 mV	630.531 mV	662.813 mV	2.04	2.04	2.05	100.00 %	0.0227774	0.0312783	639.008 mV	646.446 mV	654.015 mV	5.14644 mV	3.81501 mV
432		P	0.645 V	0.685 V	Gaussian	Samples	100268	0	0.00 %	23	665.973 mV	3.83312 mV	11.4994 mV	649.925 mV	682.267 mV	1.65	1.82	1.65	100.00 %	0.023244	0.0303011	658.514 mV	665.963 mV	673.55 mV	5.16403 mV	3.82804 mV
433		P	0.662 V	0.709 V	Gaussian	Samples	100268	0	0.00 %	24	685.484 mV	3.83494 mV	11.5048 mV	669.352 mV	701.86 mV	2.04	2.04	2.04	100.00 %	0.0229052	0.0287073	678.027 mV	685.473 mV	693.052 mV	5.16146 mV	3.82614 mV
434		P	0.684 V	0.724 V	Gaussian	Samples	100268	1	0.00 %	25	704.98 mV	3.84089 mV	11.5227 mV	634.017 mV	721.196 mV	1.65	1.82	1.65	100.00 %	-0.0415589	1.17165	697.511 mV	704.97 mV	712.539 mV	5.15902 mV	3.82433 mV
435		P	0.703 V	0.743 V	Gaussian	Samples	100268	1	0.00 %	26	724.489 mV	3.83893 mV	11.5168 mV	653.554 mV	740.698 mV	1.61	1.87	1.61	100.00 %	-0.0440728	1.17359	717.032 mV	724.477 mV	732.032 mV	5.15902 mV	3.82433 mV
436		P	0.723 V	0.763 V	Gaussian	Samples	100268	1	0.00 %	27	744.001 mV	3.83495 mV	11.5049 mV	673.126 mV	760.192 mV	1.65	1.83	1.65	100.00 %	-0.0452716	1.1709	736.53 mV	743.994 mV	751.537 mV	5.15604 mV	3.82212 mV
437		P	0.742 V	0.782 V	Gaussian	Samples	100268	1	0.00 %	28	763.533 mV	3.83037 mV	11.4911 mV	692.567 mV	779.777 mV	1.61	1.87	1.61	100.00 %	-0.0467892	1.18107	756.073 mV	763.528 mV	771.055 mV	5.15097 mV	3.81836 mV
438		P	0.762 V	0.802 V	Gaussian	Samples	100268	1	0.00 %	29	783.061 mV	3.84941 mV	11.5482 mV	634.009 mV	799.449 mV	1.64	1.82	1.64	100.00 %	-0.565143	22.3636	775.601 mV	783.062 mV	790.553 mV	5.14454 mV	3.81359 mV
439		P	0.781 V	0.821 V	Gaussian	Samples	100268	1	0.00 %	30	802.606 mV	3.84531 mV	11.5359 mV	653.519 mV	818.884 mV	1.59	1.87	1.59	100.00 %	-0.567223	22.4731	795.155 mV	802.602 mV	810.092 mV	5.13899 mV	3.80948 mV
440		P	0.801 V	0.841 V	Gaussian	Samples	100268	1	0.00 %	31	822.151 mV	3.84368 mV	11.5311 mV	673.077 mV	838.315 mV	1.63	1.83	1.63	100.00 %	-0.569694	22.5069	814.699 mV	822.155 mV	829.626 mV	5.13804 mV	3.80878 mV
441		P	0.82 V	0.86 V	Gaussian	Samples	100268	1	0.00 %	32	841.712 mV	3.84379 mV	11.5314 mV	692.639 mV	857.908 mV	1.59	1.88	1.59	100.00 %	-0.570649	22.4977	834.256 mV	841.716 mV	849.182 mV	5.13399 mV	3.80577 mV
Test	Name	Type	Low L.	High L.	Shape	Source	Execs	Fails	Fails %	Flow ID	Mean	Sigma	3xSigma	Min	Max	Cpk	Cpl	Cpu	Yield	Skew	Kurtosis	P2.5%	P50% - Median	P97.5%	IQR	IQR SD
442		P	0.84 V	0.88 V	Gaussian	Samples	100268	0	0.00 %	33	861.275 mV	3.81588 mV	11.4477 mV	845.201 mV	877.407 mV	1.64	1.86	1.64	100.00 %	0.00921444	0.0220939	853.812 mV	861.278 mV	868.748 mV	5.13452 mV	3.80617 mV
443		P	0.86 V	0.9 V	Gaussian	Samples	100268	0	0.00 %	34	880.856 mV	3.81952 mV	11.4586 mV	865.023 mV	897.058 mV	1.67	1.82	1.67	100.00 %	0.0082134	0.0220421	873.384 mV	880.861 mV	888.331 mV	5.13846 mV	3.80909 mV
444		P	0.879 V	0.919 V	Gaussian	Samples	100268	0	0.00 %	35	900.454 mV	3.8278 mV	11.4834 mV	884.462 mV	916.682 mV	1.62	1.87	1.62	100.00 %	0.00768267	0.0201306	892.959 mV	900.461 mV	907.943 mV	5.15097 mV	3.81836 mV
445		P	0.899 V	0.939 V	Gaussian	Samples	100268	0	0.00 %	36	920.065 mV	3.8402 mV	11.5206 mV	904.083 mV	936.422 mV	1.64	1.83	1.64	100.00 %	0.00839755	0.0206975	912.541 mV	920.071 mV	927.568 mV	5.17398 mV	3.83542 mV
446		P	0.29 V	0.297 V	Gaussian	Samples	100268	0	0.00 %	37	293.121 mV	588.601 uV	1.7658 mV	290.49 mV	295.711 mV	1.77	1.77	2.20	100.00 %	-0.0036459	0.00746272	291.963 mV	293.121 mV	294.27 mV	790.507 uV	585.995 uV
447		P	-0.5 LSB	0.5 LSB	Bi-Modal (clear modes)	Samples	100268	7	0.01 %	38	11.4251 mLSB	453.008 mLSB	1.35902 LSB	-16.0315 LSB	127.601 LSB	0.3595	0.3763	0.3595	99.99 %	221.962	62822.4	-269.697 mLSB	100.327 mLSB	274.119 mLSB	331.449 mLSB	245.7 mLSB
448		P	-1.0 LSB	1.0 LSB	Bi-Modal (clear modes)	Samples	100268	5	0.00 %	39	-229.164 mLSB	452.039 mLSB	1.35612 LSB	-127.9 LSB	527.163 mLSB	0.5684	0.5684	0.9064	100.00 %	-226.359	63522.5	-500.737 mLSB	-253.48 mLSB	221.239 mLSB	163.063 mLSB	120.877 mLSB
460		P	0.606 V	0.646 V	Gaussian	Samples	100261	0	0.00 %	40	626.944 mV	3.81234 mV	11.437 mV	611.158 mV	643.302 mV	1.67	1.83	1.67	100.00 %	0.022071	0.0317485	619.507 mV	626.935 mV	634.471 mV	5.13148 mV	3.80392 mV
461		P	0.607 V	0.647 V	Gaussian	Samples	100261	0	0.00 %	41	628.193 mV	3.8168 mV	11.4504 mV	612.605 mV	644.507 mV	1.64	1.85	1.64	100.00 %	0.02233	0.0310383	620.746 mV	628.184 mV	635.73 mV	5.13399 mV	3.80577 mV
462		P	0.608 V	0.648 V	Gaussian	Samples	100261	0	0.00 %	42	629.388 mV	3.81982 mV	11.4595 mV	613.612 mV	645.792 mV	1.62	1.87	1.62	100.00 %	0.0218296	0.0307263	621.937 mV	629.381 mV	636.921 mV	5.14048 mV	3.81059 mV
463		P	0.61 V	0.65 V	Gaussian	Samples	100261	0	0.00 %	43	630.586 mV	3.82318 mV	11.4695 mV	614.715 mV	646.99 mV	1.69	1.79	1.69	100.00 %	0.0221011	0.030465	623.125 mV	630.578 mV	638.129 mV	5.144 mV	3.81319 mV
464		P	0.611 V	0.651 V	Gaussian	Samples	100261	0	0.00 %	44	631.785 mV	3.82637 mV	11.4791 mV	615.955 mV	648.124 mV	1.67	1.81	1.67	100.00 %	0.0225045	0.0304926	624.319 mV	631.773 mV	639.329 mV	5.14603 mV	3.8147 mV
465		P	0.612 V	0.652 V	Gaussian	Samples	100261	0	0.00 %	45	632.985 mV	3.82952 mV	11.4886 mV	617.135 mV	649.35 mV	1.66	1.83	1.66	100.00 %	0.022135	0.0293299	625.523 mV	632.978 mV	640.532 mV	5.14996 mV	3.81761 mV
466		P	0.613 V	0.653 V	Gaussian	Samples	100261	0	0.00 %	46	634.188 mV	3.8333 mV	11.4999 mV	618.355 mV	650.505 mV	1.64	1.84	1.64	100.00 %	0.0224938	0.0289736	626.707 mV	634.182 mV	641.748 mV	5.1595 mV	3.82468 mV
467		P	0.614 V	0.654 V	Gaussian	Samples	100261	0	0.00 %	47	635.391 mV	3.83649 mV	11.5095 mV	619.514 mV	651.758 mV	1.62	1.86	1.62	100.00 %	0.0222309	0.0283515	627.906 mV	635.38 mV	642.957 mV	5.16099 mV	3.82579 mV
468		P	0.616 V	0.656 V	Gaussian	Samples	100261	0	0.00 %	48	636.598 mV	3.84056 mV	11.5217 mV	620.739 mV	652.91 mV	1.68	1.79	1.68	100.00 %	0.0227069	0.0287259	629.102 mV	636.59 mV	644.166 mV	5.16546 mV	3.8291 mV
Test	Name	Type	Low L.	High L.	Shape	Source	Execs	Fails	Fails %	Flow ID	Mean	Sigma	3xSigma	Min	Max	Cpk	Cpl	Cpu	Yield	Skew	Kurtosis	P2.5%	P50% - Median	P97.5%	IQR	IQR SD
469		P	0.617 V	0.657 V	Gaussian	Samples	100261	0	0.00 %	49	637.806 mV	3.84364 mV	11.5309 mV	621.891 mV	654.149 mV	1.66	1.80	1.66	100.00 %	0.0223393	0.0282649	630.302 mV	637.797 mV	645.379 mV	5.171 mV	3.83321 mV
470		P	0.618 V	0.658 V	Gaussian	Samples	100261	0	0.00 %	50	639.016 mV	3.84764 mV	11.5429 mV	623.07 mV	655.358 mV	1.64	1.82	1.64	100.00 %	0.0225967	0.0281457	631.514 mV	639.008 mV	646.602 mV	5.17249 mV	3.83432 mV
471		P	0.619 V	0.659 V	Gaussian	Samples	100261	0	0.00 %	51	640.228 mV	3.85084 mV	11.5525 mV	624.14 mV	656.627 mV	1.62	1.84	1.62	100.00 %	0.0225727	0.0281088	632.714 mV	640.221 mV	647.819 mV	5.17899 mV	3.83913 mV
472		P	0.621 V	0.661 V	Gaussian	Samples	100261	0	0.00 %	52	641.444 mV	3.85447 mV	11.5634 mV	625.467 mV	657.618 mV	1.69	1.77	1.69	100.00 %	0.0224071	0.0276008	633.926 mV	641.436 mV	649.036 mV	5.18101 mV	3.84063 mV
473		P	0.622 V	0.662 V	Gaussian	Samples	100261	0	0.00 %	53	642.662 mV	3.85841 mV	11.5752 mV	626.648 mV	658.942 mV	1.67	1.79	1.67	100.00 %	0.0222066	0.0281629	635.132 mV	642.651 mV	650.265 mV	5.189 mV	3.84655 mV
474		P	0.623 V	0.663 V	Gaussian	Samples	100261	0	0.00 %	54	643.883 mV	3.86281 mV	11.5884 mV	627.802 mV	660.196 mV	1.65	1.80	1.65	100.00 %	0.0226283	0.0275506	636.352 mV	643.876 mV	651.497 mV	5.19598 mV	3.85172 mV
475		P	0.624 V	0.664 V	Gaussian	Samples	100261	0	0.00 %	55	645.109 mV	3.86769 mV	11.6031 mV	629.063 mV	661.497 mV	1.63	1.82	1.63	100.00 %	0.0219525	0.0264705	637.564 mV	645.099 mV	652.723 mV	5.21147 mV	3.86321 mV
476		P	17 mV	19 mV	Gaussian	Samples	100261	0	0.00 %	56	18.1646 mV	167.654 uV	502.962 uV	17.442 mV	18.886 mV	1.66	2.32	1.66	100.00 %	0.0155024	0.0385429	17.836 mV	18.1645 mV	18.4955 mV	224 uV	166.049 uV
477		P	-0.5 LSB	0.5 LSB	Bi-Modal (clear modes)	Samples	100261	4	0.00 %	57	-9.60325 mLSB	161.873 mLSB	485.618 mLSB	-501.638 mLSB	2.0558 LSB	1.01	1.01	1.05	100.00 %	0.091958	-0.696456	-264.81 mLSB	-72.0993 mLSB	244.635 mLSB	289.107 mLSB	214.312 mLSB
478		P	-0.5 LSB	0.5 LSB	Bi-Modal (clear modes)	Samples	100261	3	0.00 %	58	-20.4716 mLSB	140.691 mLSB	422.073 mLSB	-461.015 mLSB	2.03972 LSB	1.14	1.14	1.23	100.00 %	0.344409	-0.0520401	-226.18 mLSB	-85.0395 mLSB	216.789 mLSB	251.651 mLSB	186.547 mLSB
490		P	31	31	Categories	Samples	29358	264	0.90 %	59	30.9795	0.345911	1.03773	0	31	-0.0197	-0.0197	0.0197	99.10 %	-53.6108	4432.65	31	31	31	0	0
499		P	n/a .	n/a .	Bi-Modal (clear modes)	Samples	100257	0	0.00 %	60	2.76499 s	383.095 ms	1.14929 s	1.531 s	11.156 s	n/a .	n/a .	n/a .	100.00 %	5.20146	66.9967	2.032 s	2.703 s	3.203 s	312 ms	231.282 ms
559		P	n/a .	n/a .	Unknown	Samples	100257	0	0.00 %	61	2.76528 s	383.05 ms	1.14915 s	1.546 s	11.156 s	n/a .	n/a .	n/a .	100.00 %	5.2023	67.026	2.032 s	2.703 s	3.203 s	313 ms	232.024 ms
560		P	-3.0 LSB	3.0 LSB	Categories	Samples	100257	0	0.00 %	62	0 LSB	0 LSB	0 LSB	0 LSB	0 LSB	n/a .	n/a .	n/a .	100.00 %	n/a .	n/a .	0 LSB	0 LSB	0 LSB	0 LSB	0 LSB
568		P	-3.0 LSB	3.0 LSB	Unknown	Samples	100257	21	0.02 %	63	-818.103 mLSB	28.1267 LSB	84.3802 LSB	-1.95354 KLSB	1.36831 LSB	0.0259	0.0259	0.0452	99.98 %	-69.0629	4768.43	-1.14746 LSB	-383.142 mLSB	208.32 mLSB	317.44 mLSB	235.315 mLSB
580		P	2.4 V	2.6 V	Unknown	Samples	100236	52	0.05 %	64	2.48703 V	55.1925 mV	165.578 mV	-1.7395 mV	4.84 V	0.5256	0.5256	0.6823	99.95 %	-41.6596	1931.46	2.47 V	2.48798 V	2.50757 V	12.4509 mV	9.22975 mV


Die X locations
20 30 40 50
Die Y locations
10 20 30 40 50 60



Test results (mV)
Data count (8145 samples found)
High Limit
Low Limit
Mean

Part Average Testing



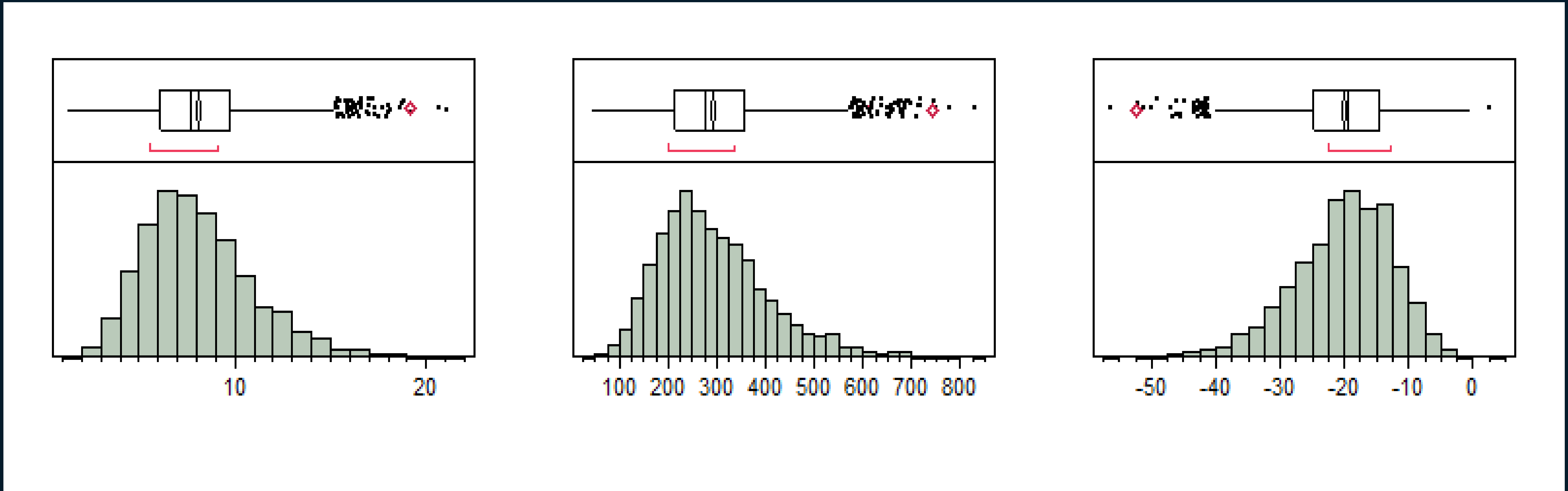
DPAT Limits

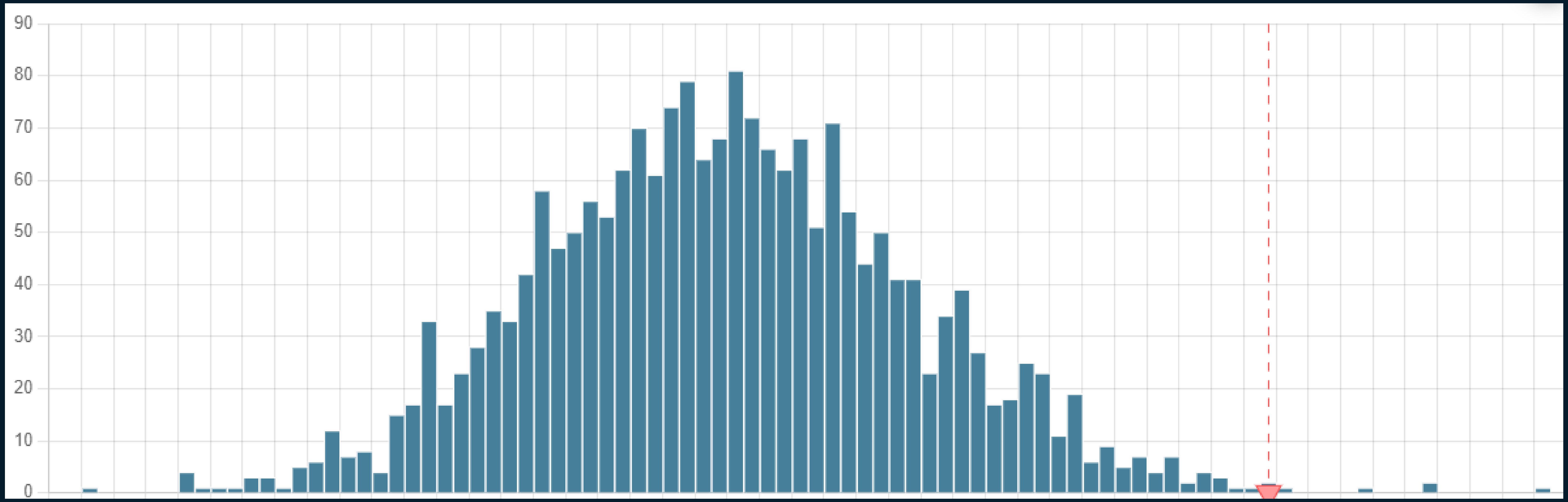
Method	Results (out of 50)	Yield Hit
DPAT Production Rule Set	0	0

Method	Results (out of 50)	Yield Hit
DPAT Production Rule Set	0	0
DPAT Aggressive	0	0.9%

Method	Results (out of 50)	Yield Hit
DPAT Production Rule Set	0	0
DPAT Aggressive	0	0.9%
DPAT More Aggressive	1	12.6%

Multivariate Methods.
What is a multivariate outlier?




90
80
70
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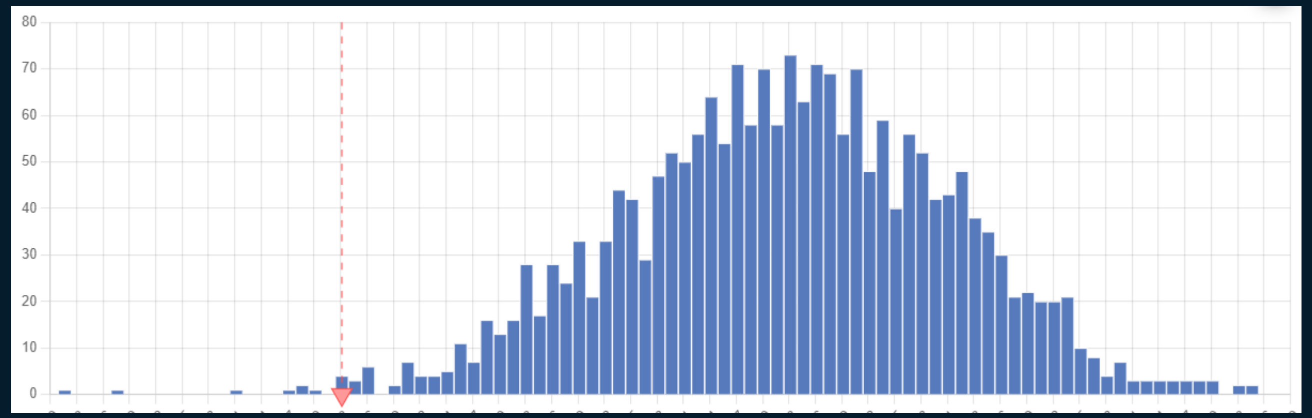
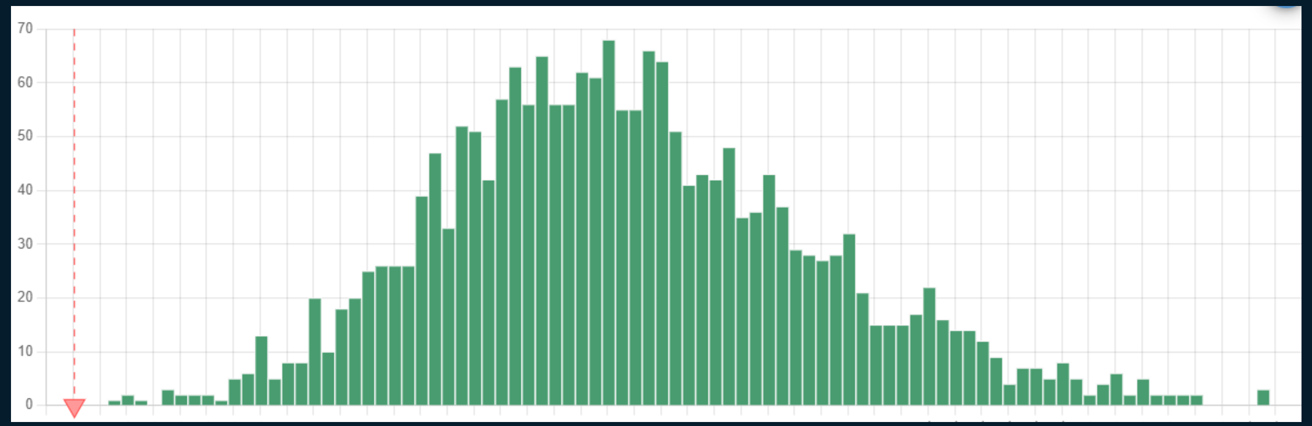
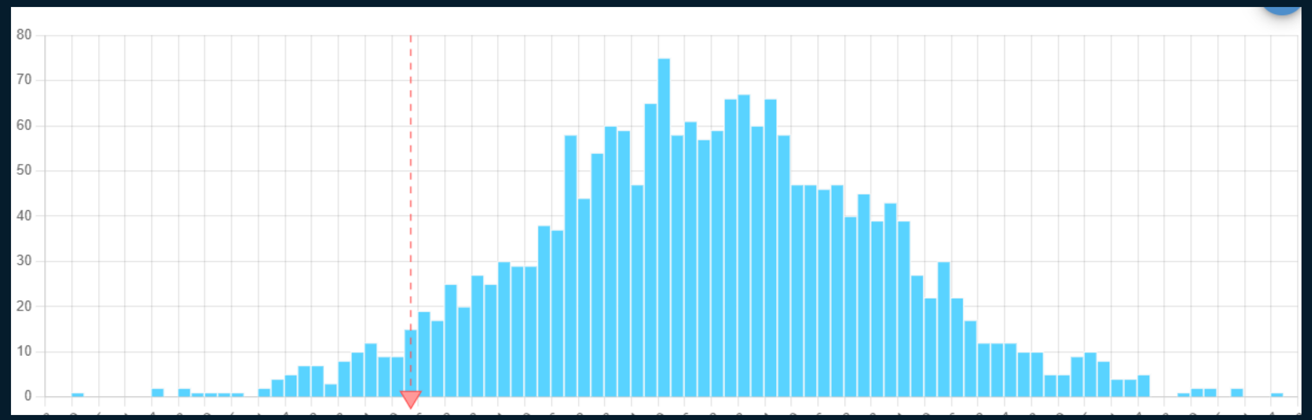
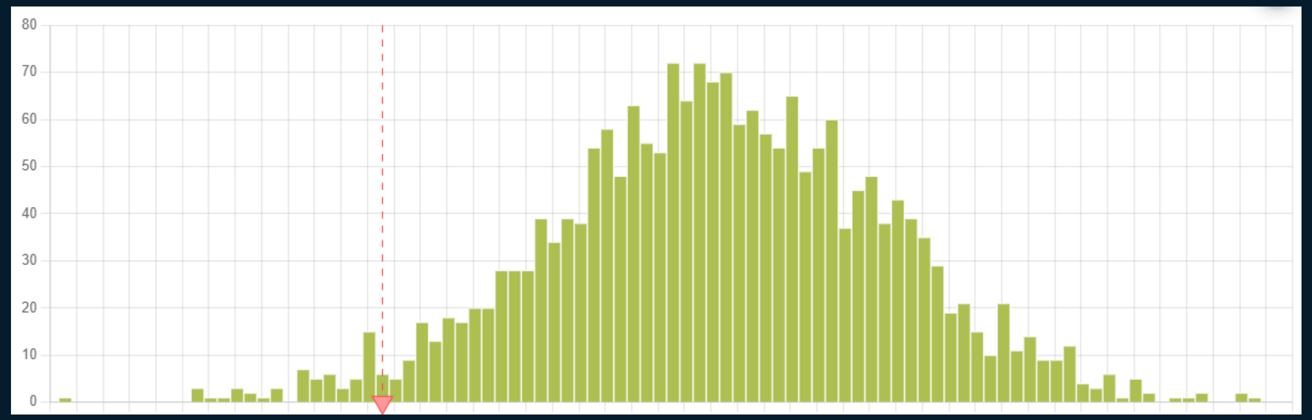
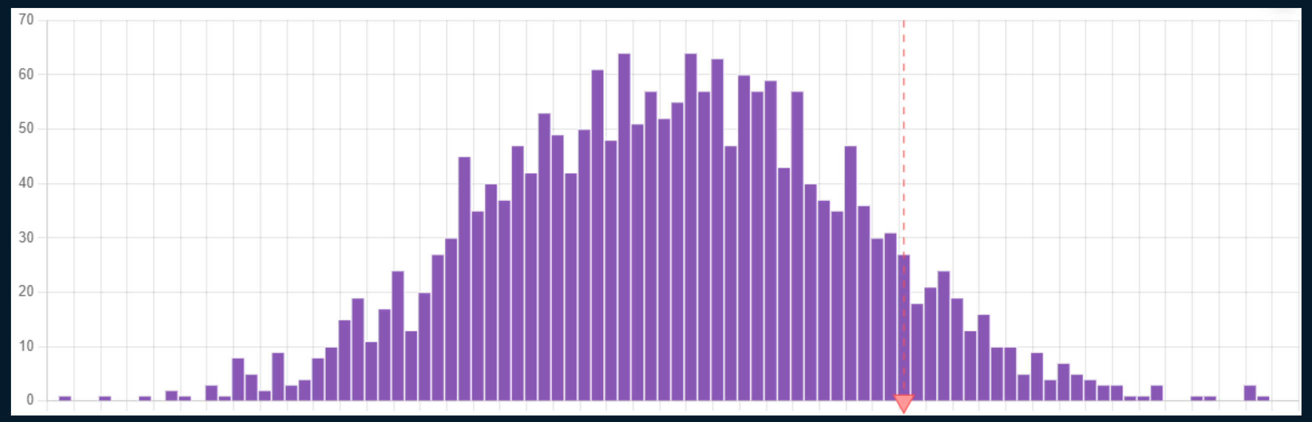
40
30
20
10
0



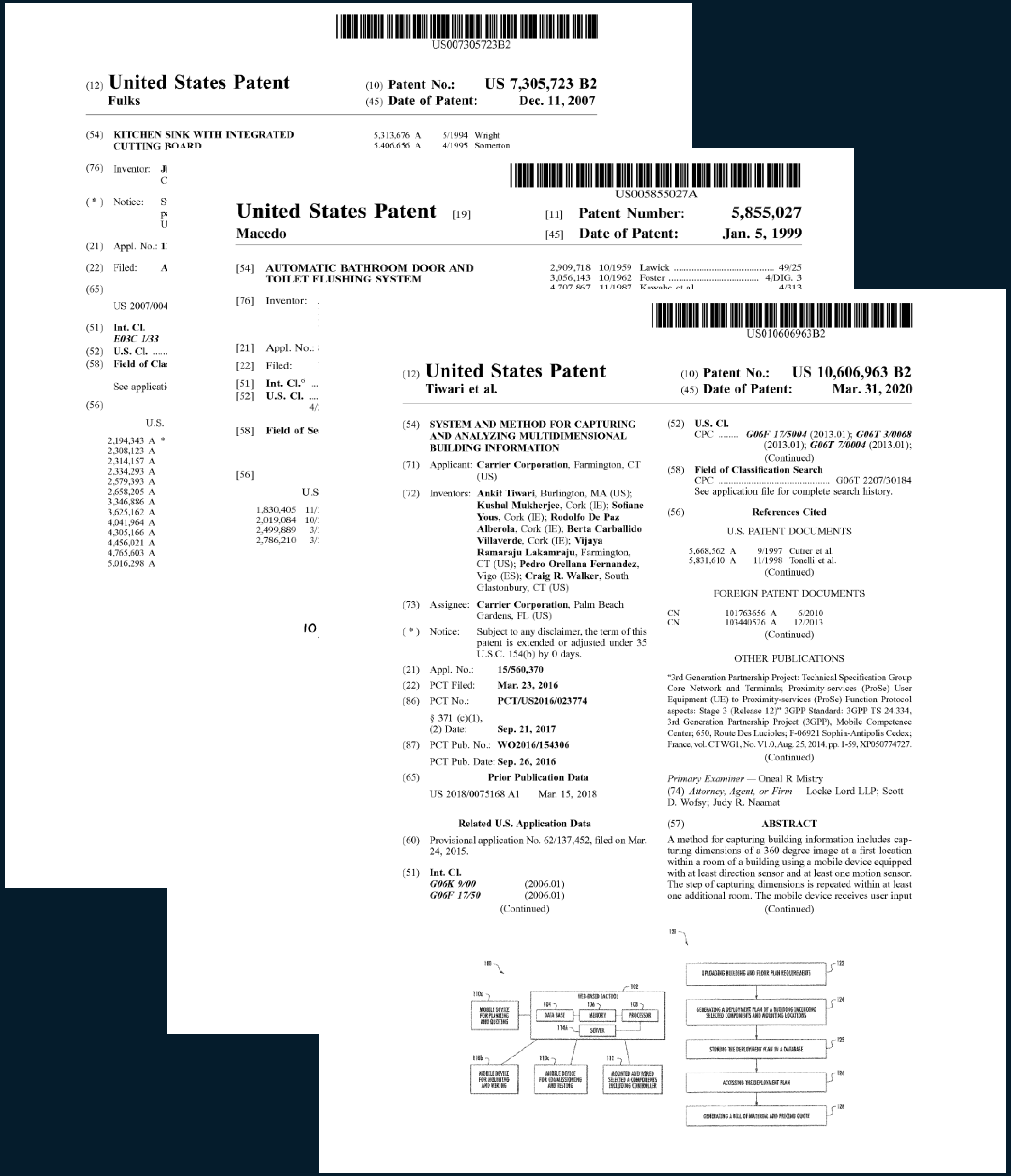








Method	Results *(out of 50)*	Yield Hit
DPAT Production Rule Set	0	0
DPAT Aggressive	0	0.9%
DPAT More Aggressive	1	12.6%
MultiVariable 1 : Z(σ) Stacking	**8**	**3%**


US007305723B2

(12) United States Patent
Fulks

(10) Patent No.: US 7,305,723 B2
(45) Date of Patent: Dec. 11, 2007

(54) KITCHEN SINK WITH INTEGRATED CUTTING BOARD

US005855027A

United States Patent [19]
Macedo

[11] Patent Number: 5,855,027
[45] Date of Patent: Jan. 5, 1999

[54] AUTOMATIC BATHROOM DOOR AND TOILET FLUSHING SYSTEM

US010606963B2

(12) United States Patent
Tiwari et al.

(10) Patent No.: US 10,606,963 B2
(45) Date of Patent: Mar. 31, 2020

(54) SYSTEM AND METHOD FOR CAPTURING AND ANALYZING MULTIDIMENSIONAL BUILDING INFORMATION

(71) Applicant: Carrier Corporation, Farmington, CT (US)

(72) Inventors: Ankit Tiwari, Burlington, MA (US); Kushal Mukherjee, Cork (IE); Sofiane Yous, Cork (IE); Rodolfo De Paz Alberola, Cork (IE); Berta Carballido Villaverde, Cork (IE); Vijaya Ramaraju Lakamraju, Farmington, CT (US); Pedro Orellana Fernandez, Vigo (ES); Craig R. Walker, South Glastonbury, CT (US)

(73) Assignee: Carrier Corporation, Palm Beach Gardens, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: 15/560,370
(22) PCT Filed: Mar. 23, 2016
(86) PCT No.: PCT/US2016/023774
§ 371 (c)(1), (2) Date: Sep. 21, 2017
(87) PCT Pub. No.: WO2016/154306
PCT Pub. Date: Sep. 26, 2016

(65) Prior Publication Data
US 2018/0075168 A1 Mar. 15, 2018

Related U.S. Application Data
(60) Provisional application No. 62/137,452, filed on Mar. 24, 2015.

(51) Int. Cl.
G06K 9/00 (2006.01)
G06F 17/50 (2006.01)
(Continued)

(52) U.S. Cl.
CPC G06F 17/5004 (2013.01); G06T 3/0068 (2013.01); G06T 7/0004 (2013.01);
(Continued)

(58) Field of Classification Search
CPC G06T 2207/30184
See application file for complete search history.

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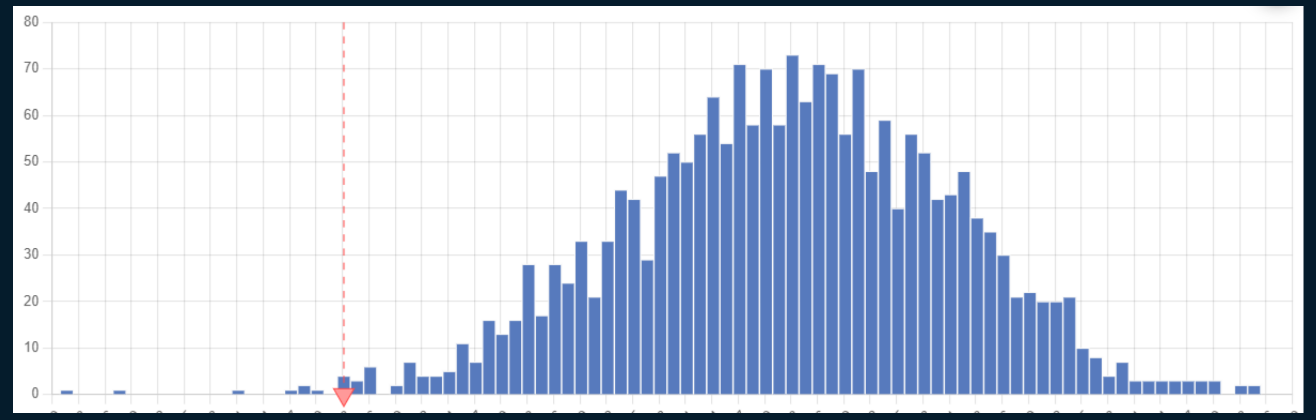
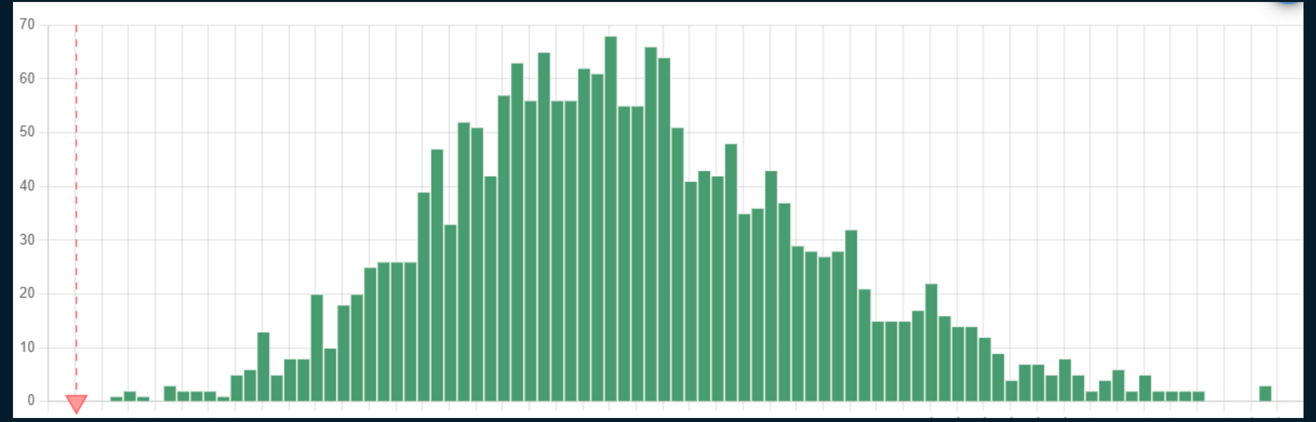
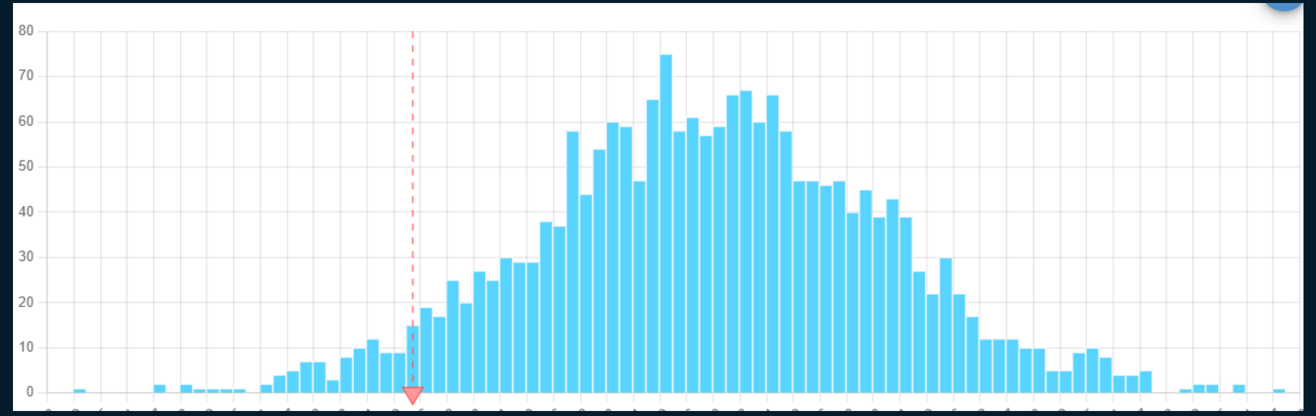
(Continued)

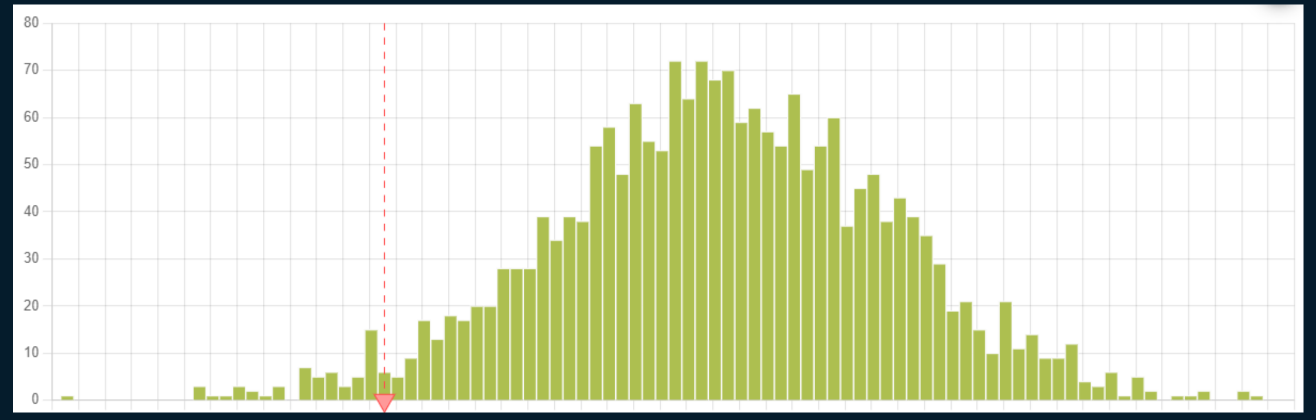
Primary Examiner — Oneal R Mistry
(74) Attorney, Agent, or Firm — Locke Lord LLP; Scott D. Wofsy; Judy R. Naamat

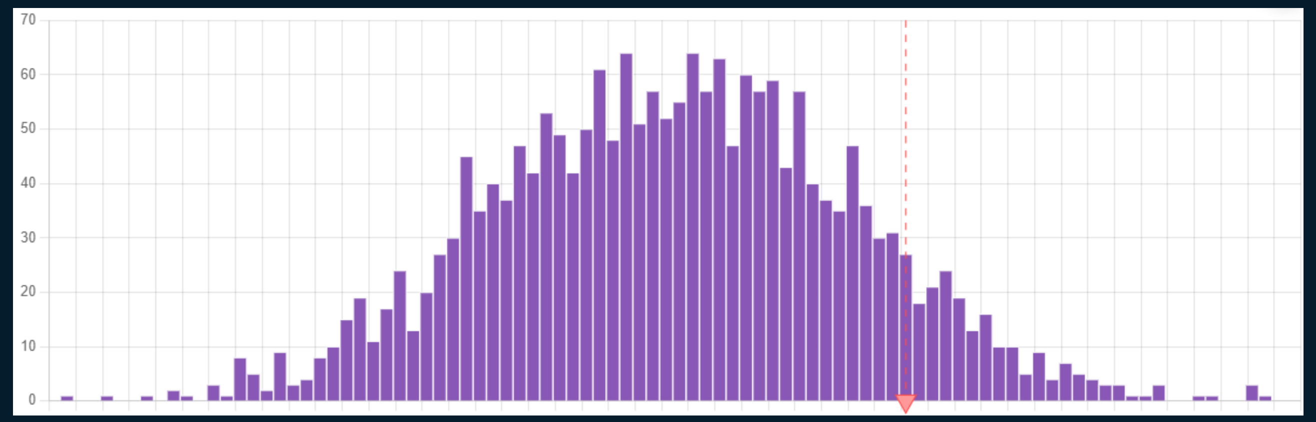
(57) ABSTRACT
A method for capturing building information includes capturing dimensions of a 360 degree image at a first location within a room of a building using a mobile device equipped with at least direction sensor and at least one motion sensor. The step of capturing dimensions is repeated within at least one additional room. The mobile device receives user input
(Continued)

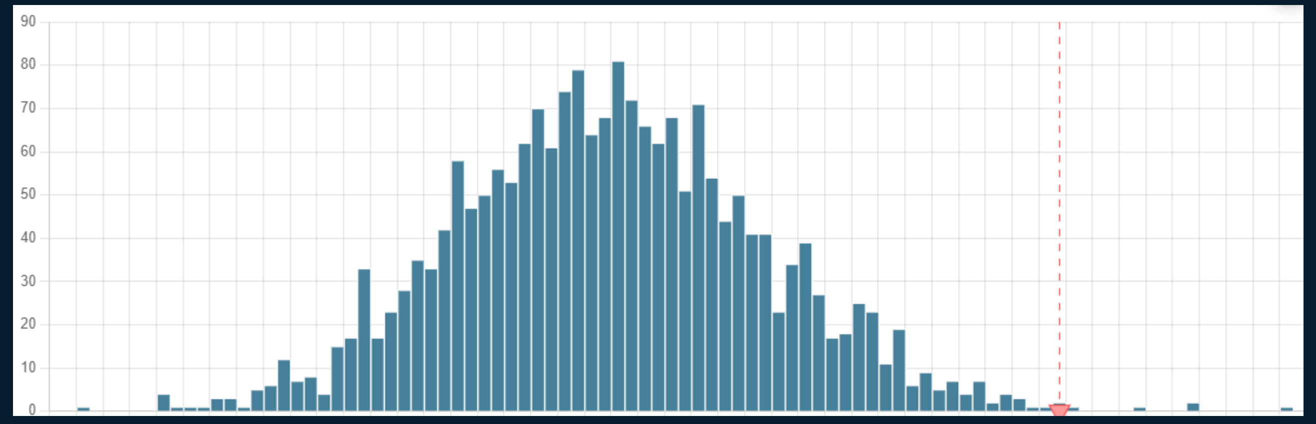












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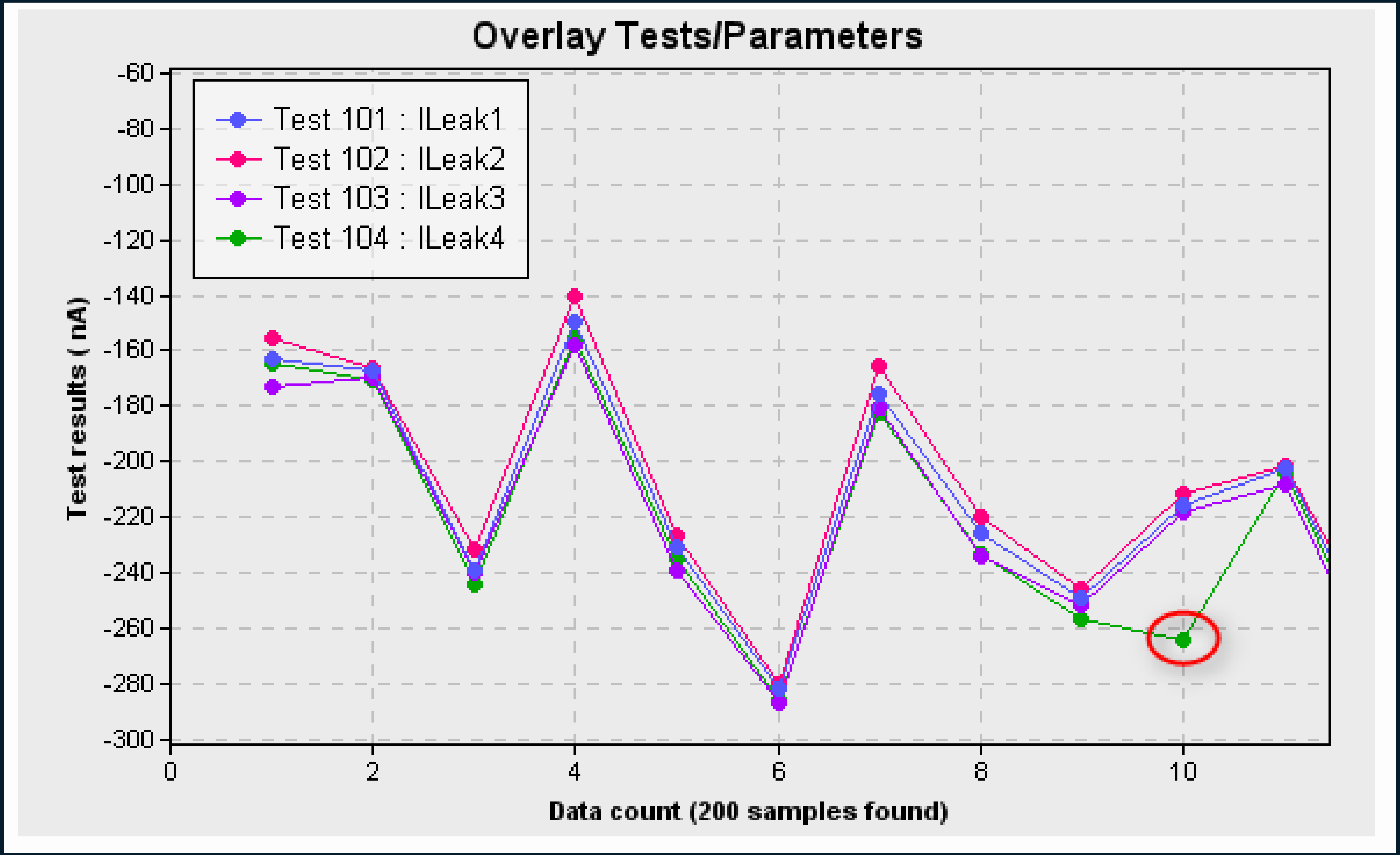
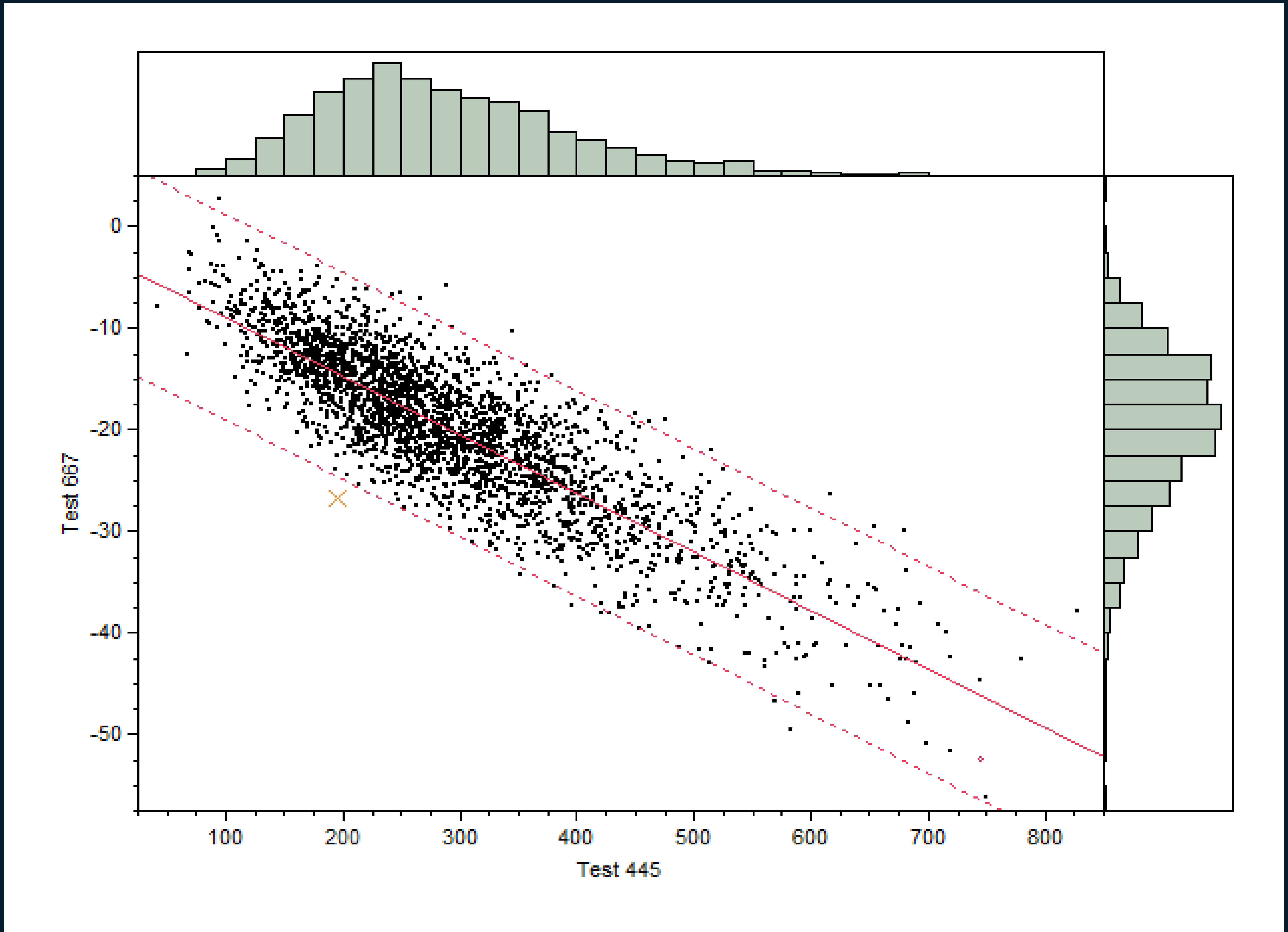
Correlations?



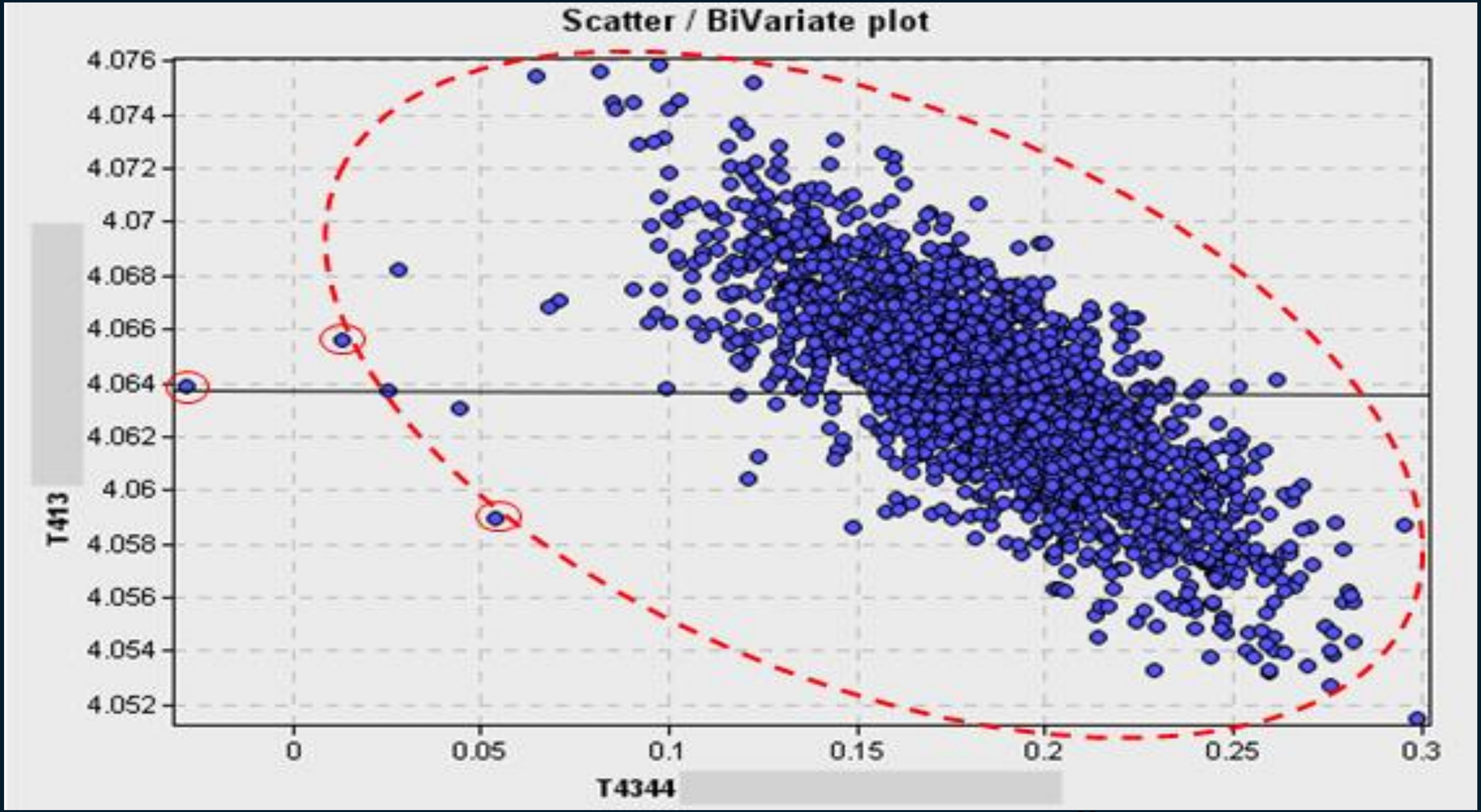
Leblond, Nicolas & Jochen Stephan. "*Multi-Variate Part-Average-Testing Analysis to Improve Outlier Identification.*" Semicon Europa 2014. Grenoble, France Oct 2014

Correlations?



Correlations?

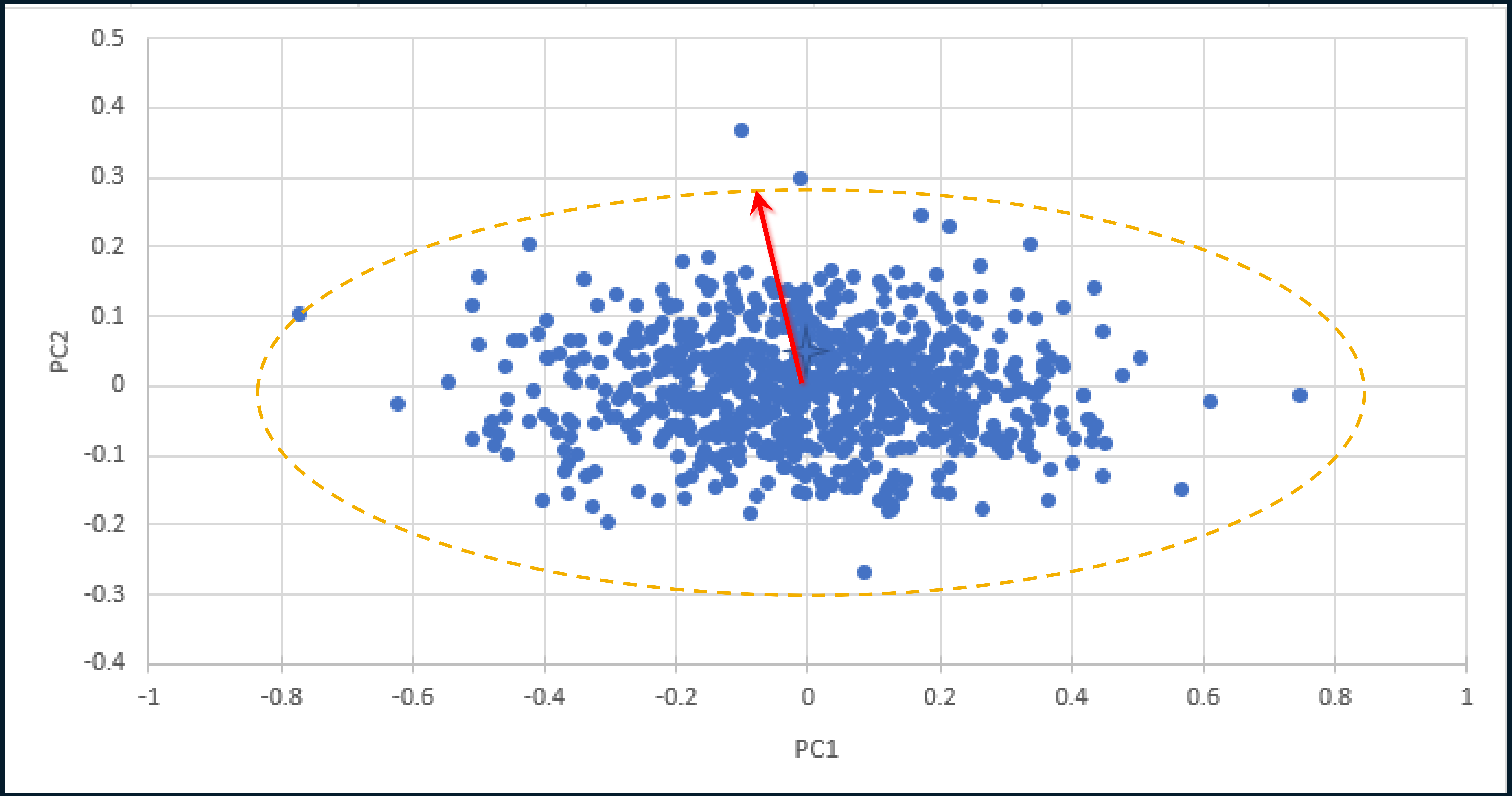
$$y = \pm\frac{b}{a}\sqrt{a^2 - x^2} = \pm\sqrt{(a^2 - x^2)(1 - e^2)}.$$



Method	Results *(out of 50)*	Yield Hit
DPAT Production Rule Set	0	0
DPAT Aggressive	0	0.9%
DPAT More Aggressive	1	12.6%
MultiVariable 1 : Z(σ) Stacking	8	3%
MultiVariable 2 : MV-PAT; Pearson Correlation	**21**	**5.5%**

Covariance Matrices, Mahalanobis Distance, and PCA? *(and an Oxford Comma)*

$$D^2 = (x - m)^T \cdot C^{-1} \cdot (x - m)$$ *



* Cansiz, S. (2022, January 26). *Mahalanobis Distance and Multivariate Outlier Detection in R.* https://towardsdatascience.com/mahalonobis-distance-and-outlier-detection-in-r-cb9c37576d7d

Method	Results *(out of 50)*	Yield Hit
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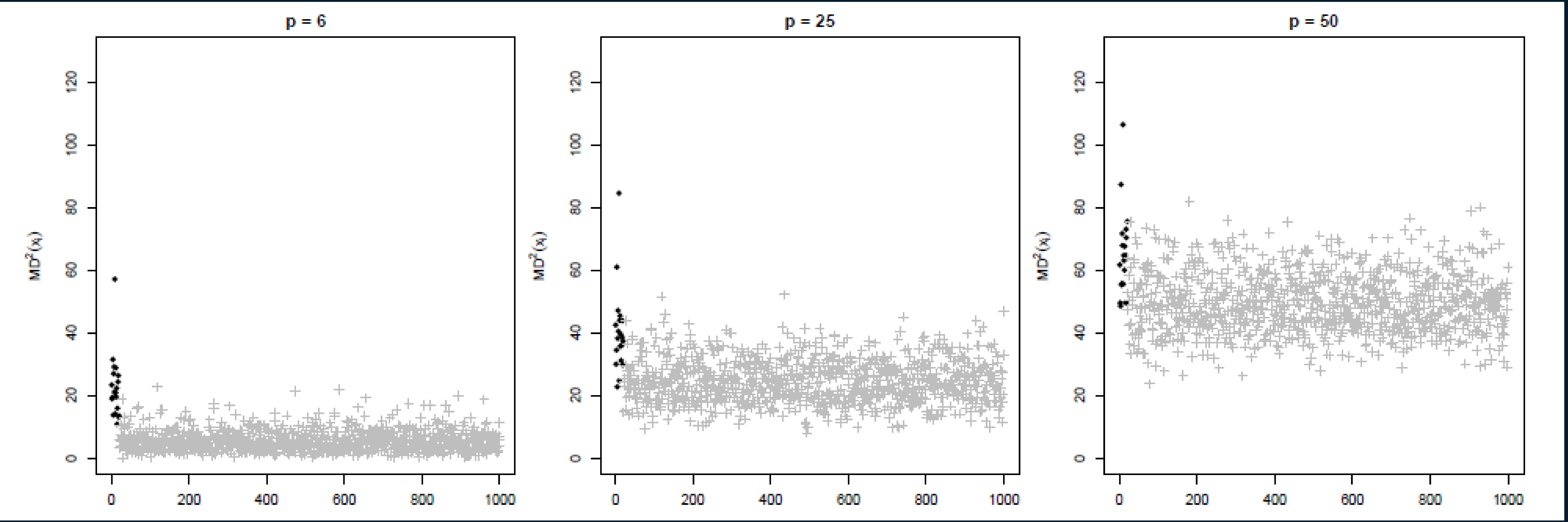
DPAT More Aggressive	1	12.6%
MultiVariable 1 : Z(σ) Stacking	8	3%
MultiVariable 2 : MV-PAT Pearson Correlation	21	5.5%
MultiVariable 3 : PCA & Mahanalobis Distance	**24**	**4.4%**
MultiVariable 4: Same as above, more aggressive	**27**	**13.1%**

Problem: The objective of Principal Component Analysis is not outlier detection.

By definition, outliers may be lost.

Another Problem: Mahalanobis distance performs poorly as *p* increases.*

Distributions approach Gaussian as p increases, reducing signal in the noise. (These data have p=1,156).

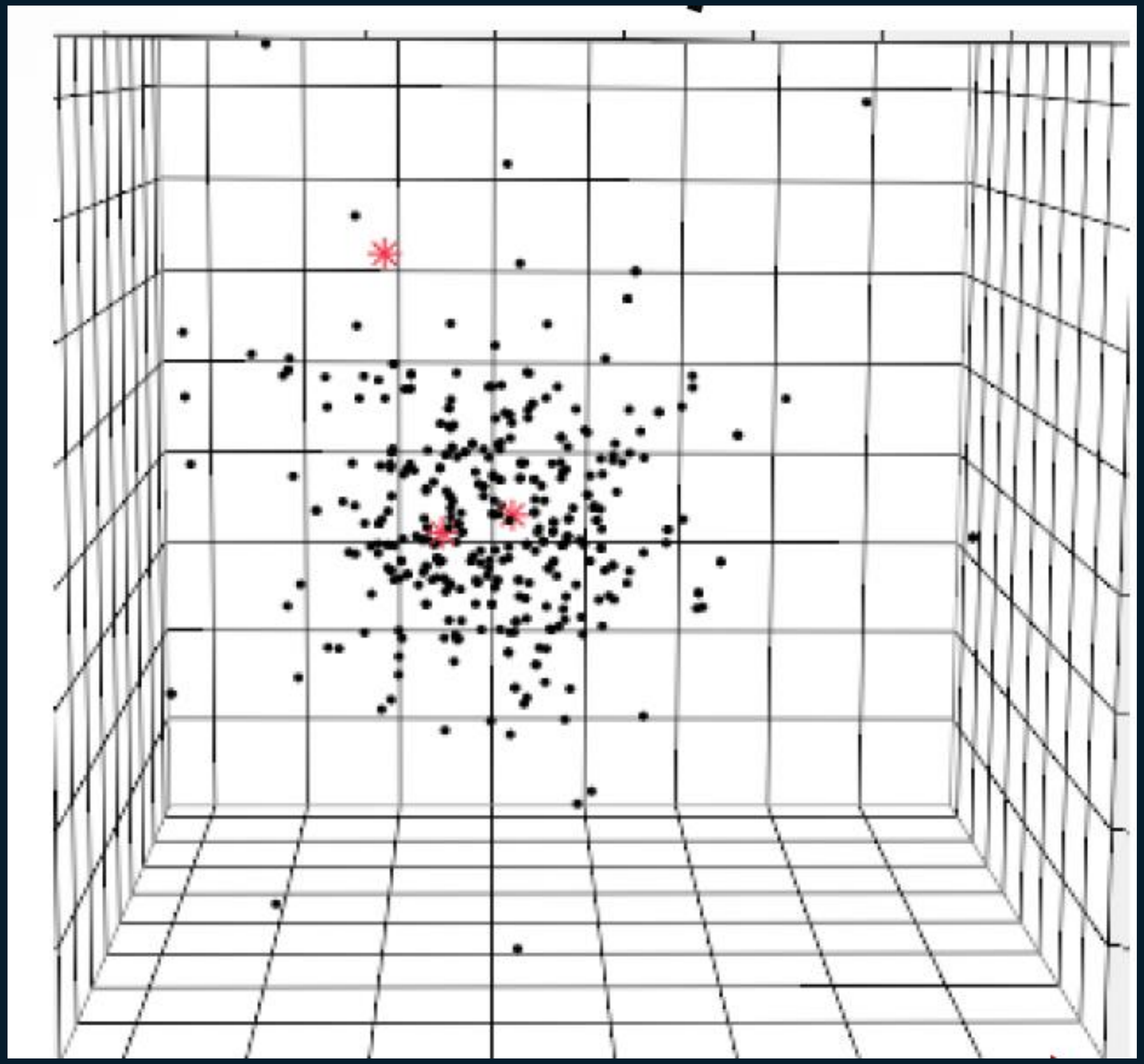


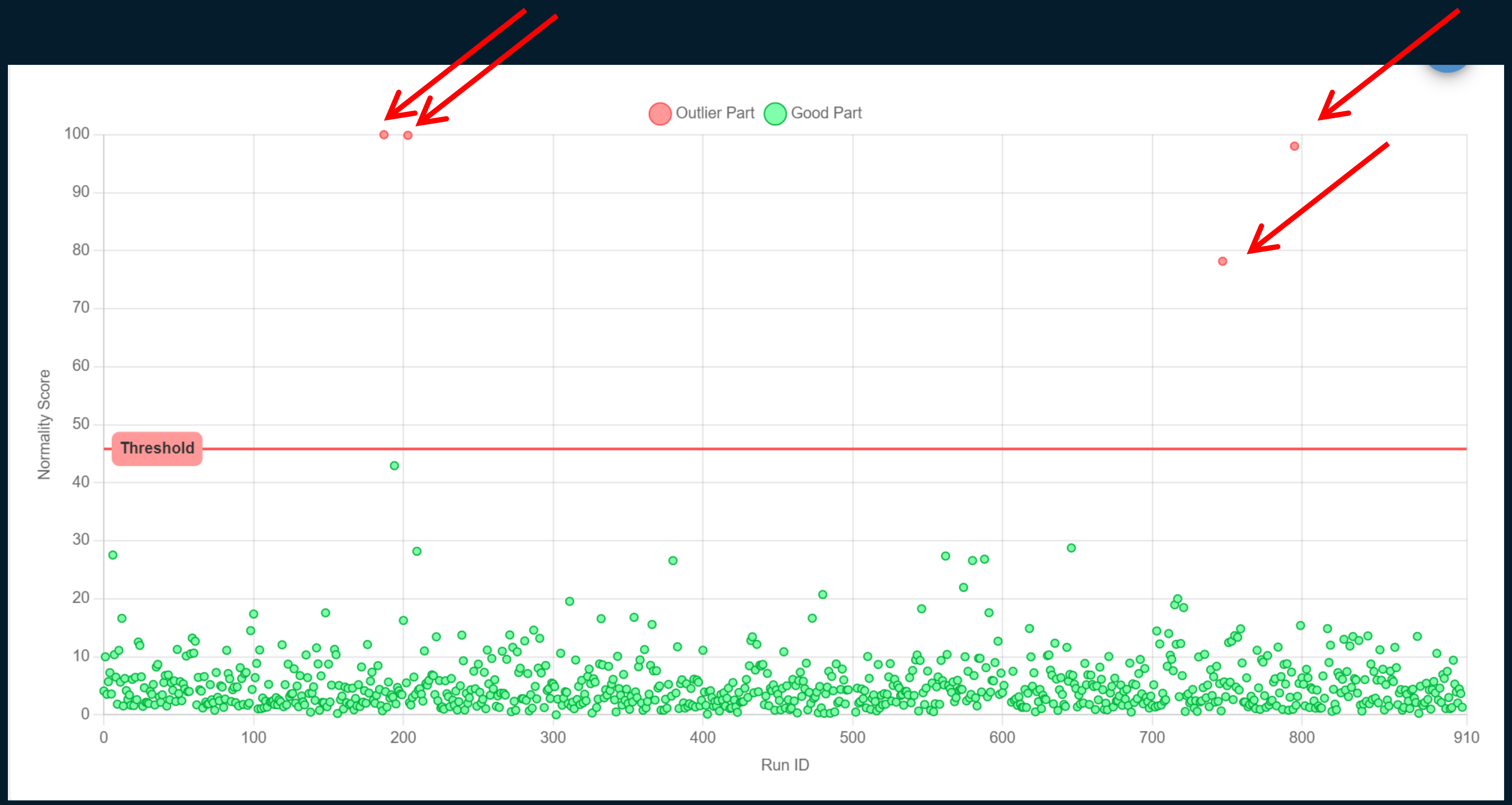
* Allessandrino, S., et al; (ST Microelectronics & Ippon Innovation) *From Space to Automotive: Advanced Detection of Burn-in Rejects on SiC Products Using a New Statistical Screening Approach.* Automotive Reliability & Test Europe. 5 Feb, 2021

Back to the Drawing Board

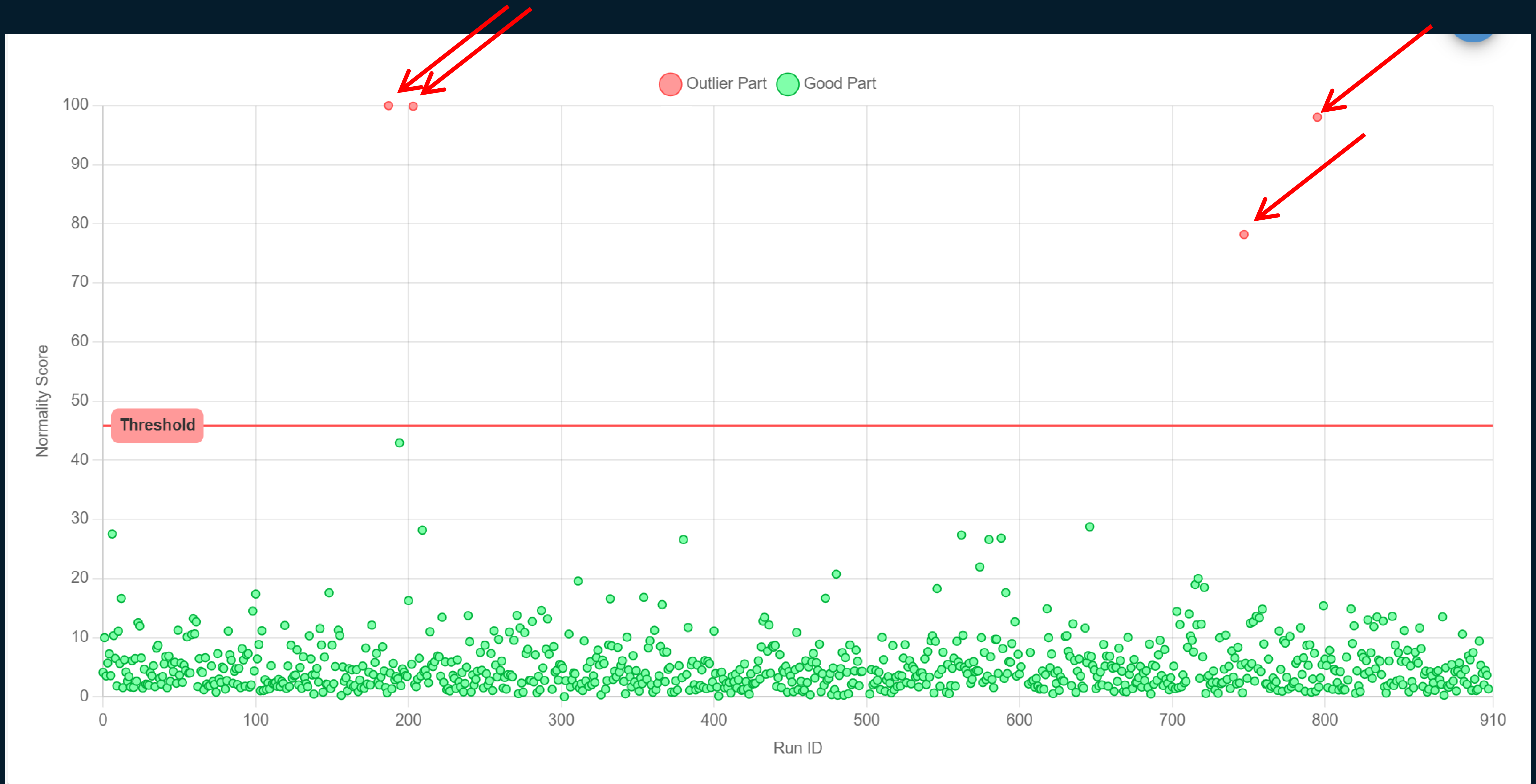
Actual smart guy.

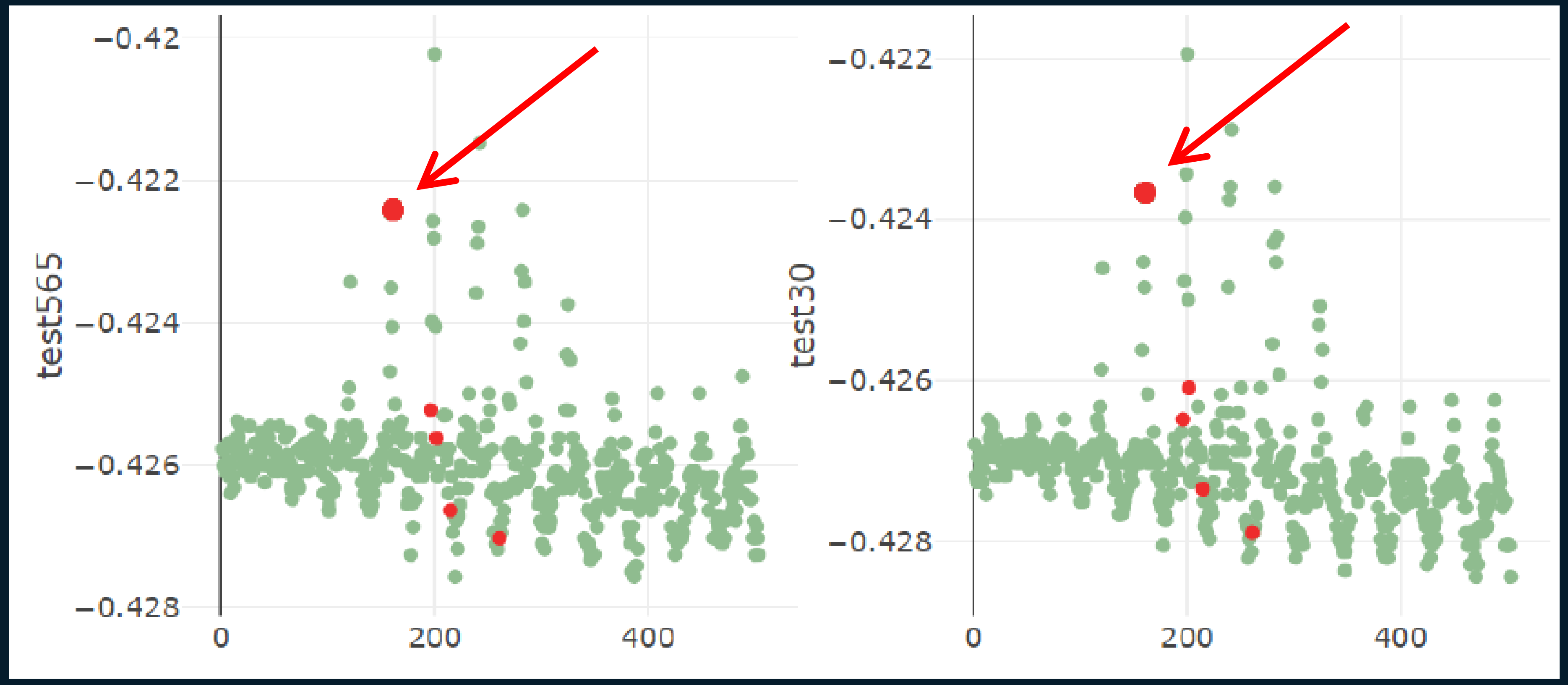
A new method: *Orion* by Galaxy

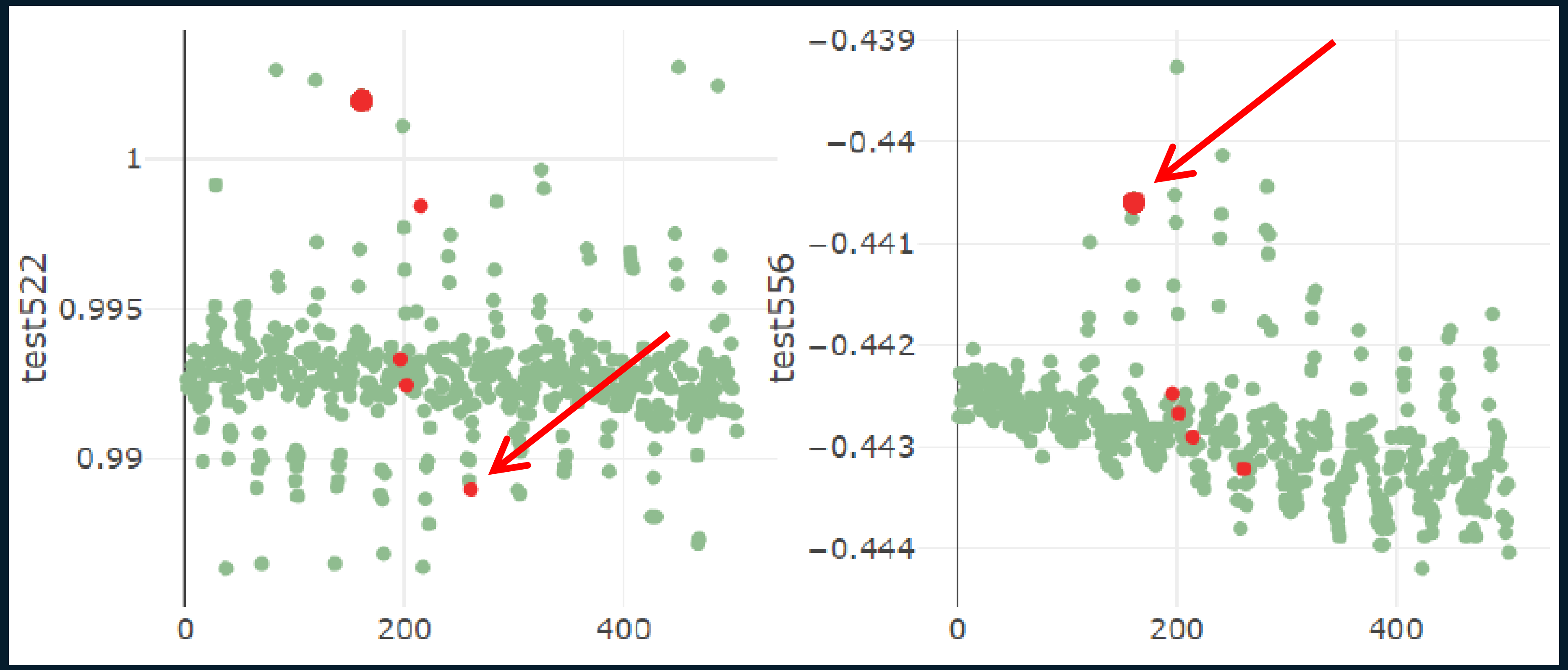




A new method: *Orion* by Galaxy







* Ibid

Best results achieved by:

- Run traditional DPAT at relatively loose settings. (Ie: 9σ for Gaussian)
- Run Orion Omnivariate on remaining good die that did not fail the above methods.

Not tested in this experiment:

- Run NNR using typical settings with site-bias correction.
- Run GPAT to capture Good Die in Bad Neighborhood.

Method	Results (out of 50)	Yield Hit
DPAT Production Rule Set	0	0
DPAT Aggressive	0	0.9%
DPAT More Aggressive	1	12.6%
MultiVariable 1 : Z(σ) Stacking	8	3%
MultiVariable 2 : MV-PAT using Pearson Correlation	21	5.5%
MultiVariable 3 : PCA & Mahanalobis Distance	24	4.4%
MultiVariable 4: Same as above more aggressive	27	13.1%
Orion Omnivariate	**44** *	**2.4%** *

** Your mileage may vary.*

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