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Sandia National Laboratories

Development of a Data Management Methodology for a COTS Part Testing Program to Meet the Needs of a Broad Range of Users

PRESENTED BY

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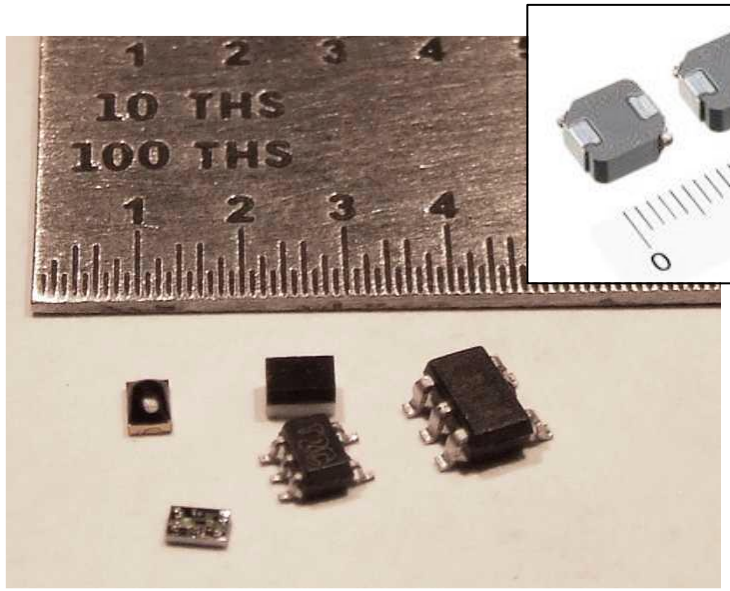
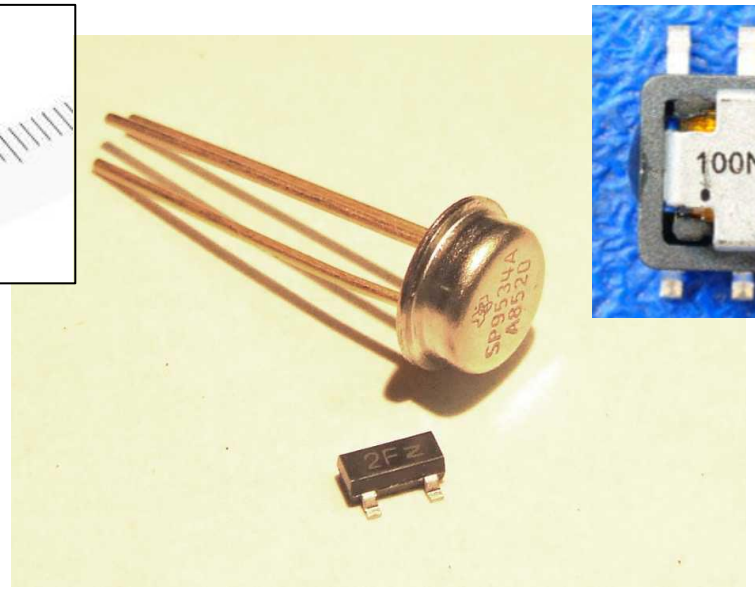
Overview

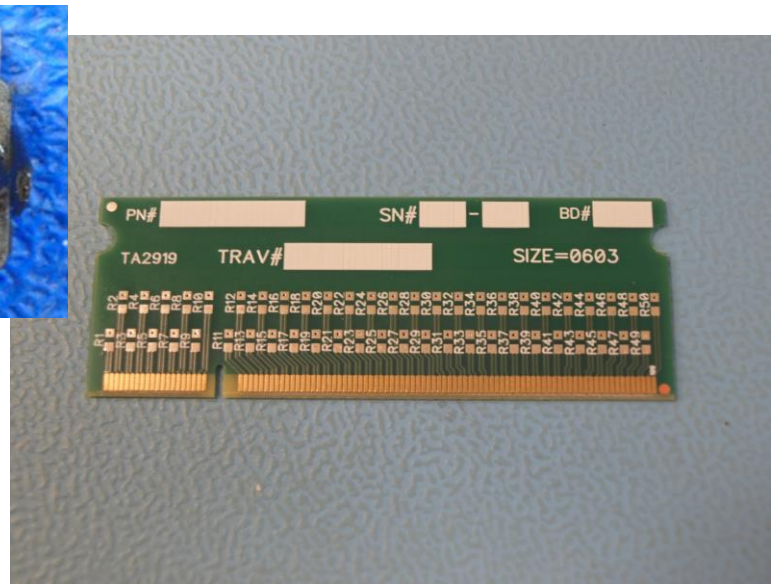
- Introduction to Sandia and High-Reliability Electronic Components group
- Commercial-off-the-shelf (COTS) surveillance testing program
- Electronic Component Analysis & Test Tracking (eCATT) System
- What is preventing COTS data from being fully leveraged?
- Current dispersed state of COTS data
- Proposed solution: relational table-based data structure
- Understanding COTS data users/consumers
- Demonstration of proposed solution: restructuring and analysis of Long Term Dormant Storage (LTDS) data from multiple user perspectives.
- Demonstration of proposed solution: Restructuring and analysis of metal-oxide field effect transistor (MOSFET) data from multiple user perspectives.
- Discussion of future work

Sandia & High-Rel Electronic Components Group

- Sandia is a U.S. NNSA research & development laboratory focused on delivering essential science and technology to solve our nation's most challenging security issues.
  - Sandia's primary mission is ensuring the U.S. nuclear arsenal is safe, secure, and reliable, and can fully support our nation's deterrence policy.
- Sandia's High-Reliability Electronic Components group responsible for development and delivery of high reliability electronic products for national security systems:
  - Includes selection and qualification of commercial-off-the-shelf (COTS) parts.

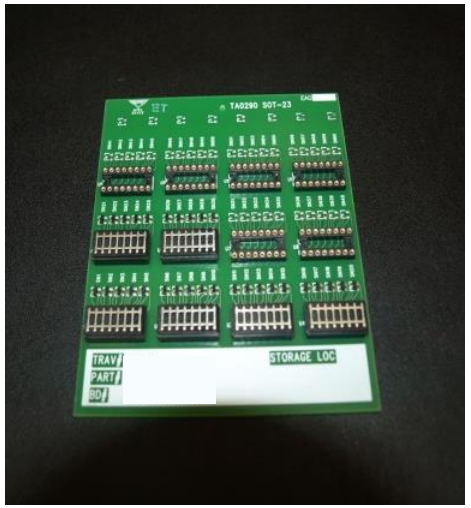


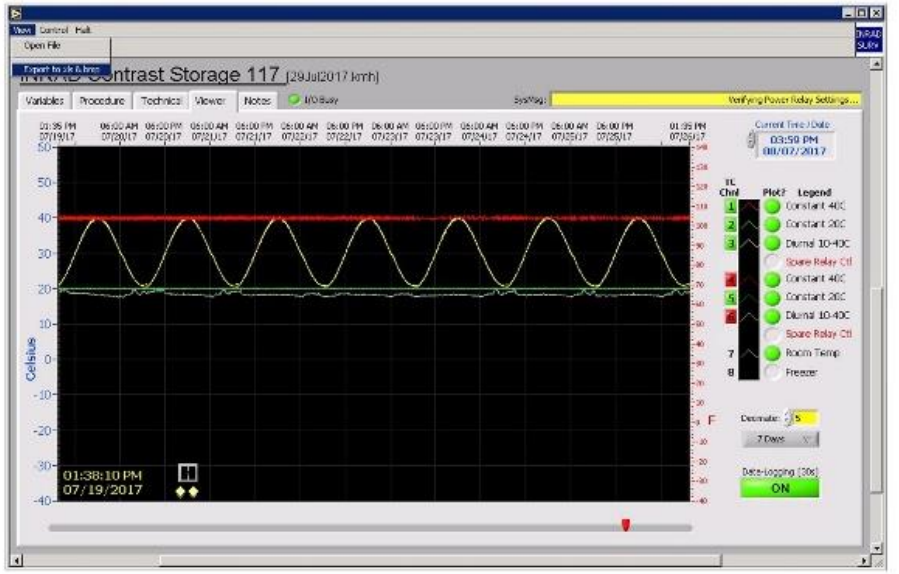


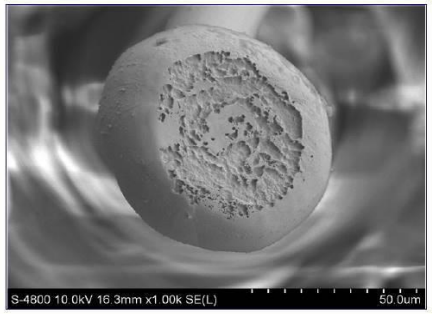


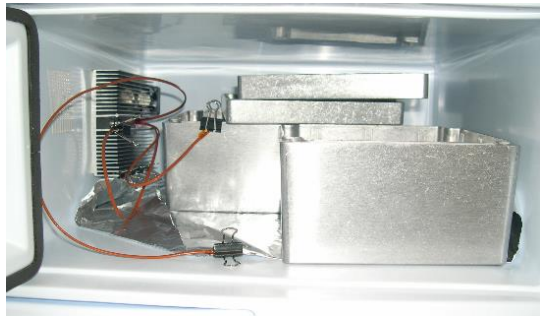
COTS Surveillance Testing Program

- COTS surveillance testing program established to characterize long-term performance and reliability of electronic parts under adverse environmental conditions (e.g., humidity and temperature cycling, high radiation) and aid in part selection:
  - Electrical testing data/metadata available for thousands of COTS parts maintained within the Electronic Component Analysis and Test Tracking (eCATT) system.









Electronic Component Analysis & Test Tracking (eCATT) System

- Tracks movement of COTS parts as they undergo surveillance testing.
- Records steps used in processing parts and environmental conditions that parts are exposed.
- Process for collecting raw data and recording test metadata is highly structured and organized, allowing the test lab to move hundreds of parts through in an efficient and trackable way.

Steps performed in processing parts for eCATT Traveler #19555

eCATT
ELECTRONIC COMPONENT ANALYSIS AND TEST TRACKING

Help

Traveler # Go

eCATT Home | Travelers & Steps | Results | Parts | Labs | Reports

Travelers & Steps

> eCATT Home > Travelers & Steps > Edit / View Traveler & Steps

Edit / View Traveler & Steps

Expand All | Collapse All | Use icon to expand data, and icon to collapse. Use action buttons for traveler and each step.

Traveler Number 2020-3512-0019555 **Mfg. Part Number**

Step	Subcategory	Test Engineer	Lab	Start Date	End Date	Step Actions
1	Incoming traveler review			10/27/2020	10/29/2020	Post Print PDF XML JIT
2	Pull Parts from Inventory			10/29/2020	11/16/2020	Post Print PDF XML JIT
3	Serialize			11/16/2020	11/16/2020	Post Print PDF XML JIT
4	Tesec			11/16/2020	11/18/2020	Post Print PDF XML JIT
5	Temperature Bake			11/18/2020	11/25/2020	Post Print PDF XML JIT
6	Temp./Humidity			11/25/2020	12/02/2020	Post Print PDF XML JIT
7	Reflow			12/02/2020	12/02/2020	Post Print PDF XML JIT
8	Tesec			12/02/2020	12/03/2020	Post Print PDF XML JIT
9	DRM - Stats, Charts, Deltas			12/03/2020	12/05/2020	Post Print PDF XML JIT
10	Split Travelers			12/05/2020	12/07/2020	Post Print PDF XML JIT
11	Traveler final review			12/07/2020	12/07/2020	Post Print PDF XML JIT

Tester data file for eCATT Traveler #19555

	A	B	C	D	E	F	G	H	I	J	K
1	DTA File Name	19555_Post_PreCond_Amb.dta									
2	DTA File Created Date Time	03 12 2020 14:37:00									
3	TST File Name for DTA										
4	XLSX File Name	19555_Post_PreCond_AmbDTA.xlsx									
5	XLSX File Created Time	03 12 2020 15:51:10									
6	Operator										
7	Station	A									
8	Device Name										
9	Lot Name	N/A									
10	Comment	Post Pre Cond @ Room									
11	Last N&P Check	03 12 2020 09:38:19									
12	DataLog Rate	1									
13	Number of Tests	9									
14	Quantity Logged	166									
15	Datalog Quantity to Log	32767									
16	Test		1	2	3	4	5	6	7	8	9
17	Item		CONT	BVDSS	VTH	SAME	IDSS	IGSS	RDON	RDON	VF
18	Limit		0	575	1.3	2.3	1.00E-07	1.00E-07	45	45	1.2
19	Limit Min Max			>	>	<	<	<	<	<	<
20	Limit Units			V	V		A	A	R	R	V
21	Bias 1			ID	IG	T#	VDS	VSG	ID	ID	IAK
22	Bias 1 Value		0	0.00025	9.40E-05	3	590	20	0.09	0.09	0.09
23	Bias 1 Units			A	A		V	V	A	A	A
24	Bias 2			VMAX					VG	VG	
25	Bias 2 Value		0	580	0	0	0	0	4.5	10	0
26	Bias 2 Units			V					V	V	
27	Time		0.00078	0.3	0.3	0	0.3	0.3	0.00038	0.00038	0.02
28	Time Units		s	s	s	s	s	s	s	s	s
29	Wafer Data	No									
30	Serial	Bin									
31	1	2		579.8	1.885	1.885	1.38E-10	2.47E-11	25.8	24.1	0.7506
32	2	2		579.8	1.893	1.893	1.44E-10	2.64E-11	25.61	24.55	0.7509
33	3	2		579.7	1.876	1.876	1.56E-10	2.53E-11	25.64	24.01	0.7506
34	4	2		579.8	1.888	1.888	1.59E-10	2.74E-11	25.33	23.74	0.7511
35	5	2		579.8	1.886	1.886	1.27E-10	3.37E-11	25.08	23.51	0.7508
36	6	2		579.8	1.873	1.873	1.22E-10	2.42E-11	26.18	24.14	0.7504
37	7	2		579.8	1.879	1.879	1.37E-10	2.37E-11	26.31	24.88	0.7502
38	8	2		579.8	1.879	1.879	1.52E-10	2.41E-11	26.25	24.17	0.7504

Sheet1

What is preventing COTS data from being fully leveraged?

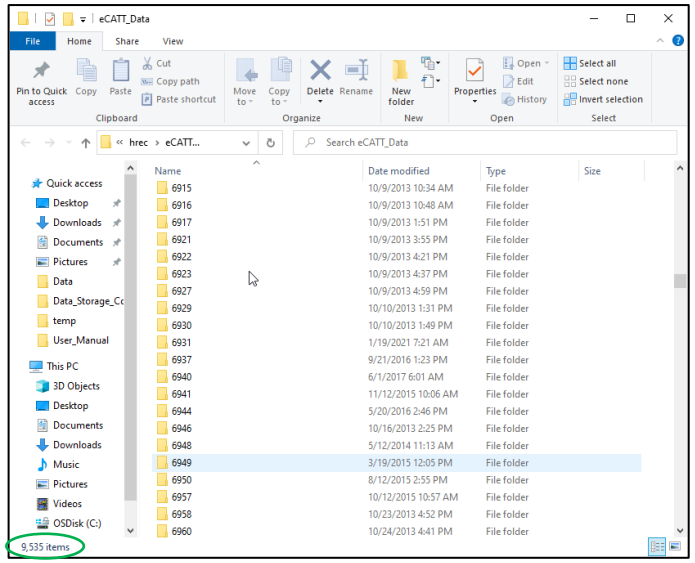
- Large volumes of data are being collected for COTS testing and surveillance, but these data sets are not being fully leveraged to identify potential performance issues within tested parts due to:
  - Organization of data within eCATT, a system designed to maximize efficiencies and meet the needs of the test lab which are very specific. The foundation exists within the eCATT system and test lab procedures, but understanding and leveraging these data is a daunting task for other users.
  - Dispersed nature of metadata.
  - A need for a more complete, robust suite of data analysis tools easily applied to a broad range of data.
  - Incomplete understanding of the data users/consumers (e.g., technologists testing parts, component engineers, surveillance engineers, statistical analysts, management, customers) and their needs. An understanding of COTS data users/consumers and their needs should impact how the data are organized (e.g., ensure that necessary data fields are stored) and analyzed.
  - Lack of clear documentation of all questions to be answered by the tests, creating challenges for users unfamiliar with testing.

COTS Data Organization and Storage Challenges

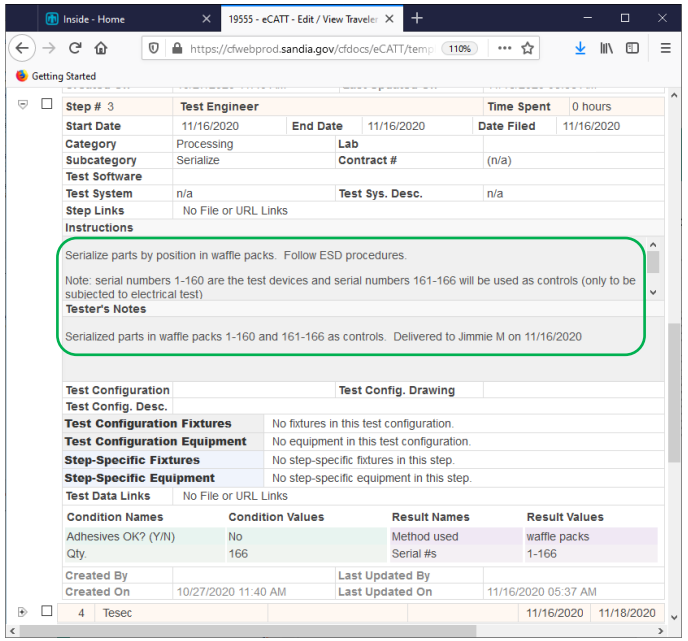
- COTS electrical testing data are collected with multiple types of testers (Tesec, Microflex, Vee, B1506A), each of which can output data in a different format.
- Similarly, image data are collected for COTS parts using different imaging modalities (e.g., x-ray, CT, thermal imaging).
- Electrical test data are spread across multiple files and folders in disparate file formats.
- Metadata specifying environmental and testing conditions that different subsets of parts were exposed to are not typically documented in tester data files, and instead must be determined from manual review of recorded steps in eCATT system.
- There is a growing need to organize and store these dispersed data sets and accompanying metadata so that they can be analyzed and understood by an expanding range of COTS data users/consumers.

Current Dispersed State of COTS Data

Electrical test data stored in thousands of folders in multiple formats



Metadata stored in eCATT system



Part information in manufacturer data sheets

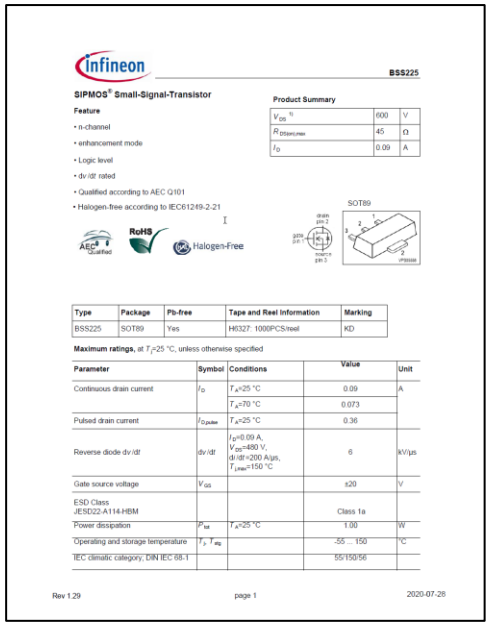
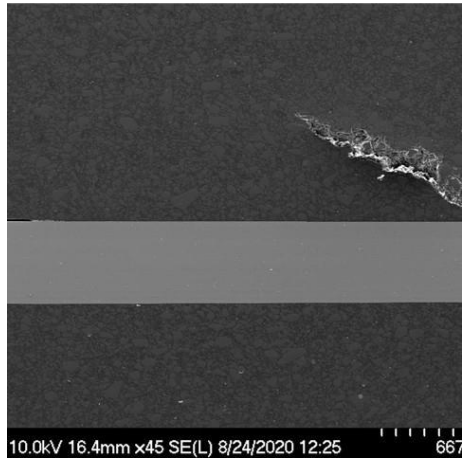


Image data embedded in reports/stored separately



Difficult to perform analyses desired by broad range of users given the current dispersed state of COTS data

Proposed Solution: Relational Table-based Data Structure

- Consolidate information contained in multiple COTS data files and eCATT system into a relational table-based structure, where each table corresponds to a key class of information collected for COTS testing program.
- Key tables (classes of information) identified:
  - Test Data* – Electrical testing data collected in a step for eCATT Traveler Number.
  - Test Information* – Metadata describing each test data collection (e.g., test date, test data file name, operator).
  - Test Variable Information* – Information regarding variables/measurements included in each test data collection (e.g., units, low limit, high limit).
  - Part Information – Information for each part in COTS testing program (e.g., manufacturer, MFR part number, data sheet, part type, part subtype).
  - Traveler Number Information† – Metadata describing each eCATT Traveler Number (e.g., Traveler number, Traveler type, Traveler status, part quantity, instructions, notes).
  - Traveler Step Information† – Information associated with each step of an eCATT Traveler Number (e.g., step number, category, subcategory, start date, end date)
- Consolidated, relational table-based structure offers several advantages:
  - Data can be easily retrieved across multiple tests, enabling improved data visualizations & analyses.
  - Resulting tables can be directly translated into a relational database.

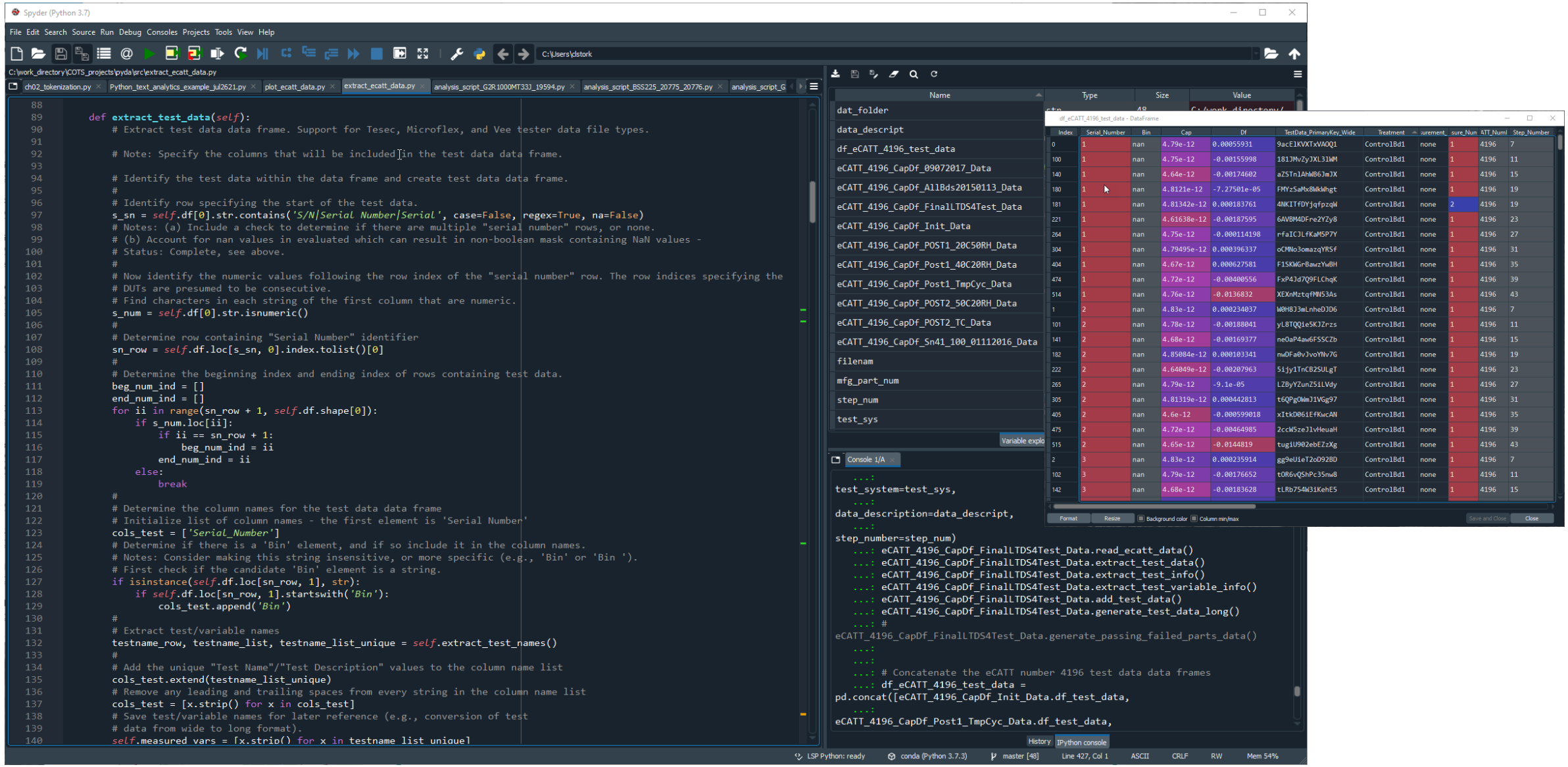
* Prototype table structure implemented

† Can be extracted from the eCATT system

Implementing Prototype Table Structure: Python-based Tools

- Developing Python-based tools for automatically extracting information from COTS tester data files and organizing it into three relational data tables:
  - Test Data
  - Test Information
  - Test Variable Information
- Problem: COTS electrical testing data are collected with multiple types of testers, each of which can output fields (e.g., part number, serial numbers) in different format.
- Implemented Solution: Simplify process of identifying fields within multiple tester data file formats utilizing text analytics, specifically regular expressions that allow for flexible pattern matching.
  - Support for four most common tester data file types (Tesec, Microflex, Vee, B1506A).
- For example, regular expressions can be designed which recognize that the following text strings refer to the same field:
  - “Serial Number”, “Serial”, and “S/N”
  - “Operator” and “Test Engineer”
  - “Part No.” and “Part Number”
  - “High Limit” and “Hi Limit”

Implementing Prototype Table Structure: Python-based Tools



Understanding the Range of COTS Data Users/Consumers

Data User/Consumer	Data Needs(?)	Needs Currently Addressed?
Test lab staff	The ability to easily and accurately track movement of COTS parts and record testing data.	Yes, within eCATT
Component engineers	Access to ALL details of COTS parts, suppliers, tests, and results, with the ability to cross reference and document to provide a full story of each part.	To be determined (discussions required to assess)
Surveillance engineers (systems perspective)	Understanding of how parts are aging. Determine systems impacted by aging parts and corresponding risks. Desire to be less reactive and more proactive.	No, as it is difficult to extract data for multiple parts and systems
Statistical analysts	Detailed statistics/data analytics using the full spectrum of (statistical) design, part supplier information, information garnered on testing of controls, test data details at granular level.	No, as test data are spread across multiple files and folders in disparate formats
Management (any level), customers	Results and conclusions from statistical analysis, data analytics (beyond summary statistics). Presented in mgt appropriate graphs and metrics on as needed basis.	No, information is available in eCATT but not easily accessible for these needs
Upper management, higher level customers	High level metrics for financial/project/strategy decision making. Presented in mgt appropriate graphs/metrics at regular intervals of time.	No, information is available in eCATT but not easily accessible for these needs

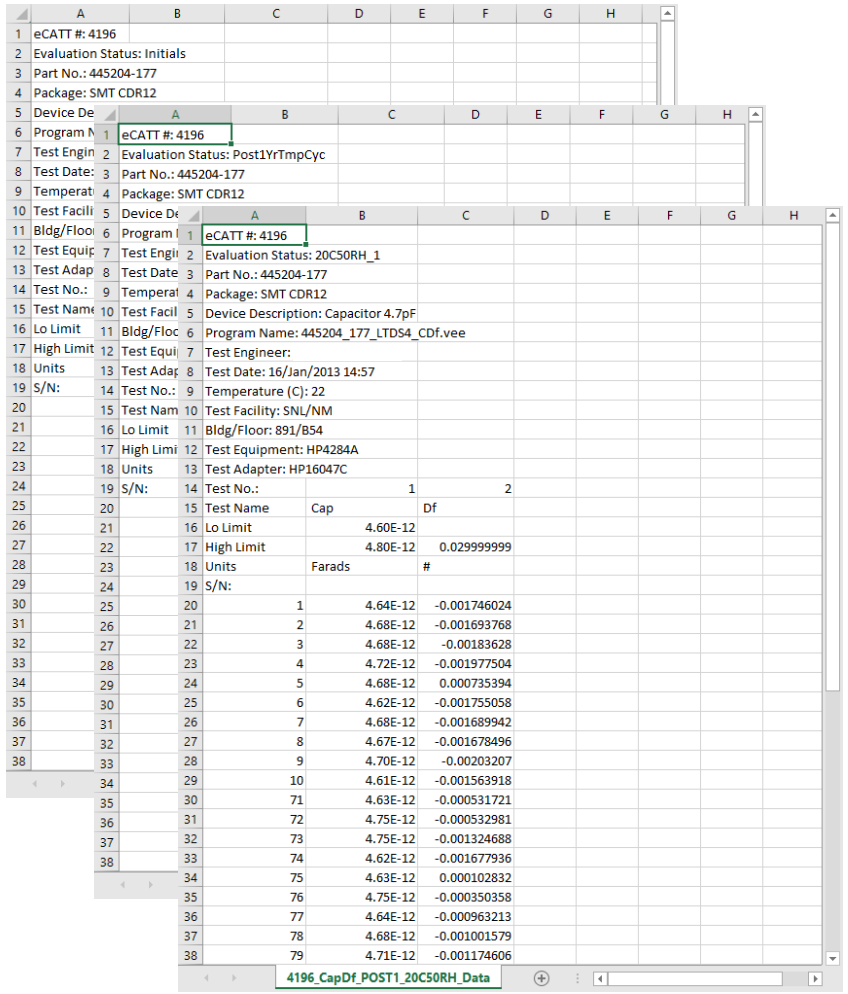
Demonstration: Long Term Dormant Storage (LTDS) Testing of Capacitor (1) – Tests Performed & Data Collected

- 100 parts placed on 1 control board and 3 test boards for LTDS testing.
- Electrical testing performed at 10 time points over 8 years:
  - Initial testing prior to environmental aging.
  - Post 1 year after temperature cycle aging (-20C to 40C).
  - Post 1 year after temperature/humidity aging (50C/20% relative humidity).
  - Post 2 years after temperature/humidity aging (40C/20% relative humidity).
  - Post 2 years after temperature cycle aging (-20C to 40C).
  - Post 2 years after temperature/humidity aging (50C/20% relative humidity).
  - Post 3 years after temperature/humidity aging (40C/20% relative humidity).
  - Post 4 years after temperature/humidity aging (40C/20% relative humidity).
  - Post 6 years after temperature/humidity aging (40C/20% relative humidity).
  - Post 8 years after temperature/humidity aging (40C/20% relative humidity).
- Measurements/variables collected:
  - Capacitance (ability of part to store electric charge)
  - Dissipation factor (measure of loss rate of energy)

Demonstration: Long Term Dormant Storage (LTDS) Testing of Capacitor (2) – Data Users and Their Questions

Data User	Question(s)
Test lab staff	Are any gross performance issues observed in each test that would require retesting? Are measurements for tested parts falling within prescribed specification limits? If not, which parts are falling outside the limits?
Component engineers	To be determined
Surveillance engineers	How are parts aging as a function of time and environmental exposure? Which systems are impacted by aging parts and what are the corresponding risks?
Statistical analysts	What is the performance of the parts across testing conditions? What is happening with the failure rate? Do parts fall inside of the specification limits? If not, do parts exceed the specification limits because the part is degrading, or due to sources of variability in the way testing was performed? What do the controls tell us about measurement variability?

Demonstration: Long Term Dormant Storage (LTDS) Testing of Capacitor (3) – Data Before and After Reorganization



	A	B	C	D	E	F	G	H
1	eCATT #: 4196							
2	Evaluation Status: Initials							
3	Part No.: 445204-177							
4	Package: SMT CDR12							
5	Device De							
6	Program N							
7	Test Engin							
8	Test Date:							
9	Temperat							
10	Test Facili							
11	Bldg/Floo							
12	Test Equip							
13	Test Adap							
14	Test No.:							
15	Test Name							
16	Lo Limit							
17	High Limit							
18	Units							
19	S/N:							

	A	B	C	D	E	F	G	H
1	eCATT #: 4196							
2	Evaluation Status: Post1YrTmpCyc							
3	Part No.: 445204-177							
4	Package: SMT CDR12							
5	Device De							
6	Program I							
7	Test Engi							
8	Test Date							
9	Temperat							
10	Test Facil							
11	Bldg/Floc							
12	Test Equi							
13	Test Adap							
14	Test No.:							
15	Test Nam							
16	Lo Limit							
17	High Limi							
18	Units							
19	S/N:							

	A	B	C	D	E	F	G	H
1	eCATT #: 4196							
2	Evaluation Status: 20C50RH_1							
3	Part No.: 445204-177							
4	Package: SMT CDR12							
5	Device Description: Capacitor 4.7pF							
6	Program Name: 445204_177_LTDS4_CDf.vee							
7	Test Engineer:							
8	Test Date: 16/Jan/2013 14:57							
9	Temperature (C): 22							
10	Test Facility: SNL/NM							
11	Bldg/Floor: 891/B54							
12	Test Equipment: HP4284A							
13	Test Adapter: HP16047C							
14	Test No.:		1		2			
15	Test Name	Cap		Df				
16	Lo Limit		4.60E-12					
17	High Limit		4.80E-12		0.029999999			
18	Units	Farads		#				
19	S/N:							
20		1	4.64E-12		-0.001746024			
21		2	4.68E-12		-0.001693768			
22		3	4.68E-12		-0.00183628			
23		4	4.72E-12		-0.001977504			
24		5	4.68E-12		0.000735394			
25		6	4.62E-12		-0.001755058			
26		7	4.68E-12		-0.001689942			
27		8	4.67E-12		-0.001678496			
28		9	4.70E-12		-0.00203207			
29		10	4.61E-12		-0.001563918			
30		71	4.63E-12		-0.000531721			
31		72	4.75E-12		-0.000532981			
32		73	4.75E-12		-0.001324688			
33		74	4.62E-12		-0.001677936			
34		75	4.63E-12		0.000102832			
35		76	4.75E-12		-0.000350358			
36		77	4.64E-12		-0.000963213			
37		78	4.68E-12		-0.001001579			
38		79	4.71E-12		-0.001174606			

4196_CapDf_POST1_20C50RH_Data

Multiple Raw Tester Data Files and Part Treatment Information from eCATT System

Information Consolidated into Multiple Relational Tables

Test Information Table

Index	eCATT_Number	Step_Number	Mfg_Part_Number	TestDate	Filename	TestTemp	Operator	TestSystem
0	4196	7		2011-08-25 08:42:00	4196_CapDf_Init_Data.csv	None		VEE
1	4196	11		2012-11-08 10:35:00	4196_CapDf_Post1_TmpCyc_Data.csv	None		VEE
2	4196	15		2013-01-16 14:57:00	4196_CapDf_POST1_20C50RH_Data.csv	None		VEE
3	4196	19		2013-08-05 13:34:00	4196_CapDf_Post1_40C20RH_Data.csv	None		VEE
4	4196	23		2014-02-26 10:12:00	4196_CapDf_POST2_TC_Data.csv	None		VEE
5	4196	27		2014-04-16 11:39:00	4196_CapDf_POST2_50C20RH_Data.csv	None		VEE
6	4196	31		2015-02-16 14:33:00	4196_CapDf_AllBds20150113_Data.csv	None		VEE
7	4196	35		2016-02-04 07:55:00	4196_CapDf_Sn41-100_01112016_Data.csv	None		VEE

Test Data Table

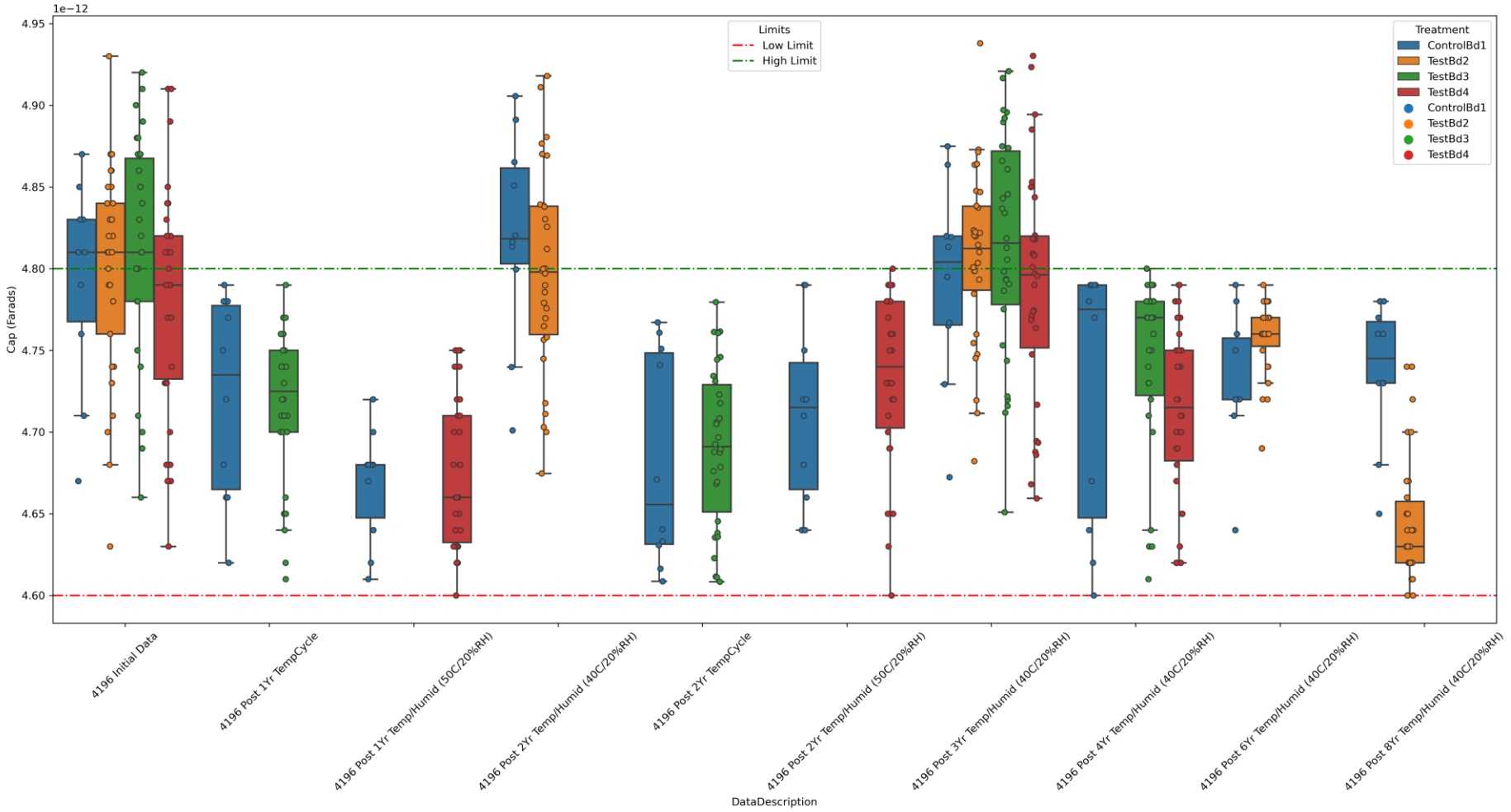
Index	Serial_Number	Bin	Cap	Df	TestData_PrimaryKey_Wide	Treatment	Measurement_Type	Measure_Number	eCATT_Number	Step_Number
0	1	nan	4.79e-12	0.00055931	bjjjpv2Rv7hbxzL	ControlBd1	none	1	4196	7
1	2	nan	4.83e-12	0.000234037	EKQJKny9OpeB2bI	ControlBd1	none	1	4196	7
2	3	nan	4.83e-12	0.000235914	FSQr0nMPK2Tv4Zp	ControlBd1	none	1	4196	7
3	4	nan	4.87e-12	0.000184406	KDJqW2W8fXjpGCe	ControlBd1	none	1	4196	7
4	5	nan	4.67e-12	1.84e-05	11Vb2m3Yw2VkFVK	ControlBd1	none	1	4196	7
5	6	nan	4.76e-12	0.000173928	5v7MML6mYoDeK01	ControlBd1	none	1	4196	7
6	7	nan	4.81e-12	0.000104115	cIcRhBNvtkDanIS	ControlBd1	none	1	4196	7
7	8	nan	4.81e-12	0.000151827	2ileRrSBskBmKqr	ControlBd1	none	1	4196	7
8	9	nan	4.85e-12	0.000608465	g58AzLGS3byO16B	ControlBd1	none	1	4196	7
9	10	nan	4.71e-12	0.000219937	VBQdyvfpBVUxJeA	ControlBd1	none	1	4196	7
10	11	nan	4.83e-12	0.000631139	7CoOObktUwkArcF	TestBd2	none	1	4196	7
11	12	nan	4.79e-12	0.000119851	NQ9AfP1jpsZJe1Z	TestBd2	none	1	4196	7
12	13	nan	4.86e-12	0.000196	WBUSD55C0uxe01E	TestBd2	none	1	4196	7
13	14	nan	4.93e-12	0.0001058	yq8DJxHYGCe2sTk	TestBd2	none	1	4196	7
14	15	nan	4.76e-12	-0.00027848	R6TZcTC4GhAcIvh	TestBd2	none	1	4196	7
15	16	nan	4.87e-12	8.27e-05	cUX8LTSR5Dnmw85	TestBd2	none	1	4196	7
16	17	nan	4.84e-12	0.000799935	NqykNUPxultnZZD	TestBd2	none	1	4196	7
17	18	nan	4.81e-12	0.000175484	pnA12UUj1UQdoog	TestBd2	none	1	4196	7
18	19	nan	4.86e-12	8.16e-05	nE2tr8ca2NPNTB2	TestBd2	none	1	4196	7

Test Variable Information Table

Index	Test_Name	Test_Number	Test_Name_Unique	Units	Low_Limit	High_Limit
0	Cap	1	Cap	Farads	4.6e-12	4.8e-12
1	Df	2	Df	nan	nan	0.03
2	Cap	1	Cap	Farads	4.6e-12	4.8e-12
3	Df	2	Df	nan	nan	0.03
4	Cap	1	Cap	Farads	4.6e-12	4.8e-12
5	Df	2	Df	#	nan	0.03
6	Cap	1	Cap	Farads	4.6e-12	4.8e-12
7	Df	2	Df	#	nan	0.03
8	Cap	1	Cap	Farads	4.6e-12	4.8e-12
9	Df	2	Df	#	nan	0.03
10	Cap	1	Cap	Farads	4.6e-12	4.8e-12
11	Df	2	Df	#	nan	0.03

Demonstration: Long Term Dormant Storage (LTDS) Testing of Capacitor (4) – Answering Statistical Analyst Questions

- Did part exceed the specification limit because part performance is changing, or due to sources of variability (days of testing, personnel, methods, instrument drift) in the testing?



Cyclical pattern observed in test data over time suggests out of spec measurements are attributable to variability in the testing.

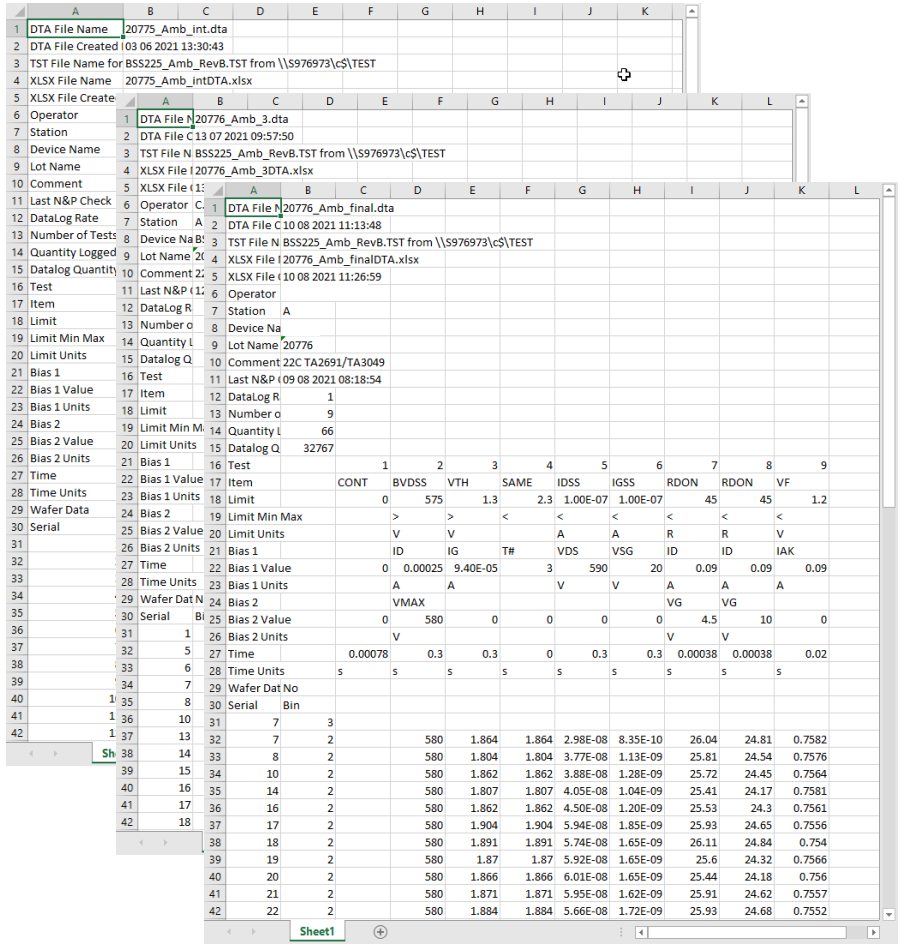
Demo: Electrical Testing of Metal-Oxide Field-Effect Transistor (MOSFET) (1) – Tests Performed and Data Collected

- 5 parts formed the control set and 80 parts formed the test set.
- Electrical testing performed at 7 time points over more than one thousand hours of exposure:
  - Testing after temperature bake (125C for 24 hours) and temperature/humidity (30C/60% RH for 8 days) exposure. “Post Preconditioning” data
  - Retest after cleaning. “Post Preconditioning Retest” data
  - Testing after temperature/humidity exposure (85C/85% RH for 7 days). “Temp/Humidity 1” data
  - Testing after further temperature/humidity exposure (85C/85% RH for 7 days). “Temp/Humidity 2” data
  - Testing after further temperature/humidity exposure (85C/85% RH for 14 days). “Temperature/Humidity 3” data
  - Testing after further temperature/humidity exposure (85C/85% RH for 21 days). “Temperature/Humidity 4” data
  - Testing after further temperature/humidity exposure (85C/85% RH for 317 hours). “Temperature/Humidity 5” data
- Measurements/variables collected:
  - Drain current (ID) at applied drain source voltage (VDS) of 590V

Demo: Electrical Testing of Metal-Oxide Field-Effect Transistor (MOSFET) (2) – Data Users and their Questions

Data User	Question(s)
Test lab staff	Are any gross performance issues observed in each test that would require retesting? Are measurements for tested parts falling within prescribed specification limits? If not, which parts are falling outside the limits?
Component engineers	To be determined
Surveillance engineers	How are parts aging as a function of time and environmental exposure? Which systems are impacted by aging parts and what are the corresponding risks?
Statistical analysts	What is the performance of the parts across testing conditions? What is happening with the failure rate? Do parts fall inside of the specification limits? If not, do parts exceed the specification limits because the part is degrading, or due to sources of variability in the way testing was performed? What do the controls tell us about measurement variability?

Demo: Electrical Testing of Metal-Oxide Field-Effect Transistor (MOSFET) (3) – Data Before and After Reorganization



Multiple Raw Tester Data Files and Part Treatment Information from eCATT System

Information Consolidated into Multiple Relational Tables

Test Information Table

Index	eCATT_Number	Step_Number	Mfg_Part_Number	TestDate	Filename	TestTemp
0	20775	none		2021-06-03 13:30:43	20775_Amb_intDTA.xlsx	None
1	20775	none		2021-06-09 12:22:16	20775_Amb2DTA.xlsx	None
2	20776	none		2021-06-22 06:40:42	20776_Amb_intDTA.xlsx	None
3	20776	none		2021-06-30 07:08:52	20776_Amb_2DTA.xlsx	None
4	20776	none		2021-07-13 09:57:50	20776_Amb_3DTA.xlsx	None
5	20776	none		2021-07-13 10:21:58	20776_Amb_3controlsDTA.xlsx	None
6	20776	none		2021-07-23 08:22:07	20776_prepoweroutDTA.xlsx	None
7	20776	none		2021-08-10 11:13:48	20776_Amb_finalDTA.xlsx	None

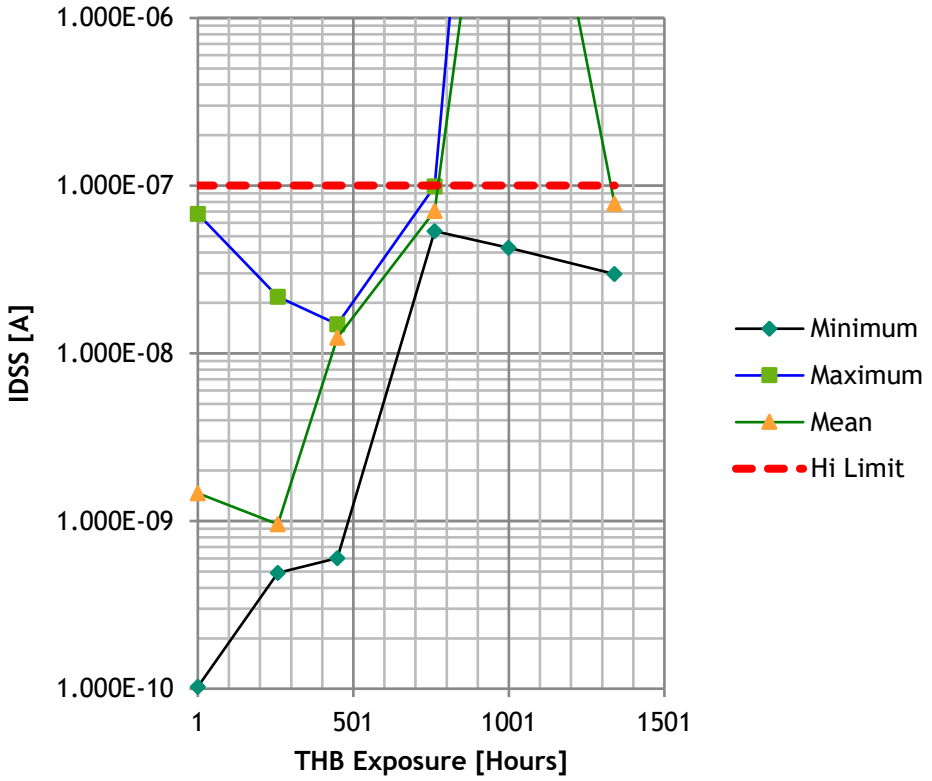
Test Data Table

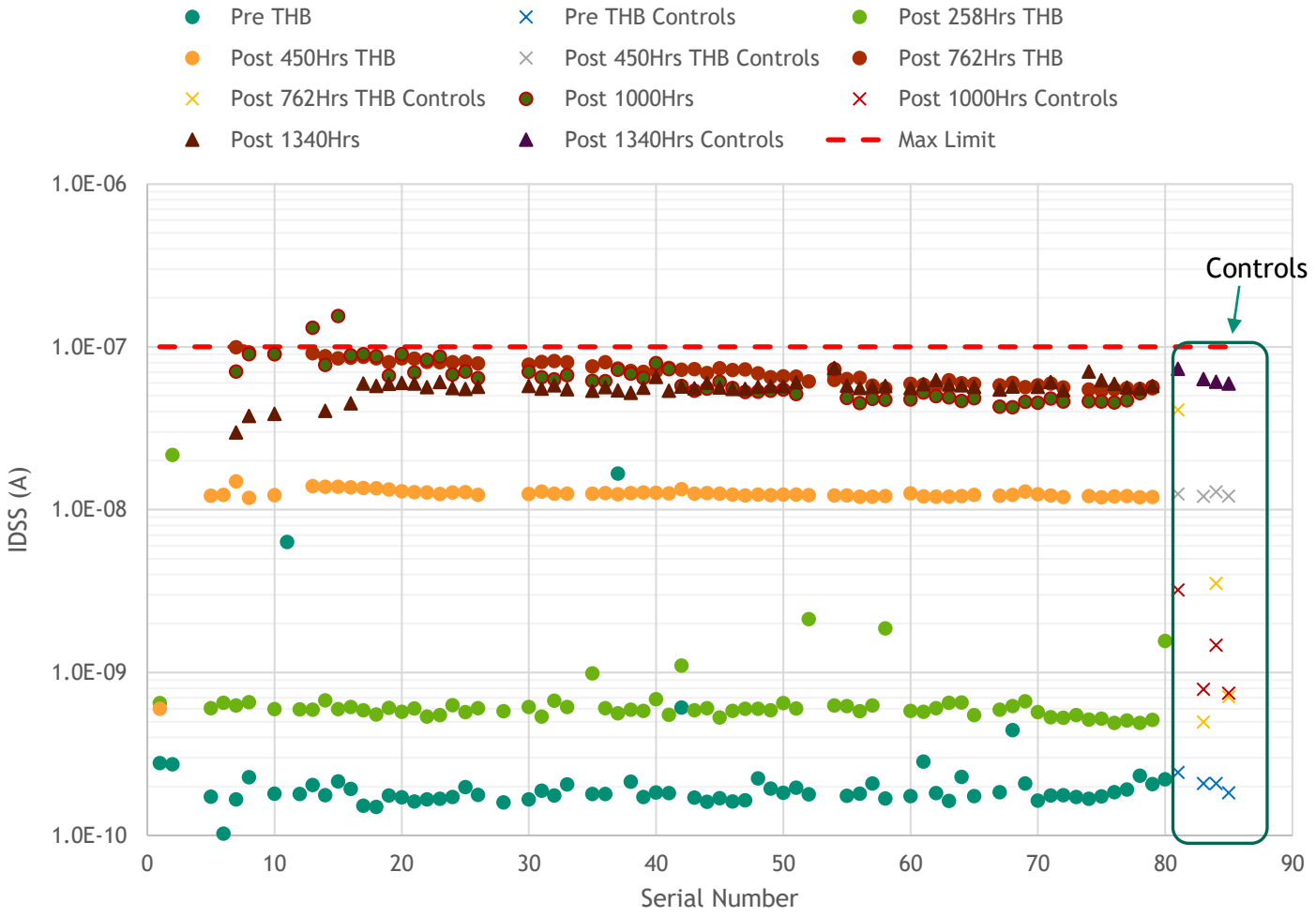
Index	Serial_Number	Bin	CONT1	BVDSS2	VTH3	SAME4	IDSS5	IGSS6	RDON7	RDON8	VF9
0	1	3	nan	580	1.875	1.875	3.202e-07	8.685e-09	24.62	23.32	0.754
1	2	3	nan	231.1	0.00548	0.00548	0.002198	0.0009999	105.7	105.5	0.7424
2	3	2	nan	580	1.89	1.89	2.777e-10	2.75e-11	24.97	23.7	0.7544
3	5	2	nan	580	1.88	1.88	4.95e-09	9.41e-11	24.81	23.51	0.7546
4	6	2	nan	580	1.885	1.885	2.718e-10	2.86e-11	25.07	23.76	0.7545
5	7	2	nan	580	1.873	1.873	4.137e-10	3.38e-11	24.48	23.17	0.7533
6	8	2	nan	580	1.88	1.88	3.513e-10	3.06e-11	22.82	21.5	0.7525
7	9	3	nan	0.9999	1.878	1.878	0.009999	0.0009999	33.7	33.87	0.7531
8	10	2	nan	580	1.88	1.88	2.274e-10	1.94e-11	25.16	23.9	0.7547
9	11	2	nan	580	1.857	1.857	8.656e-10	2.26e-11	24.92	23.66	0.7542
10	12	2	nan	580	1.899	1.899	2.437e-10	2.17e-11	25.63	24.34	0.7546
11	13	2	nan	580	1.875	1.875	2.852e-10	2.11e-11	25.43	24.15	0.7548
12	14	3	nan	22.65	19.66	19.66	0.009999	1.37e-11	105.5	105.6	0.7467

Test Variable Information Table

Index	Test_Name	Test_Number	Test_Name_Unique	Units	Low_Limit	High_Limit	Bias_1	Bias_1_Value
0	CONT	1	CONT1		nan	nan	nan	0
1	BVDSS	2	BVDSS2	V	575	nan	ID	0.00025
2	VTH	3	VTH3	V	1.3	nan	IG	9.4e-05
3	SAME	4	SAME4		nan	2.3	T#	3
4	IDSS	5	IDSS5	A	nan	1e-07	VDS	590
5	IGSS	6	IGSS6	A	nan	1e-07	VSG	20
6	RDON	7	RDON7	R	nan	45	ID	0.09

Demo: Electrical Testing of Metal-Oxide Field-Effect Transistor (MOSFET) (4) – Analysis Before Reorganization

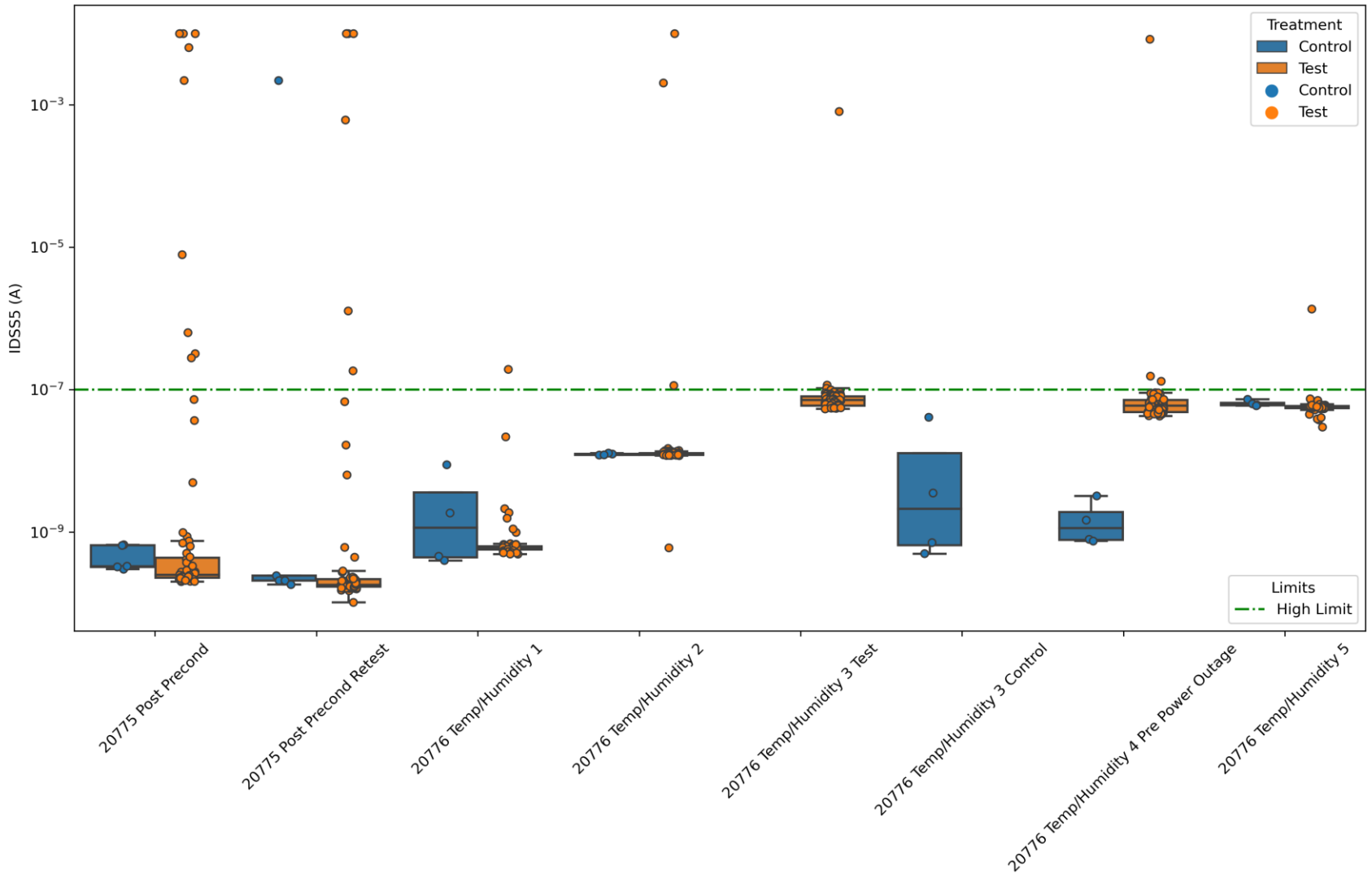




Min-mean-max plot introduces the data story, but can mask relevant details

Plot of drain current as a function of part serial number provides performance details for individual parts

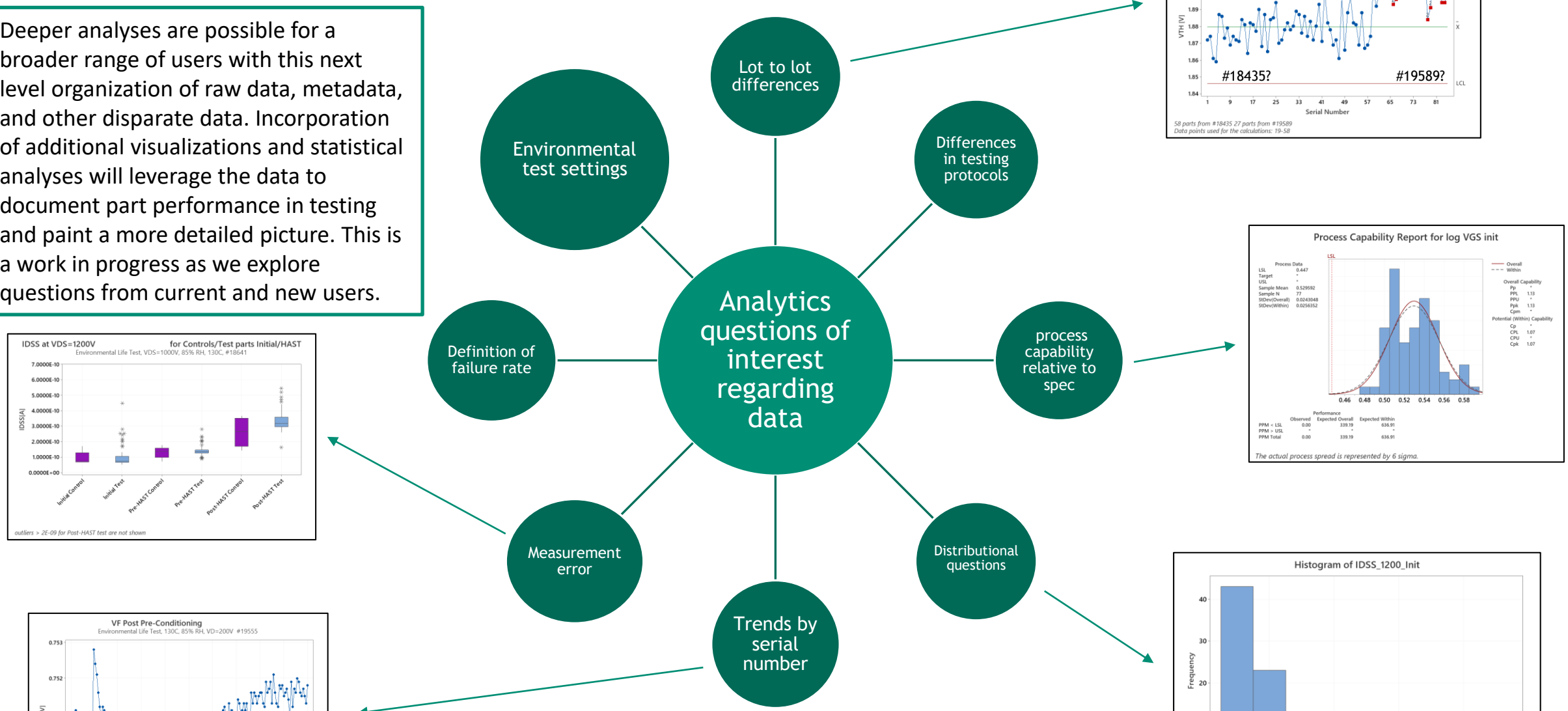
Demo: Electrical Testing of Metal-Oxide Field-Effect Transistor (MOSFET) (5) – Analysis After Reorganization



Box plot gives breadth and depth to story lost in min-mean-max plot. This is the first stage in developing additional graphs as well as analyses that will tell a more complete story of the data.

Deeper Analyses Possible with Improved Tools

Deeper analyses are possible for a broader range of users with this next level organization of raw data, metadata, and other disparate data. Incorporation of additional visualizations and statistical analyses will leverage the data to document part performance in testing and paint a more detailed picture. This is a work in progress as we explore questions from current and new users.



Conclusions/Future Work

- Continue development of data analytics tools.
  - Identify further questions that need to be addressed by data analytics.
  - Make sure tools that are being developed are targeting questions that need to be answered, within the capability of the data that are being collected.
  - Use multivariate statistical analysis to better understand part failures.
  - Leverage data available at multiple time points and under different testing conditions.
- Identify primary users/consumers of COTS testing data and their needs, in order to inform data organization and data analytics efforts.
- Collaborate with COTS database development team to establish new data organization framework.
  - Identify core set of required, non-redundant relational tables (e.g., Test Data, Test Information, Part Information).

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- Test Lab Team:
  - Clifton Aldridge
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