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Customer Success Is Our Mission

Application of Statistical Process Control Methods to Flight Test Data

NDIA National Test & Evaluation Conference 2016

Topic Session: Big Data and Knowledge Management

Raytheon Missile Systems
Craig Cowell

March 2-3 2016

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Agenda

- Problem Statement
- Proposed Solutions
- Simple Examples
- Summary
- Questions

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Problem Statement

- In the world of test and evaluation there continues to be the desire for more data and with the evolution of telemetry systems more raw data is available to the analyst than ever before
- However all that data comes with a price
  - How do we process and evaluate it all?
  - How can we look at the data in different ways to get valuable information (data mining or reusing data)?
- Secondary Problem
  - A secondary problem we deal with is with the loss of our knowledge base or limited knowledge base
  - The analysis tools we develop need to be robust enough to depend less on personnel system knowledge

What is the solution to improve how we accurately process and evaluate enormous amounts data and get more out of our data?

Proposed Solution

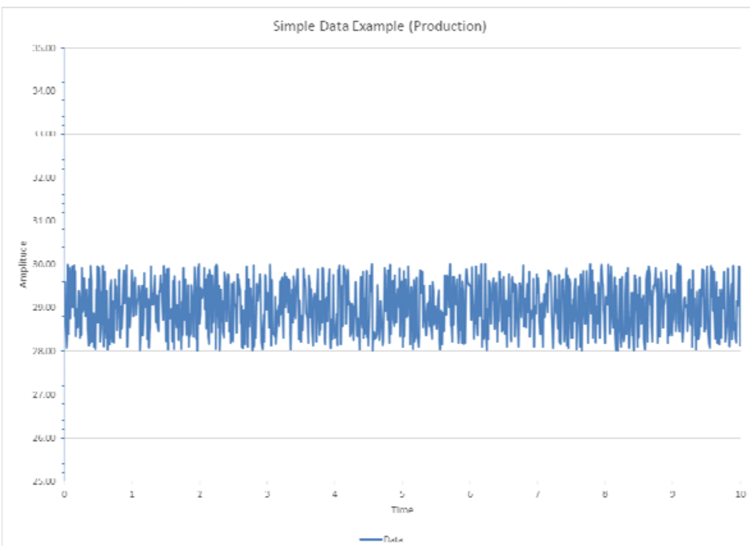
- In our factories we have developed acceptance tests and analysis tools that help us evaluate if the hardware meets requirements (pass or fail) or if there are process controls that are indicating a change in the design margin, assembly issues or even test equipment issues (data mining and data reuse)
- Why can't those same principles be applied to test and evaluation (flight test) data?

Assumptions

- For this discussion data is categorized into these types:
  - Analog data: voltages, current etc.
  - Discrete data: logic states
  - Dynamic digital data: data dependent on random or complex inputs
- For this discussion the proposed solution will be limited to Analog and Discrete data

Application of Pass/Fail Criteria

- In production an acceptance test typically measures an output and compares it to a pass/fail limit defined by a requirements document
- Typically the measurement is one dimensional (magnitude or time)

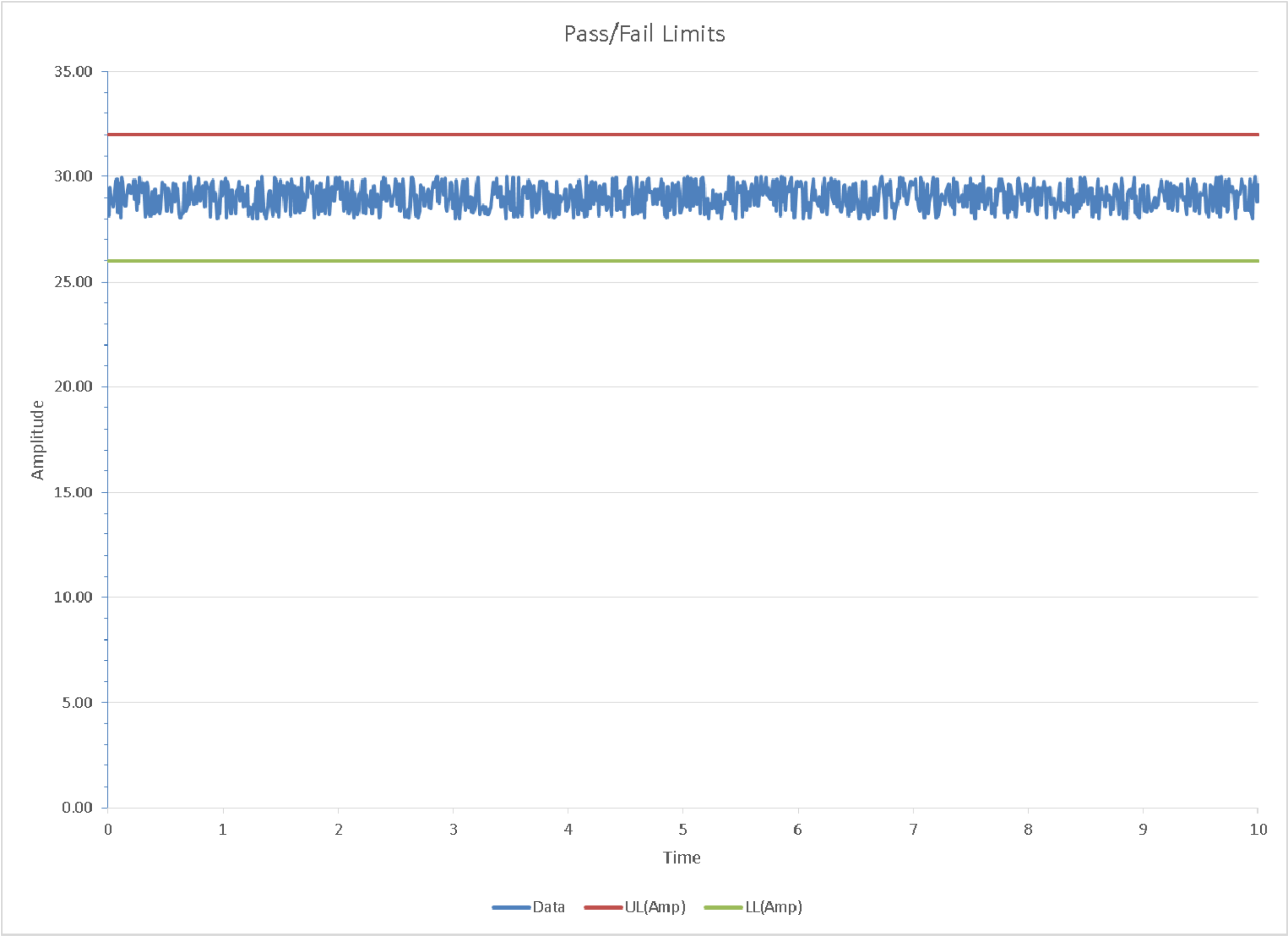


Test 123456						
Pcode	**Test Name**	**Measurement**	**UL**	**LL**	**Unit**	**Pass/Fail**
10001	Voltage A	30.2	34	26	Voltage	Pass

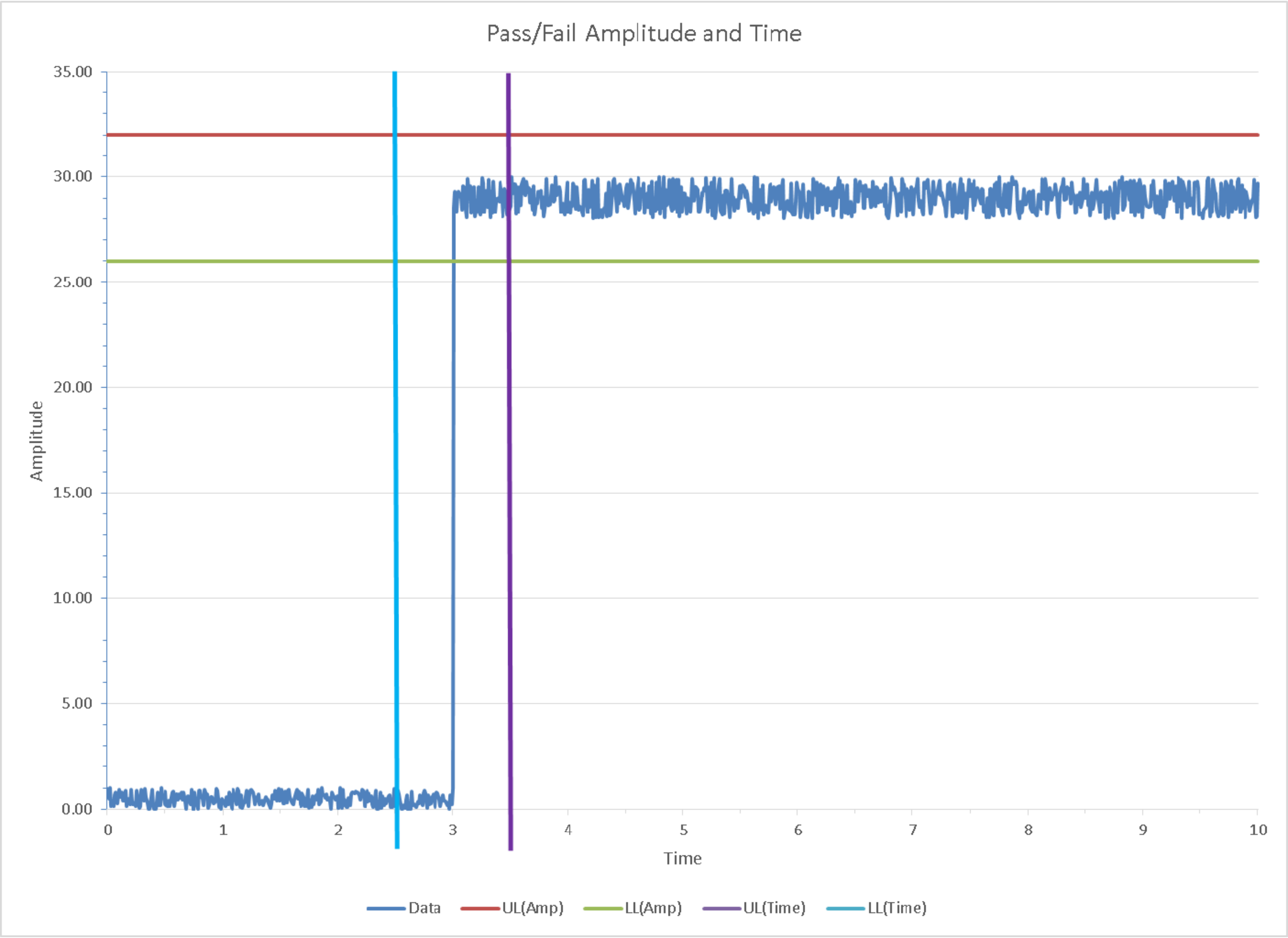
Application of Pass/Fail (Flight Test)

- The same simple solution can be applied to flight test data
- Pass/Fail criteria can be applied to many of the analog and discrete data outputs
- One added feature of flight test data not often evaluated in production are the times in which certain events occur i.e. one shot events (battery power and squibbing events) and logic timed events
- Typically these events are defined/specified in an Interface Control Document (ICD)

Simple Example (Amplitude Only)



Simple Example (Amplitude and Time)



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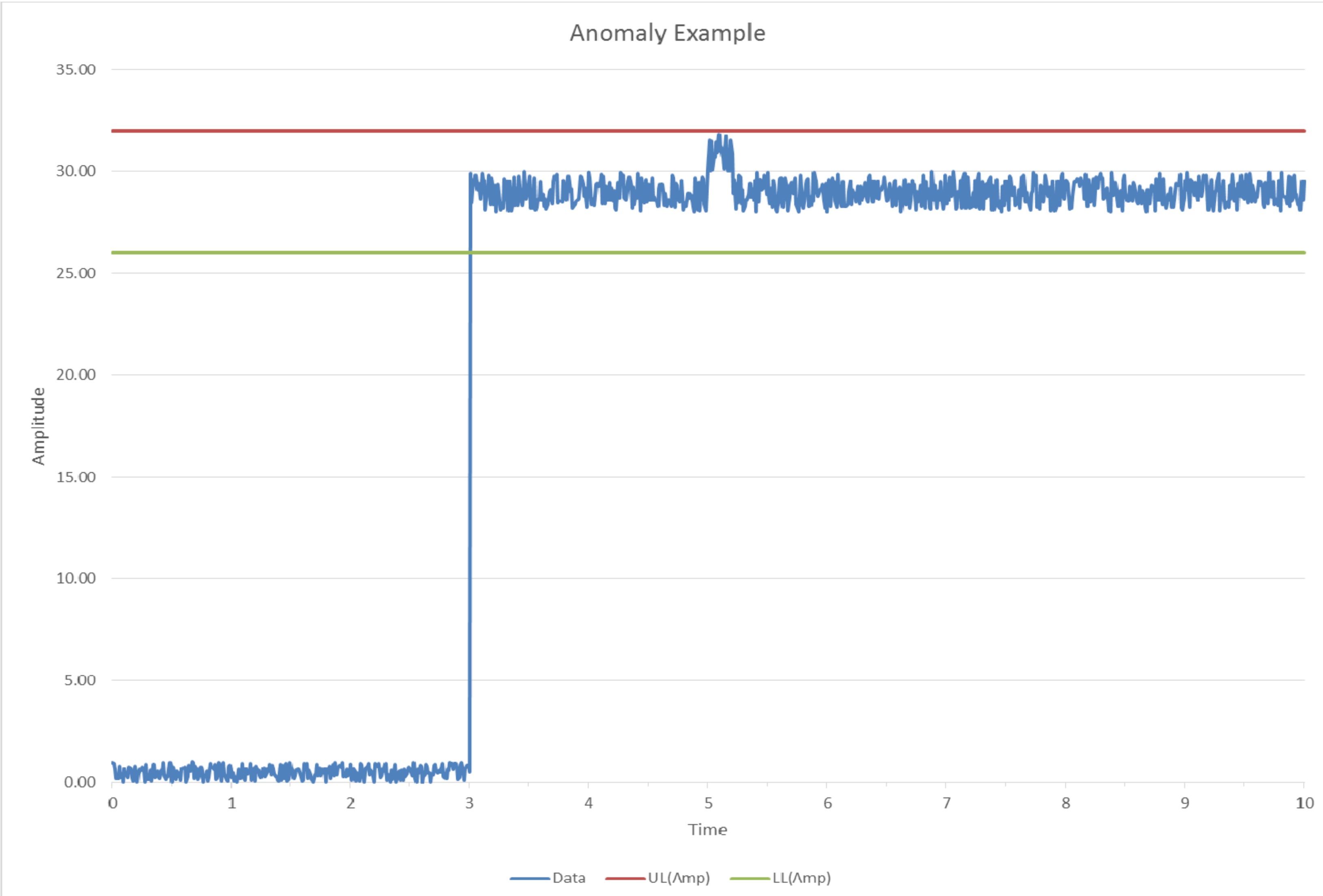
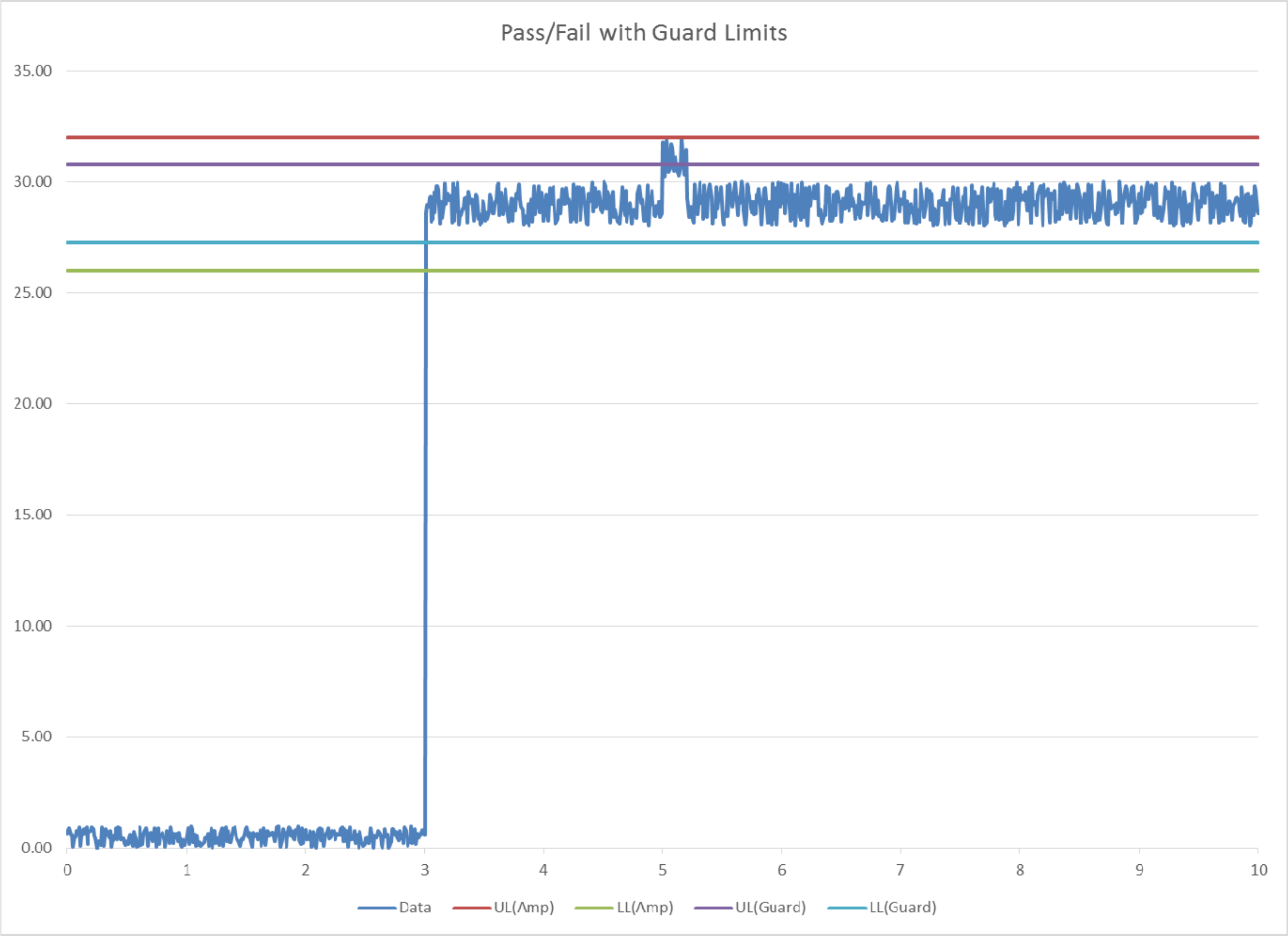
Simple Example with Amplitude Anomaly



Simple Anomaly Example with Guard Limits



Pass/Fail Summarized Report

- The automated analysis tool reports a simple pass/fail for the Telemetry variables analyzed
- The analyst can then direct his/her immediate attention to those variables to verify the failure or anomaly.
- Time is saved in not looking through hundreds of TM plots visually verifying performance
- Limits are derived from production limits or specification (accounting for error of measurement device)
- Guard limits can be set based on historical data and or desired system margin

Test 123456

Pcode	Test Name	Measurement	UL	LL	Unit	Pass/Fail
10001	Main Battery Voltage	30.2	34	26	Voltage	Pass
10002	Battery Activate Time	3.1	3.5	2.5	Seconds	Pass
10003	Main Battery STDEV	0.6	1.5	1	Voltage	Pass
10004	Main Battery Voltage Overshoot	32.5	32	28	Voltage	***Fail***

Application of a simple Pass/Fail criteria provides for a quick look data assessment

Statistical Process Control (Production)

- Statistical Process Control (SPC) is an industry standard typically applied or used in factories to measure process controls
- Typical SPC tools or measures used are
  - Western Electric Company (WECO) Rules
  - First Pass Yield
  - Process capability index or process capability ratio (CP/CPK)
  - Pareto of Failing Parameters
- The various tools when applied to the data can give a quick look assessment of test parameters over time.

SPC allows you to evaluate system design margin over time by measuring data trends using historical data

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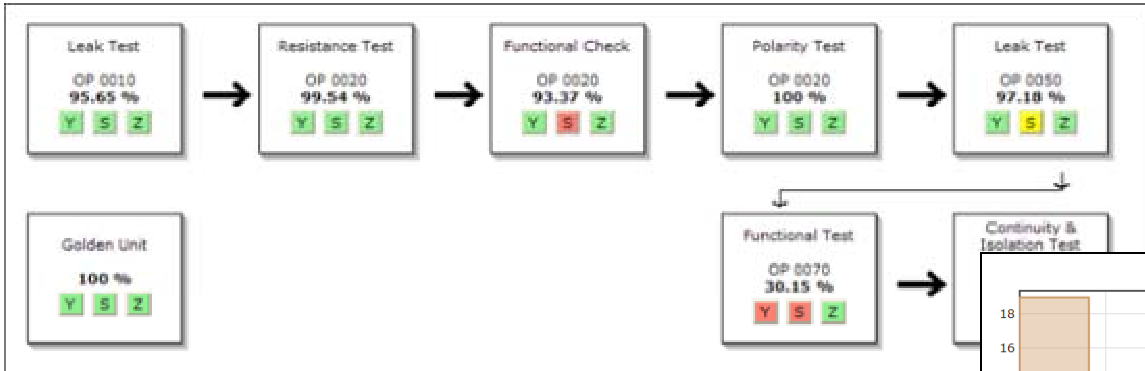
SPC Tool Examples



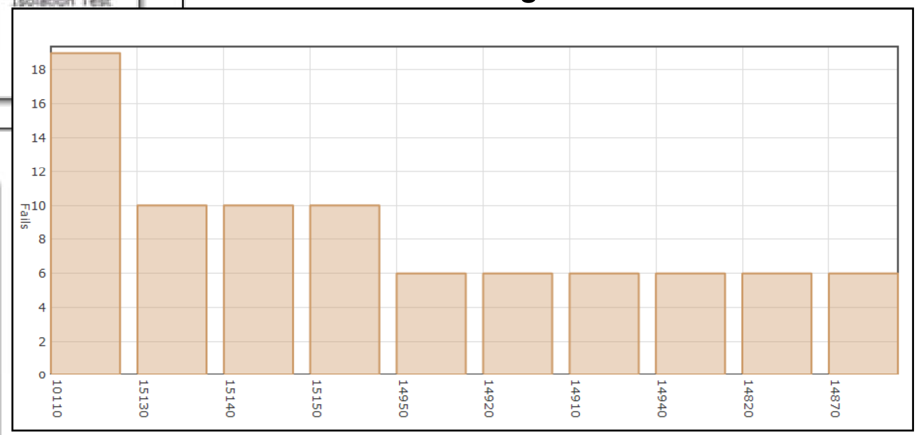
WECO Rule Violations, Yield and CP/CPK by Parameter

Partition	Pcode	Description	Units	Rule A	Rule B	Rule C	Rule D	Rule E	Rule F	Rule G	Sum	Test Count	Test Yield	CP	CPK	Baseline CP	Baseline CPK
A3A: ROLL	15110	15110	UNKNOWN	0	0	1	0	0	0	0	1	2	100 %	13.0946	4.4522	29.0662	10.2822
A3A: ROLL	15310		UNKNOWN	0	0	2	0	0	0	0	2	2	100 %	14.1421	12.7279	6.2621	6.1421
A3A: ROLL	10070		UNKNOWN	0	0	0	2	0	0	0	2	2	100 %	16.8359	11.28	16.1797	11.1867
A3A: ROLL	18140		UNKNOWN	1	0	0	0	0	0	0	1	2	100 %	2.1213	0.2357	0	0
A3A: ROLL	13620		UNKNOWN	0	0	0	0	0	0	2	2	2	100 %	25.5344	21.5668	14.06	[illegible]
A3A: ROLL	16510		UNKNOWN	0	0	2	0	0	0	0	2	2	100 %	29.3954	4.1517	8.642	[illegible]

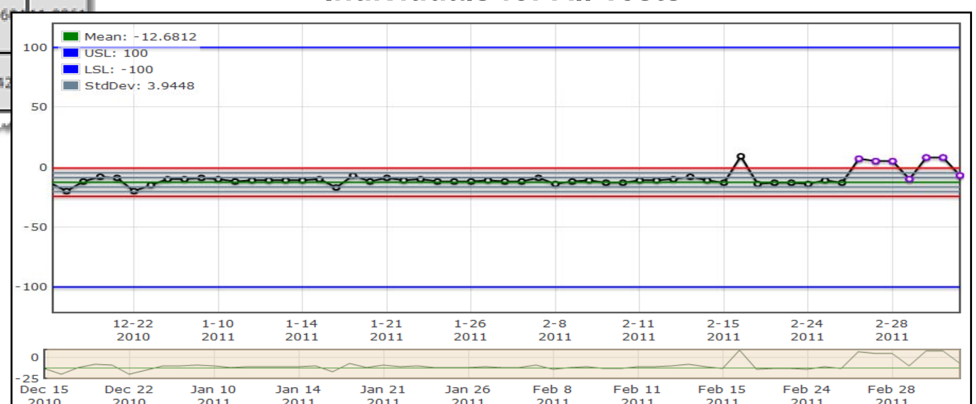
Western Electric Company (WECO) Rules

Rule 1: One point plots outside control limits. (outlier)
Rule 2: : Two out of three consecutive points plot on the same side of the center line in zone A or beyond. (shift)
Rule 3: : Four out of five consecutive points plot on the same side of the centerline in zone B or beyond. (shift)
Rule 4: : Eight consecutive points plot on one side of the centerline. (shift)
Rule 5: Seven consecutive points increasing or decreasing. (trend)

Pareto of Failing Parameters

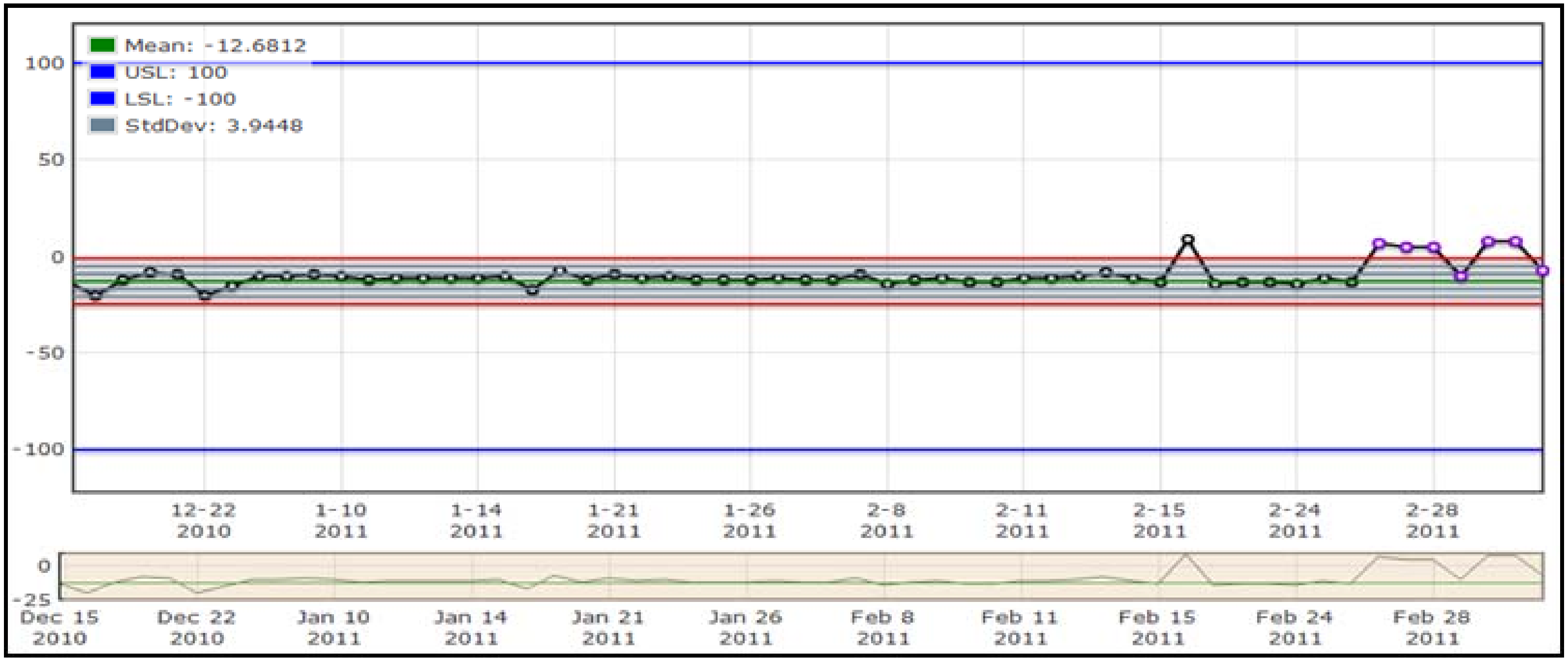


Individuals for All Tests



Control Plots and Control Limits

- In a control plot the individual test output or Pcode is plotted for every unit tested (or test flight)
- The upper and lower limit are shown (blue lines) along with the control limits (red lines) which are calculated based on the mean and standard deviation (mean+/-3*StdDev)



WECO Rules Violations and Cpk

- WECO Rules can be calculated and displayed in a simple stop light chart used to show violations of a defined rule set
- Provides a quick look assessment of potential issues
- Figure of Merit – Cpk is a value which measures how close a process is running to its specification limits, relative to the natural variability of the process. The larger the index, the less likely it is that any item will be outside the specs.

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A3A: ROLL	13620		UNKNOWN	0	0	0	0	0	0	2	2	2	100 %	25.5344	21.5668	14.0604	11.9861
A3A: ROLL	16510		UNKNOWN	0	0	2	0	0	0	0	2	2	100 %	29.3954	4.1517	8.6422	0.5968

Statistical Process Control (Flight Test)

- Application of SPC principles to Flight Test data benefits
  - Looks at all telemetry variable parameters over history
  - Highlights potential issues (automatic versus manual comparison of data parameters) again includes historical data
  - Helps point the analyst to what to look at
  - Analyst doesn’t need to be an ICD expert of the particular parameter and what to look for.
  - The tools do the work for you

SPC provides a quick look of system margins and simplifies the data deep dive for the analyst

Summary

- What is the solution to improve how we accurately process and evaluate enormous amounts data and get more out our data?
  – Application of simple Pass/Fail criteria with automated tools
    - Provides quick look pass/fail
    - With addition of guard limits can draw attention to potential data anomalies
  – Application of basic SPC tools to look at historical data to assess trends or “out of family” anomalies before they become a potential failure (good assessment of design margin)
- A secondary benefit for automated Pass/Fail analysis tools and application of SPC to flight test data is it provides some level of independency from requiring subject mater experts (SMEs) or knowledgeable analyst to evaluate the data.

Questions?