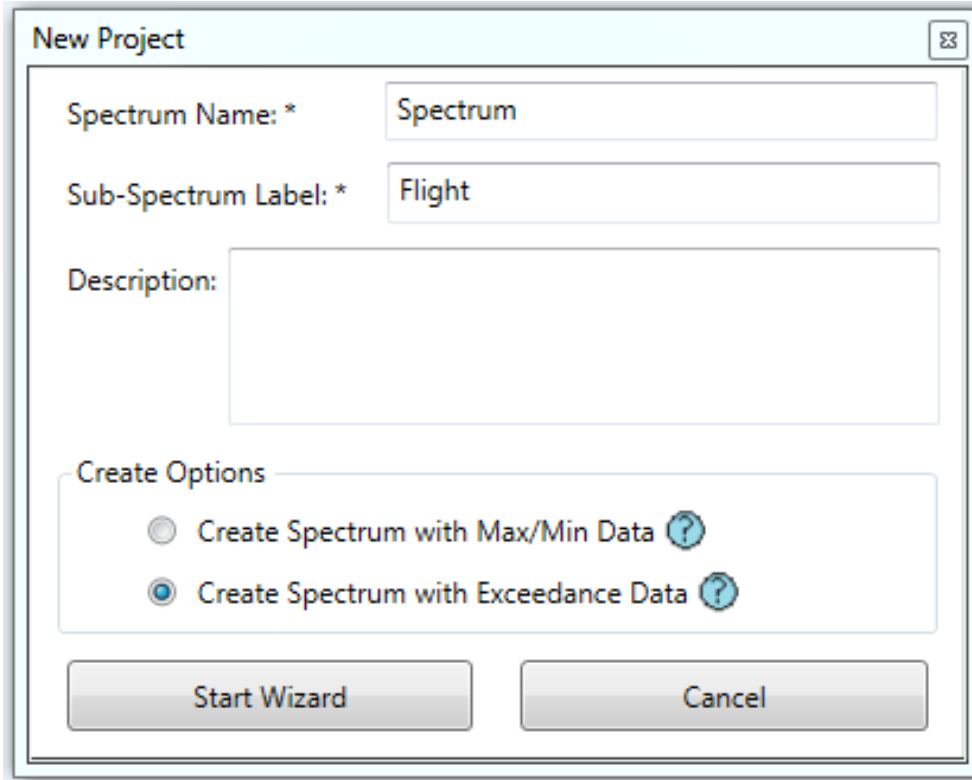


Generating a Spectrum from an Exceedance Curve

Jimmy Lambert, Jim Harter

- Originally tried to implement a method for spectrum generation contracted by the government, before deciding to go our own route
- Created two algorithms for spectrum generation from scratch in a simple console application
- Developed features that added several options to control how the spectra would be generated
- Implemented a wizard within Spectrum Manager so that a spectrum could be generated when creating a new project



New Project

Spectrum Name: * Spectrum

Sub-Spectrum Label: * Flight

Description:

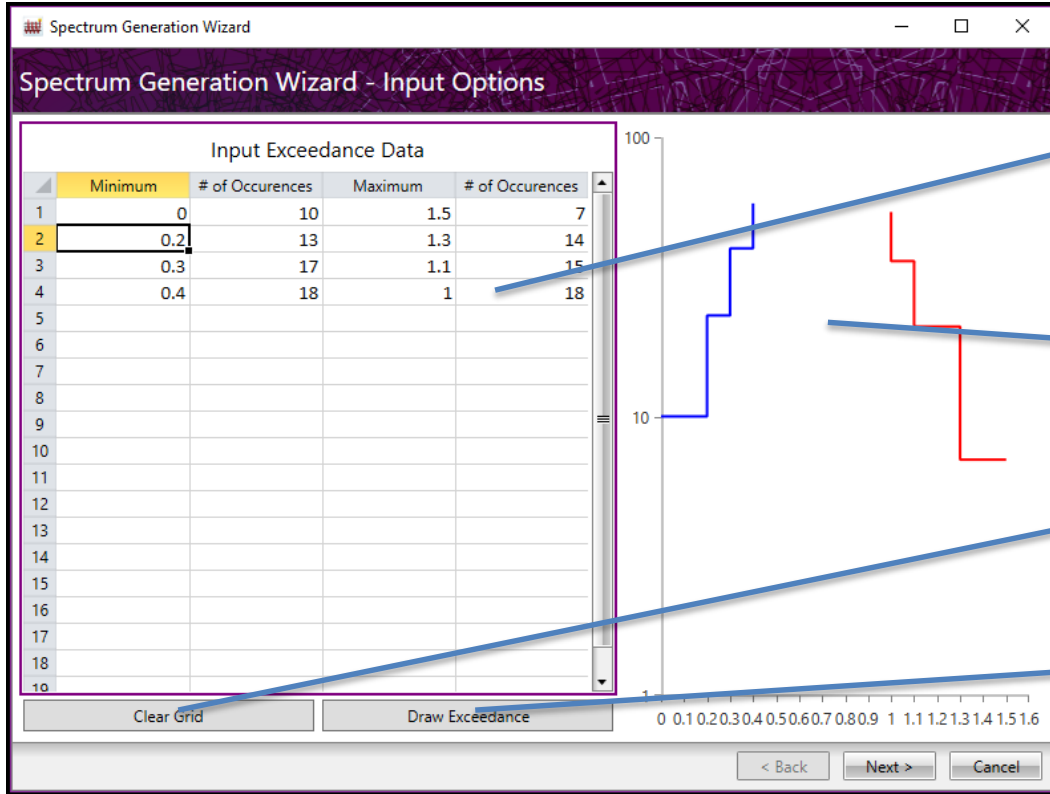
Create Options

Create Spectrum with Max/Min Data ?

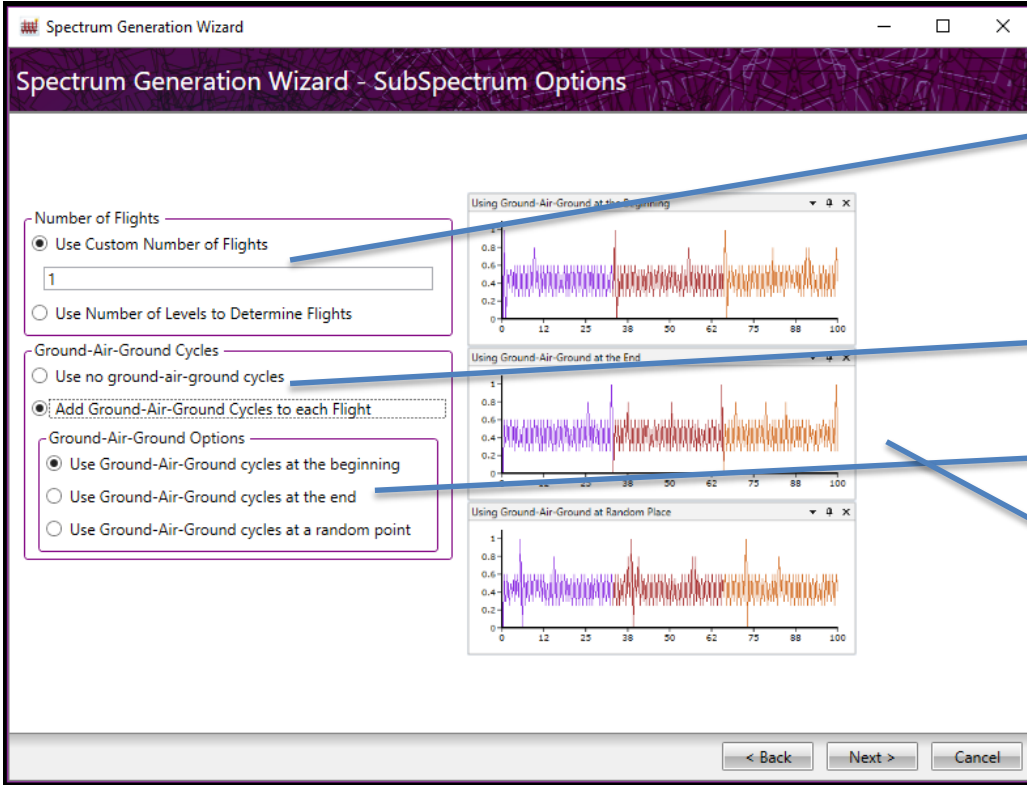
Create Spectrum with Exceedance Data ?

Start Wizard Cancel

- An new option within Spectrum Manager
- May be used when creating a new project
- Creates a spectrum using exceedance data instead of user-supplied Max/Min cyclic data



- Grid that allows the user to enter exceedance data by hand, or by copying data from another application
- Exceedance plot that displays the data in the grid
- Button that clears the exceedance plot
- Button that draws/refreshes the exceedance plot



- Buttons to select whether to enter the number of sub-spectra manually, or to determine the number of sub-spectra depending on number of levels per sub-spectrum
- Buttons to select whether to add Ground-Air-Ground cycles to the spectrum
- Buttons to select where Ground-Air-Ground cycles will be added to the spectrum
- Graphic representation that shows each position for adding Ground-Air-Ground cycles

Spectrum Generation Wizard

Spectrum Generation Wizard - Generation Methods

Use Random Pairing Method

Random Generation Options

Use Default Seed Value

Use Custom Seed Value

Random Seed: 5000

Minimum Delta Percentage: 0%

Use Incremental Pairing Method

Random Pairing Method

Min Values	
-0.5	1
-0.2	2
0	1
0.1	1

Max Values	
1	1
0.9	1
0.8	1
0.5	1
0.3	1

Result	
Min	Max
-0.2	1
0	0.9
0.1	0.8
-0.2	0.5
-0.5	0.3

Incremental Pairing Method

Min Values	
-0.5	1
-0.2	2
0	1
0.1	1

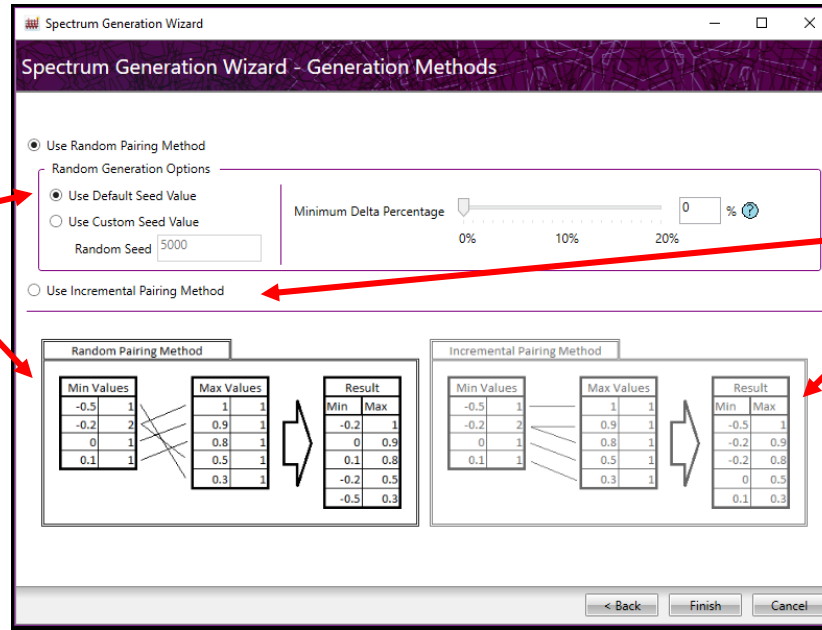
Max Values	
1	1
0.9	1
0.8	1
0.5	1
0.3	1

Result	
Min	Max
-0.5	1
-0.2	0.9
0	0.8
0	0.5
0.1	0.3

- Radio buttons that determine which spectrum generation method will be used
- Radio buttons that determine that select whether the default or a custom seed is used
- Minimum delta percentage slider and text box that determine the minimum delta percentage
- Graphics that summarize each pairing method

Currently Implemented Pairing Methods

- Random Pairing Method
- Incremental Pairing Method



Random Pairing Method

Incremental Pairing Method

- Incrementally pairs the highest maximum with the lowest minimum exceedance data
- Included as a commonly used and conservative approach
- Ideal for spectra dominated by high R-values
- Generally produces more severe spectra than the random pairing method

Incremental Pairing Method - Illustration

Incremental Pairing Method

Min Values	
-0.5	1
-0.2	2
0	1
0.1	1

Max Values	
1	1
0.9	1
0.8	1
0.5	1
0.3	1



Result	
Min	Max
-0.5	1
-0.2	0.9
-0.2	0.8
0	0.5
0.1	0.3

- This method pairs the highest max values (top of the Max Values table) with the lowest min values (top of the Min Values Table)
- Our algorithm ensures that a case where the min value is higher than the max value is not possible, while still making cycles with the maximum delta possible
- The Result table on the right shows the 5 cycles produced by the minimum and maximum exceedance tables on the left
- The nature of this algorithm means that the exceedance of the resulting spectrum is always exactly the same as the input exceedance

- Randomly pairs minimum and maximum exceedance data
- Includes a validation method that ensures each maximum is greater than its paired minimum
- Simple and straightforward method

Approach

Random Pairing Method

- The delta for a cycle is the difference between the maximum and minimum exceedance
- The delta is a way to assess the severity of the cycle
- The delta percentage is based on the highest exceedance value
- A minimum delta percentage limit can be used to increase accuracy of a generated spectrum
- Ground-Air-Ground cycles may be included to guarantee that a high delta cycle is generated in each sub-spectrum

Random Pairing Method - Illustration

Random Pairing Method

Min Values	
-0.5	1
-0.2	2
0	1
0.1	1



Max Values	
1	1
0.9	1
0.8	1
0.5	1
0.3	1



Result	
Min	Max
-0.2	1
0	0.9
0.1	0.8
-0.2	0.5
-0.5	0.3

- This method randomly pairs minimum and maximum exceedance values
- This algorithm ensures that the min value is less than the max value as it goes
- Due to this algorithm being random, it is possible that the original exceedance data may be changed, especially if a minimum delta value is selected.
- A warning is always displayed if the original exceedance data does not exactly match the exceedance data of the produced spectrum
- The Result table on the right shows the 5 cycles produced by the minimum and maximum exceedance tables on the left

Random Pairing Option

Random Seed

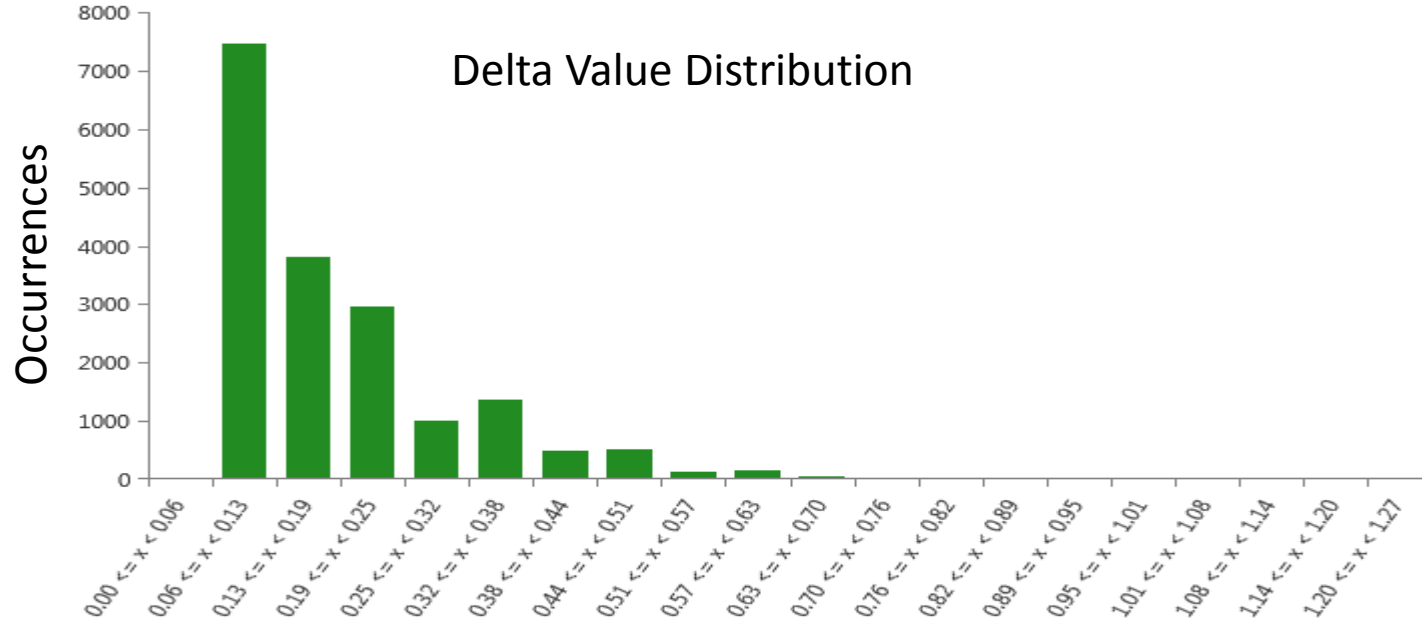
- Random seed is used in the random number generator which determines which exceedance points are paired.
- The default value is set to 5000
- The seed can be any integer
- Results from changing the random seed are generally no more than 2-3% different from any other random seed

Random Pairing Option

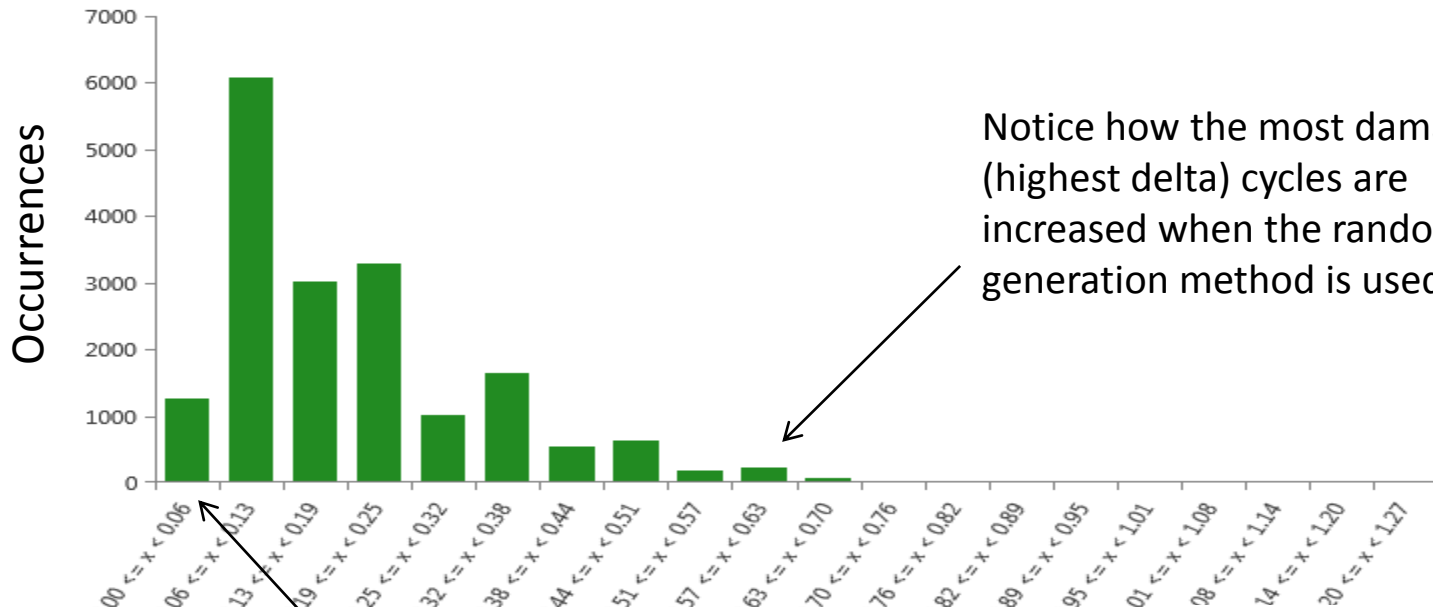
Minimum Delta Percentage

- Setting the minimum delta percentage prevents pairs from forming that have a delta value below that percentage
- Raising the delta percentage GENERALLY increases life predictions
- A delta percentage of around 10% tends to give best results
- The next few slides show how raising the minimum delta percentage effects the delta distribution of a spectrum

FALSTAFF (Original)

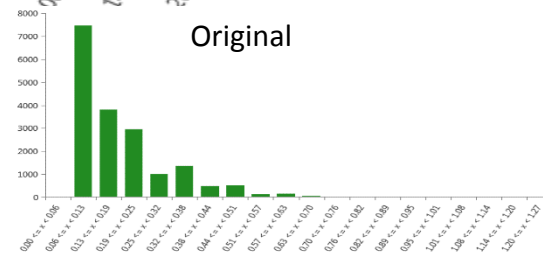


FALSTAFF Delta 0% (No Delta Correction)

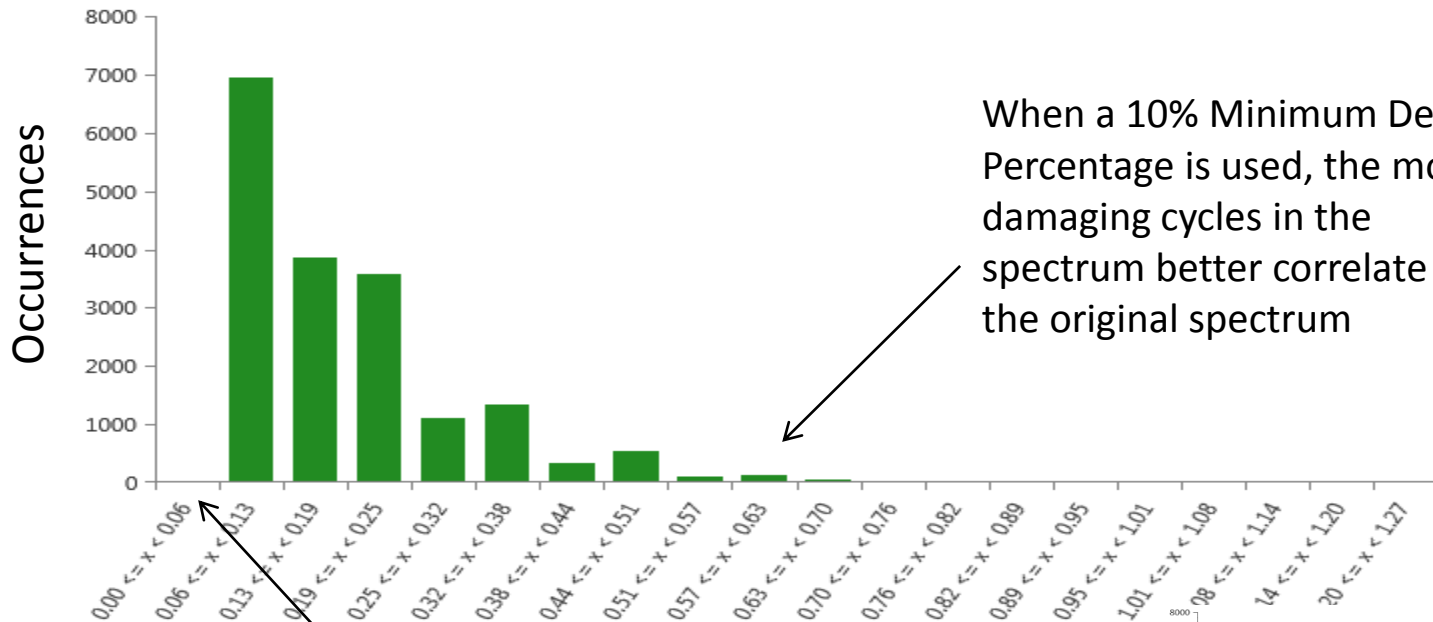


Notice how the most damaging (highest delta) cycles are increased when the random generation method is used.

Lower delta cycles appear when the random pairing method is used with no minimum delta percentage

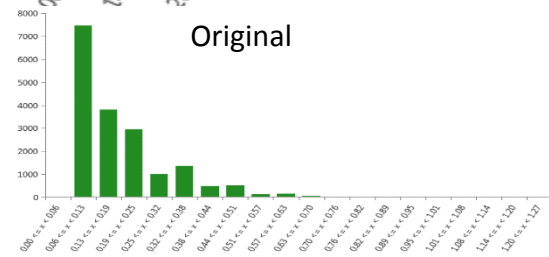


FALSTAFF 10% Delta Correction



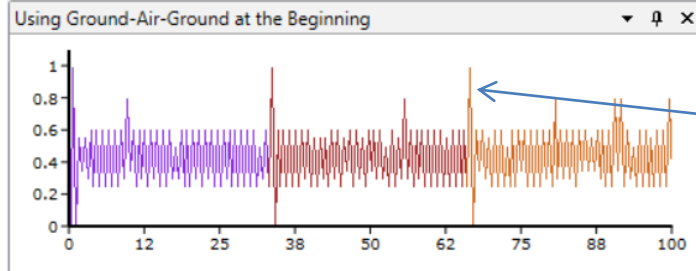
When a 10% Minimum Delta Percentage is used, the most damaging cycles in the spectrum better correlate with the original spectrum

The minimum delta percentage prevents the low delta pairs from forming

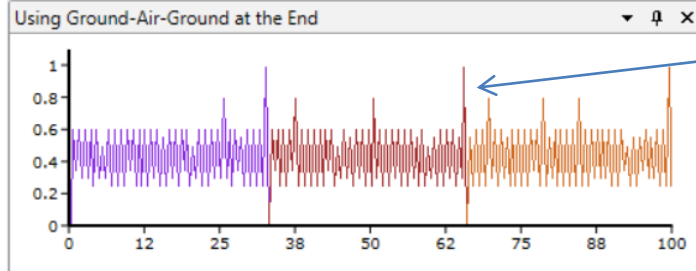


Input Option

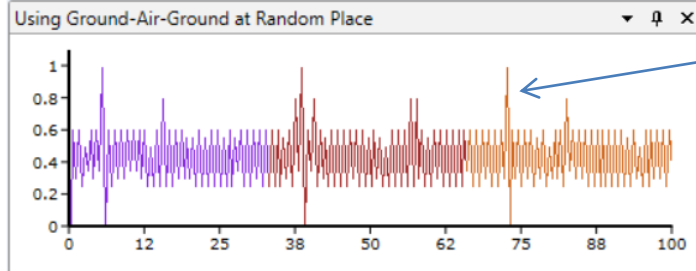
Ground-Air-Ground



Beginning of
Sub-Spectrum



End of Sub-Spectrum



Random Point within
Sub-Spectrum

- Ground-Air-Ground cycles are added from existing exceedance data by incrementally pairing the highest maximum exceedance values with the lowest minimum exceedance values
- Ground-Air-Ground cycles can be added at the beginning, end, or at a random place in each sub-spectrum
- Using Ground-Air-Ground cycles generally raises the severity of the spectrum, slightly

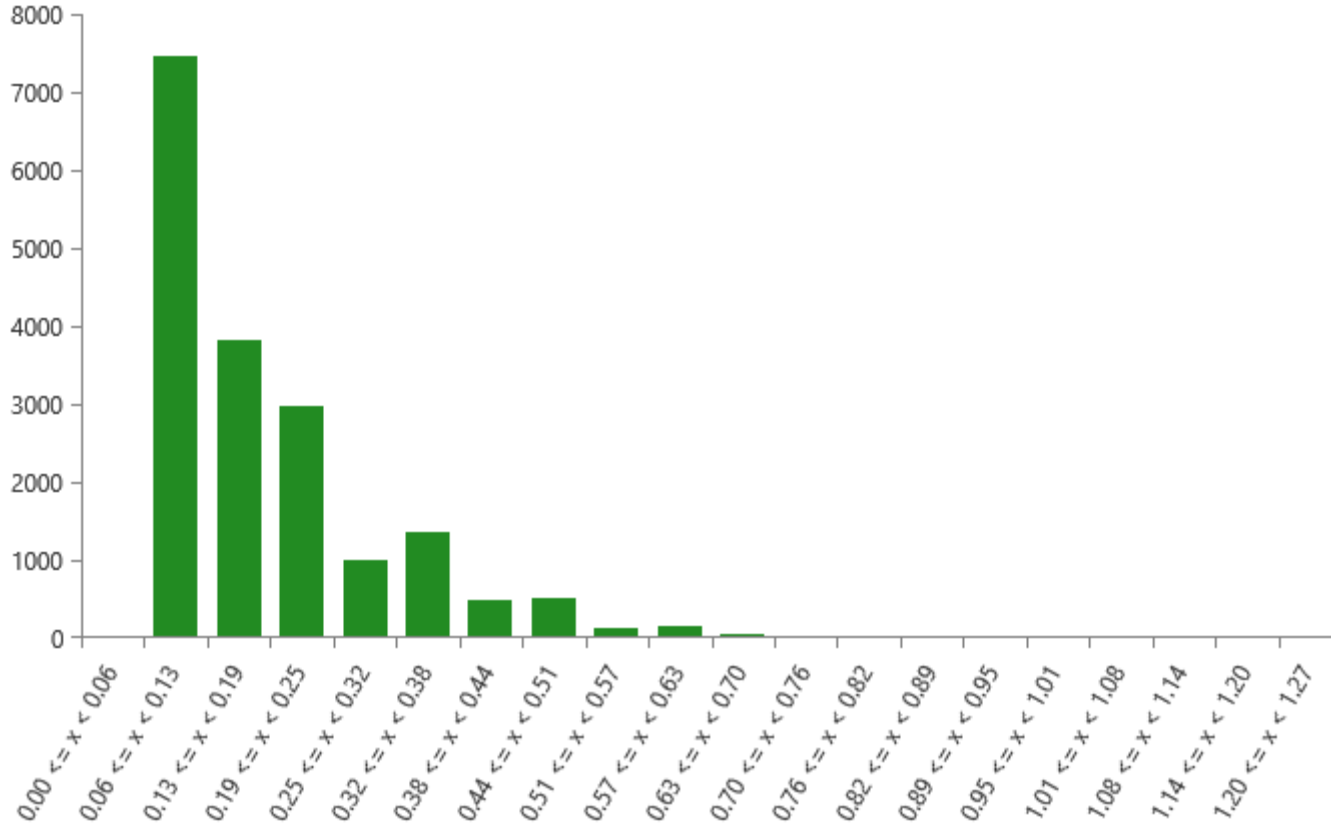
When to Use Random Pairing vs Incremental Pairing

- Random Pairing Method is recommended in most cases, where there are relatively few smaller exceedances
- Incremental Pairing Method is recommended when there are a significant number of relatively small exceedances (e.g. landing gear spectrum)
- Consider using the Random Pairing Method, along with a Minimum Delta Percentage when the original spectrum is known to be truncated

- The next few slides will show delta plots along with the % error in life predictions for the new WISPER, Falstaf, and a Transport Lower Wing Cover spectrum
- The % Error is calculated using the new Constant K/σ Classic Model in AFGROW with the following parameters:
 - Initial Crack Length $C = .1$
 - Thickness = .1
 - Width = 4
 - SMF = 14, 20

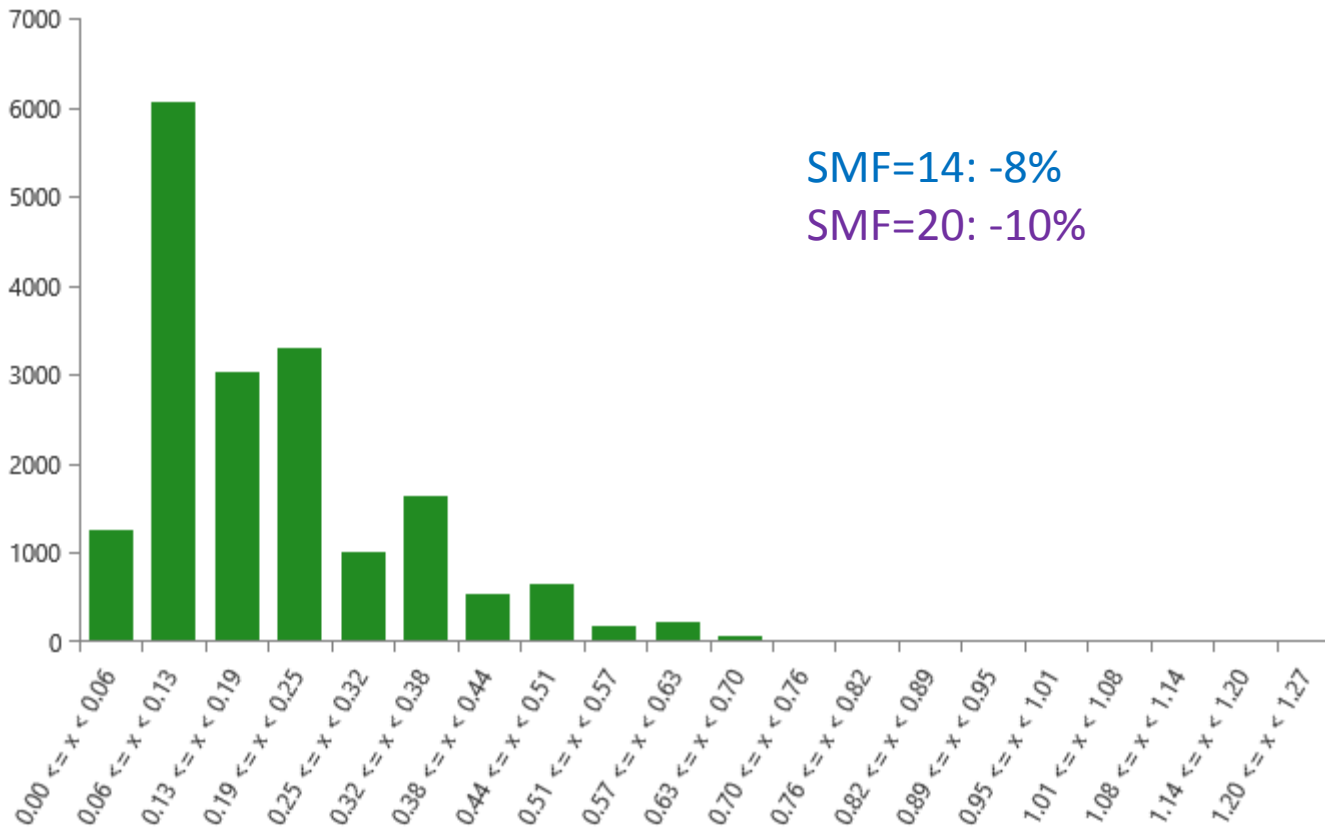
FALSTAFF (Fighter Aircraft Loading STandard For Fatigue) was developed as a benchmark fighter lower wing loading spectrum by NLR (Holland), LBF (Germany), IABG (Germany), and F&W (Switzerland). The spectrum was based on actual flight data for wing root loads from different fighter aircraft types on a variety of missions. The data were normalized to produce a uniquely defined sequence of relative loads for 200 flights.

FALSTAFF



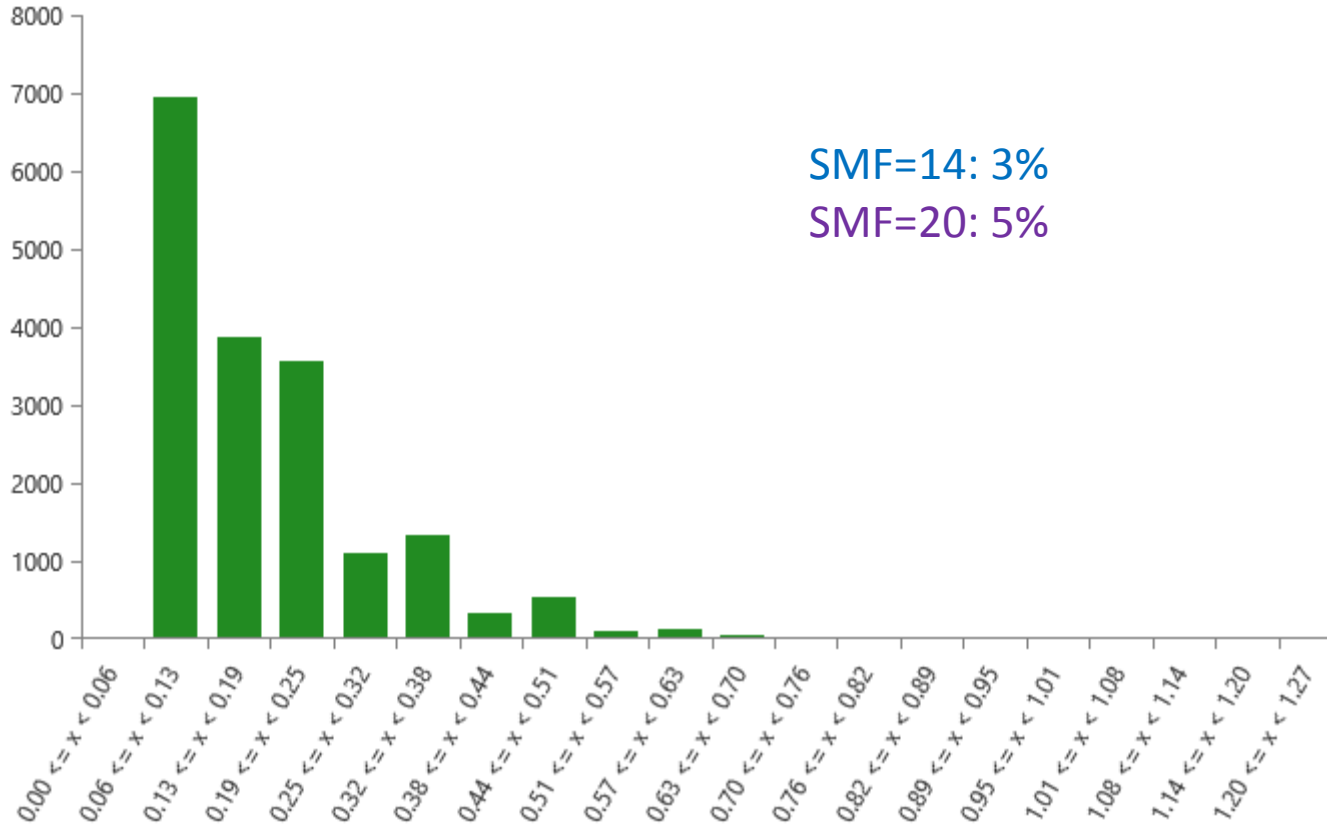
FALSTAFF Random Pairing Method

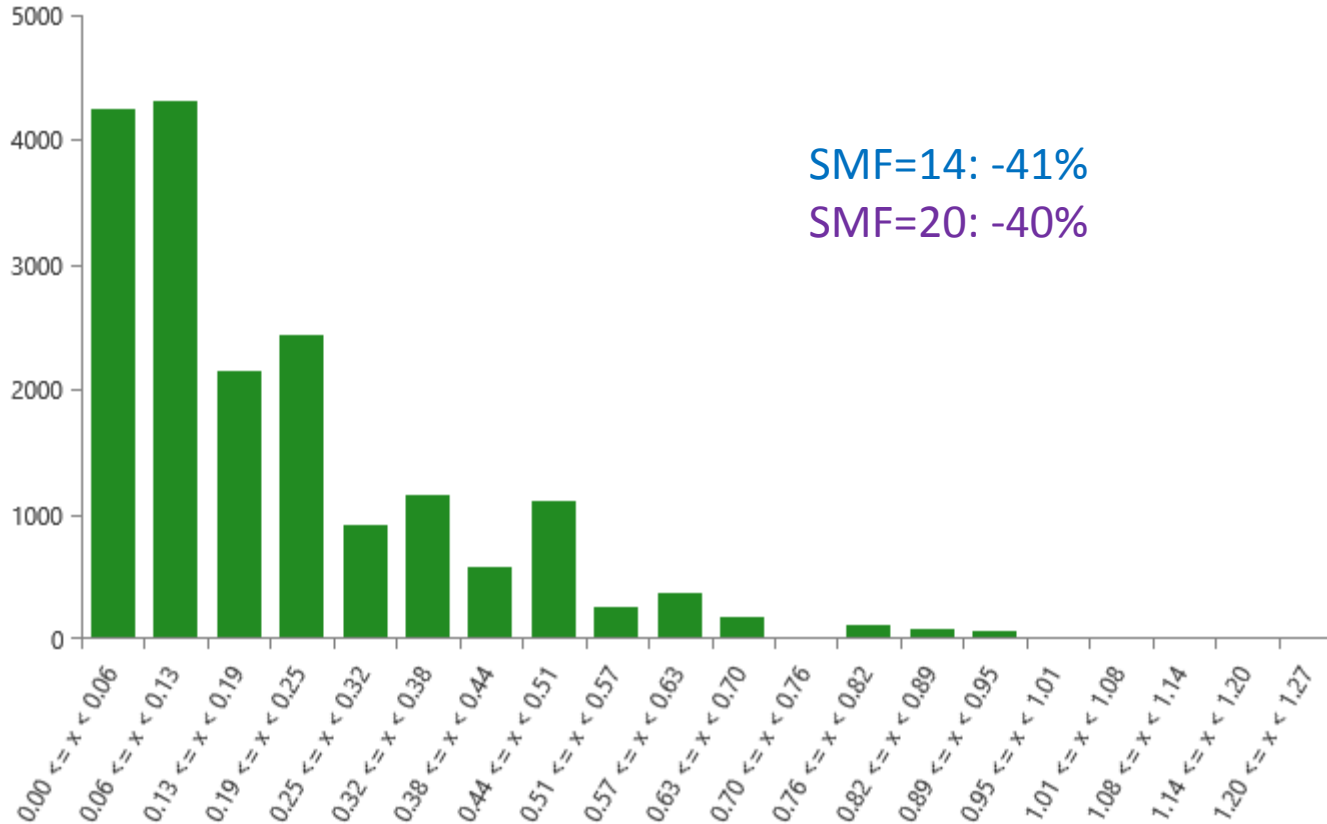
No Minimum Delta Percentage



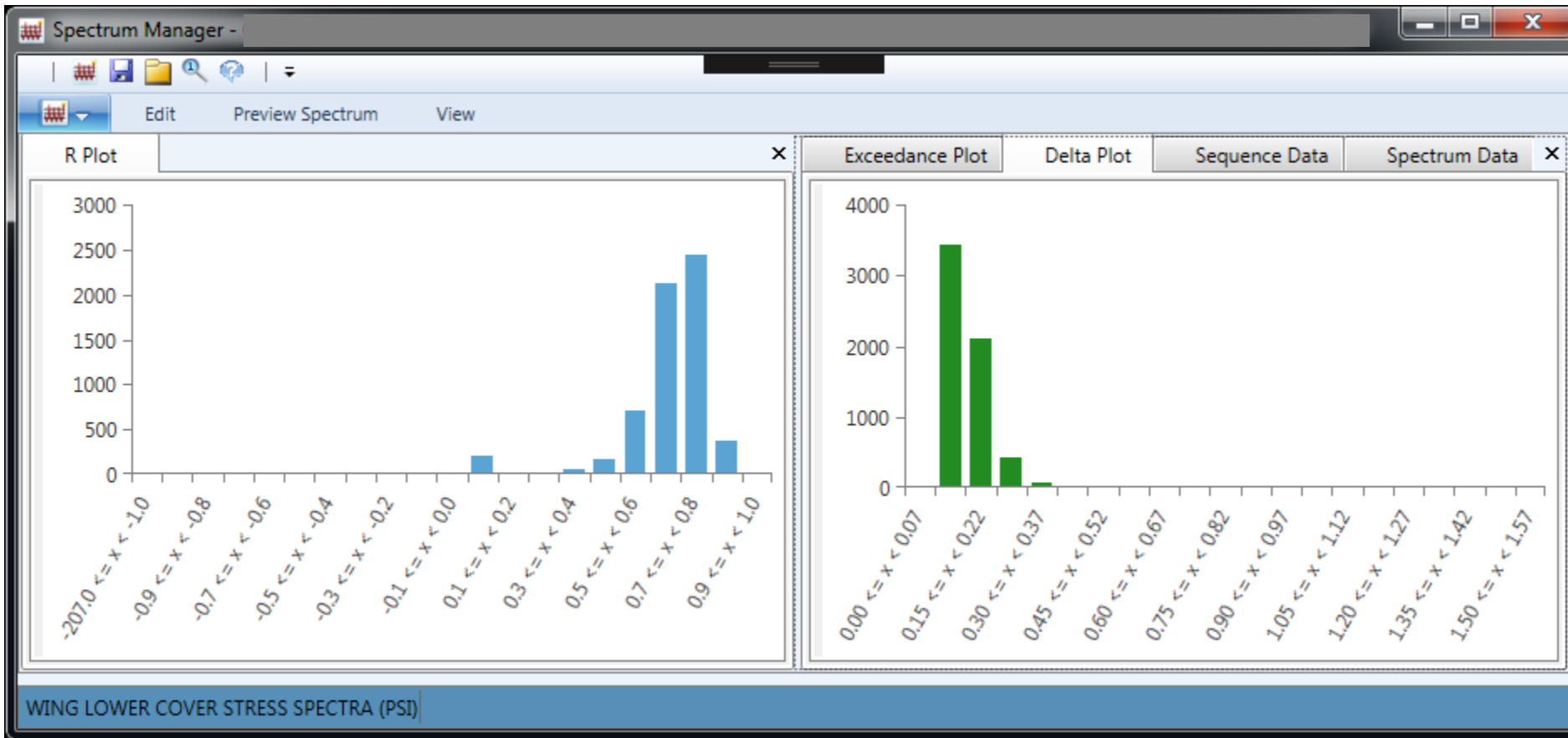
FALSTAFF Random Pairing Method

Minimum Delta Percentage 10%



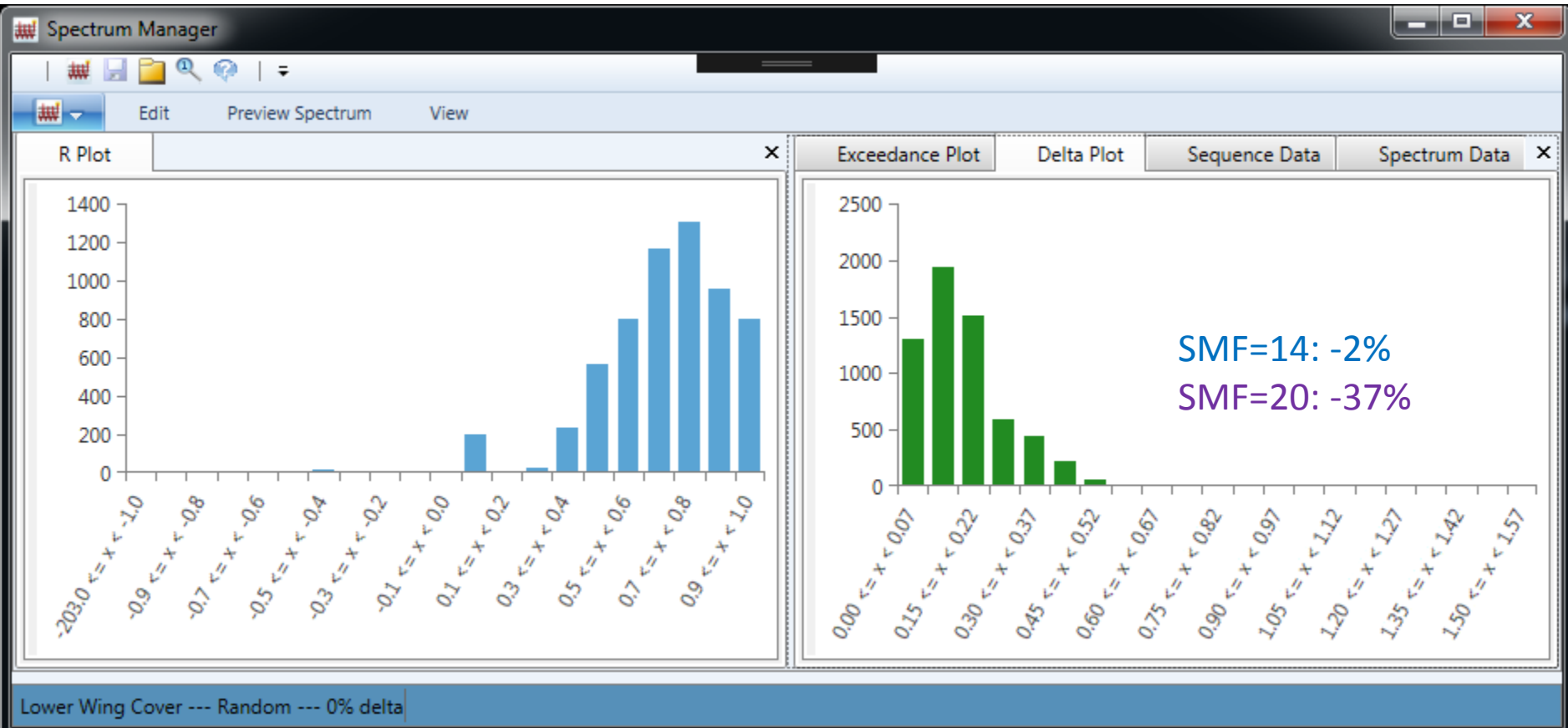


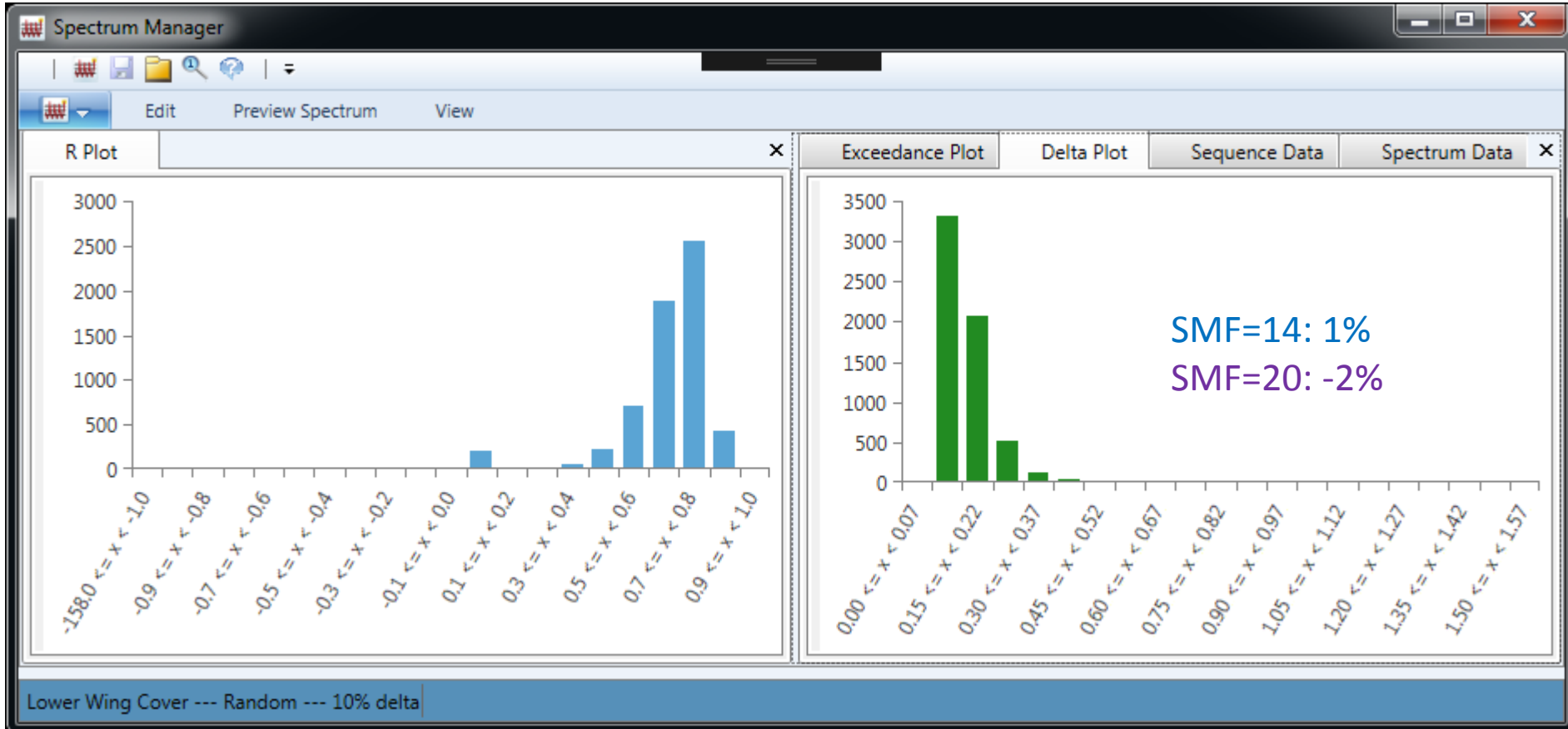
- Provided by Juan Lado
- A lower cover stress spectrum from a transport aircraft
- R and Delta Plot Comparison



Randomized Lower Wing Cover

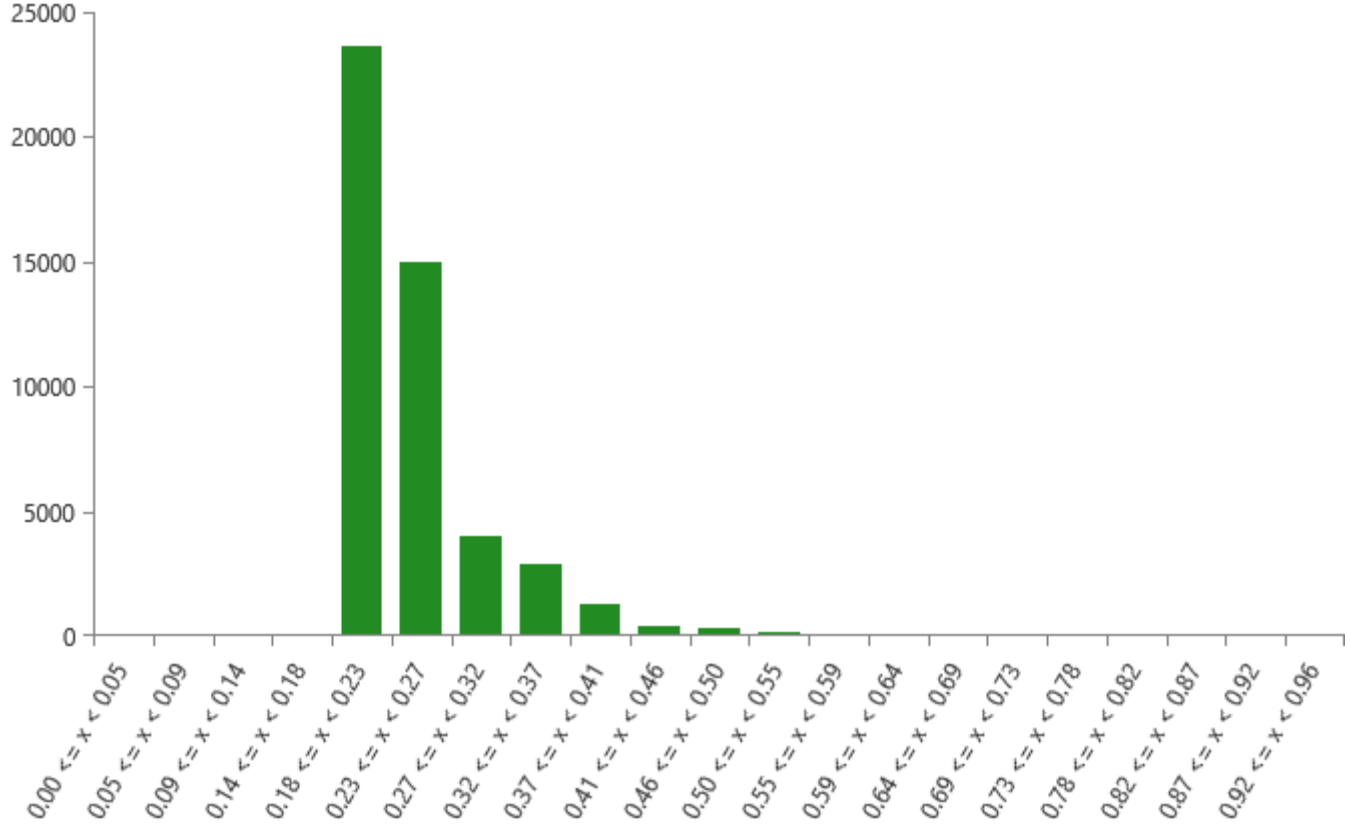
No Minimum Delta Percentage





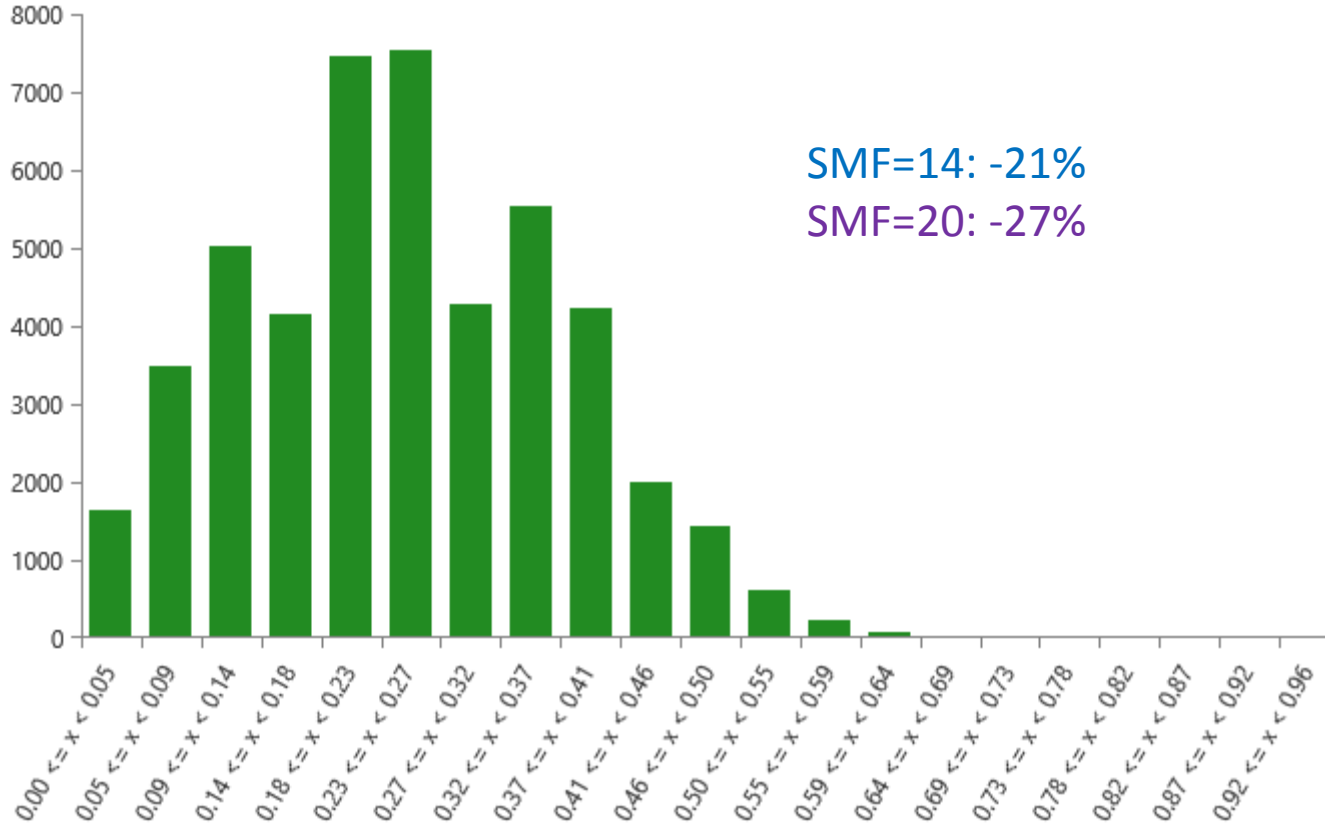
- Created by OPTIMAT BLADES
- Based on measurements from various sizes and types of wind turbines

New WISPER



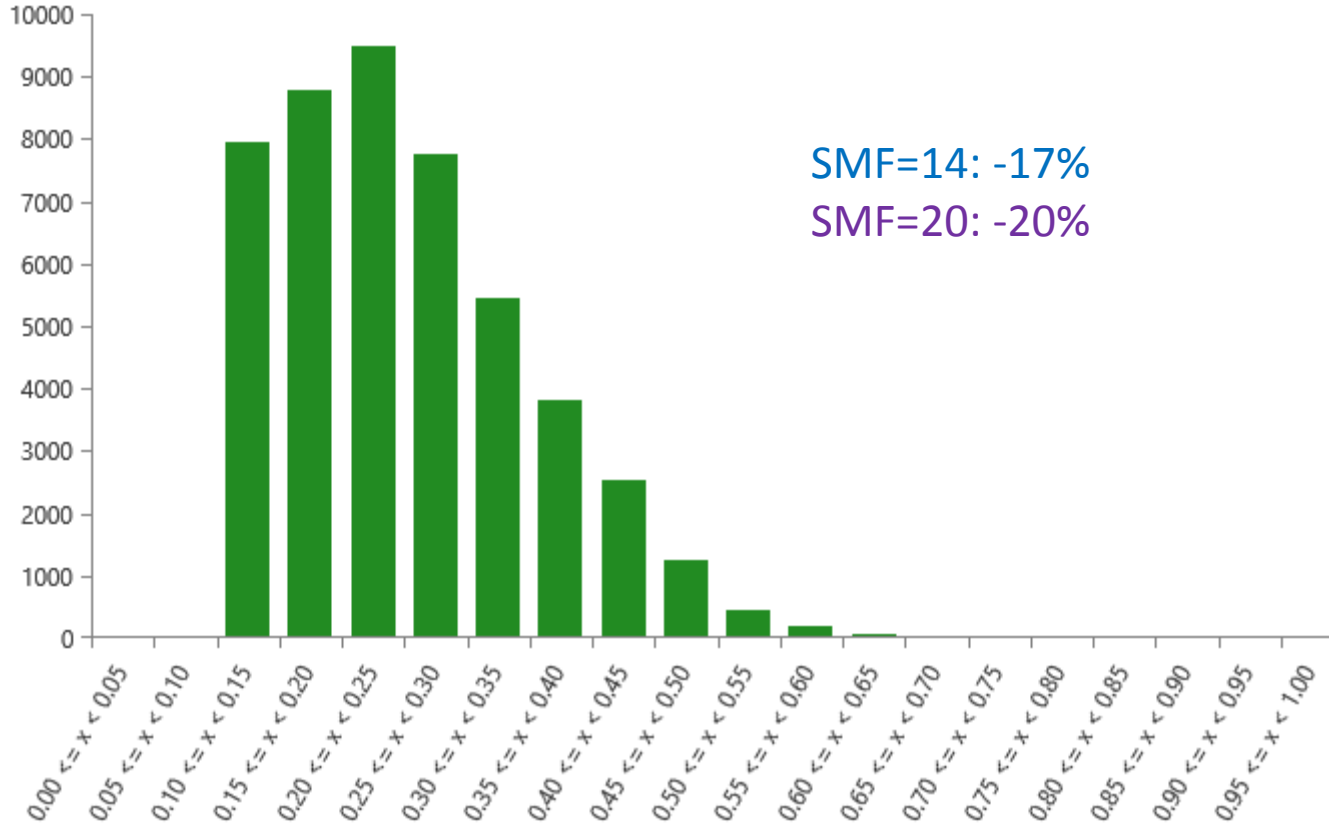
New WISPER Random Pairing Method

No Minimum Delta Percentage

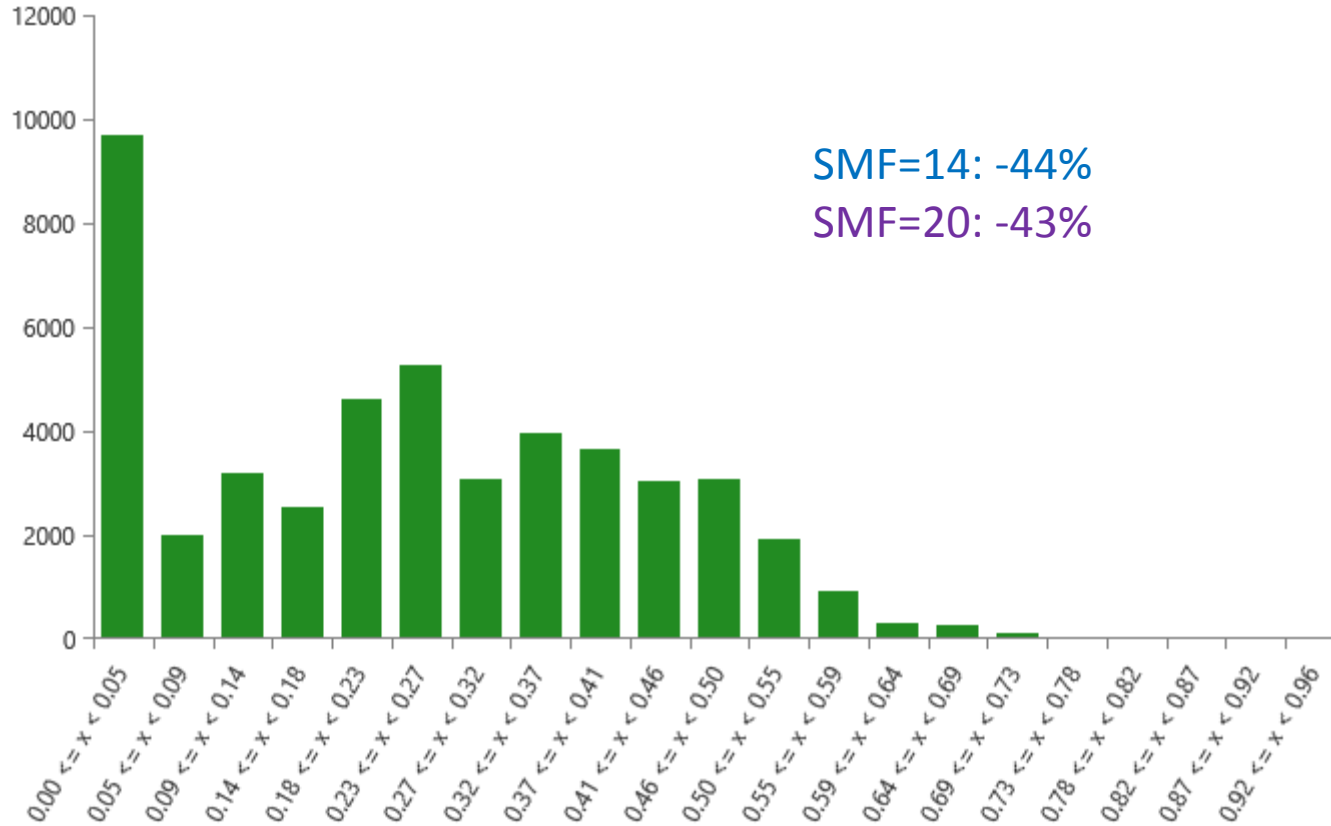


New WISPER Random Pairing Method

Minimum Delta Percentage 10%



New WISPER Incremental Pairing Method



- Expect to see spectrum generation from exceedance data in a future release of spectrum manager