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AFGROW Workshop 2020

AFGROW.NET

New Spectrum Generation Options for Spectrum Manager

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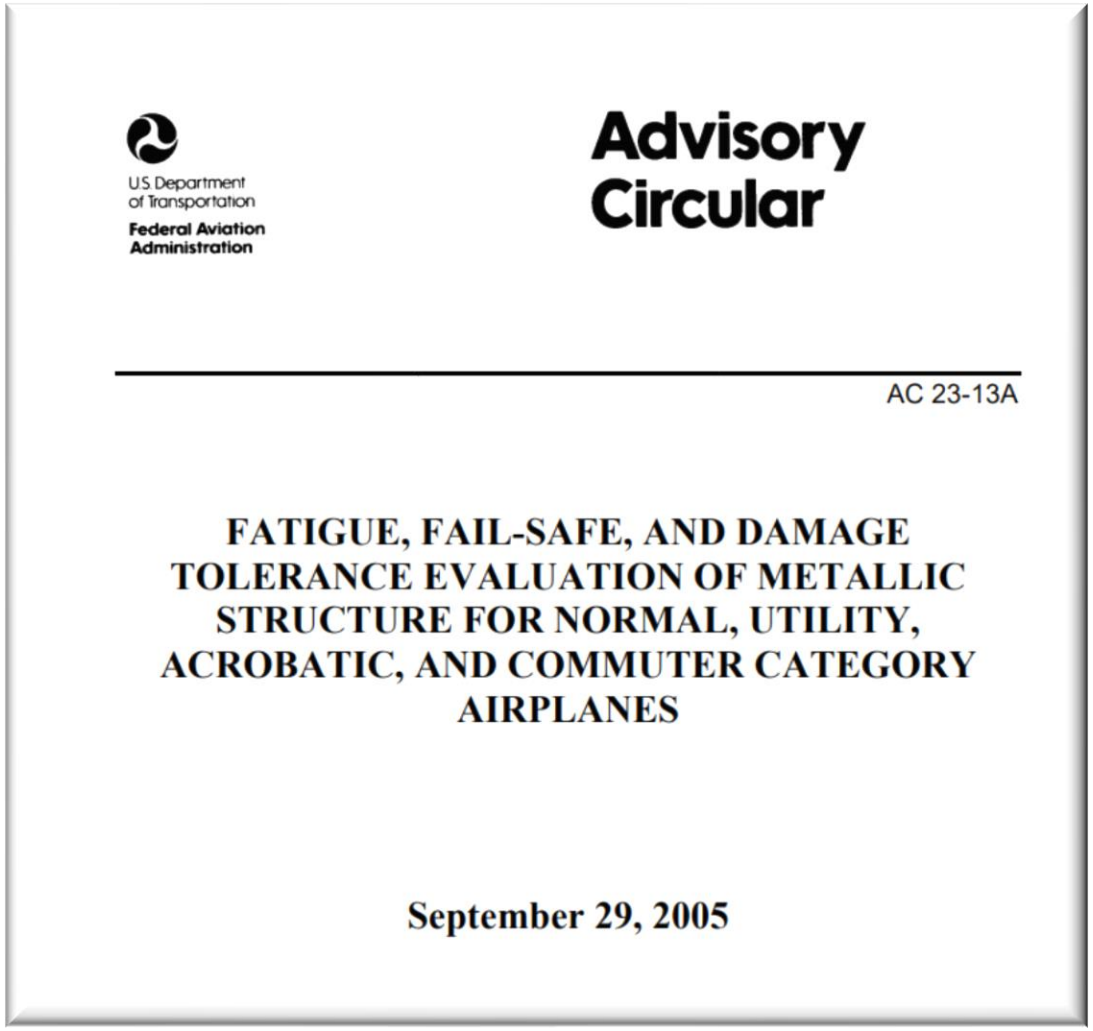
Background

Mark Thomsen asked us to think about how we could modify Spectrum Manager to generate GA usage spectra.

Guidance is provided in FAA AC 23-13A

Right now, we have the ability to generate an AFGROW spectrum using a single exceedance curve.

One of the challenges we have is how to combine gust and maneuver exceedances



U.S Department of Transportation
Federal Aviation Administration

Advisory Circular

AC 23-13A

FATIGUE, FAIL-SAFE, AND DAMAGE TOLERANCE EVALUATION OF METALLIC STRUCTURE FOR NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

September 29, 2005

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Loading Information

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replacement times is usually achieved through the use of fatigue scatter factors or other statistical adjustments.

e. Provide data for inspection and maintenance instructions and guidance information to the operators. This data should include inspection methods, inspection thresholds and intervals.

2-4. What loading spectra should I use?

a. Appendix 1 presents gust and maneuver flight load spectra in both graphic and tabulated form for the following types of airplanes and usage:

(1) Single-Engine Executive Usage (non-pressurized, engine size greater than 185 hp)

(2) Single-Engine Personal Usage (non-pressurized, engine size less than or equal to 185 hp)

(3) Single-Engine Instructional Usage (non-pressurized)

(4) Single-Engine Acrobatic Usage (non-pressurized)

(5) Twin-Engine General Usage (non-pressurized)

(6) Twin-Engine Instructional Usage (non-pressurized)

(7) Pressurized Usage

(8) Special Usage (including survey and aerial application)

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Normalizing Gust & Maneuver Loads

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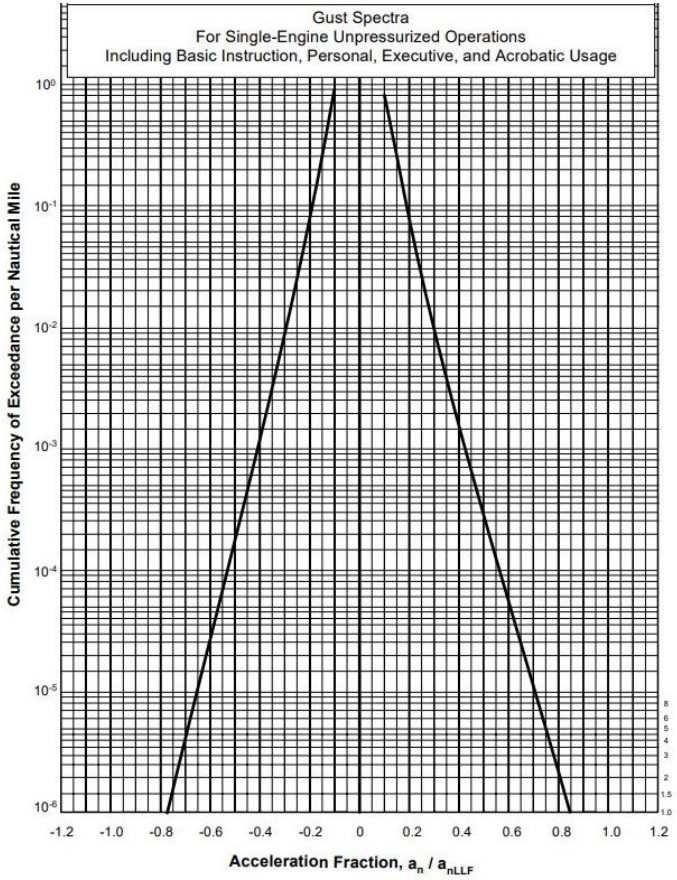
Gust and maneuver exceedances are normalized based on the incremental limit load factor at maximum gross weight.

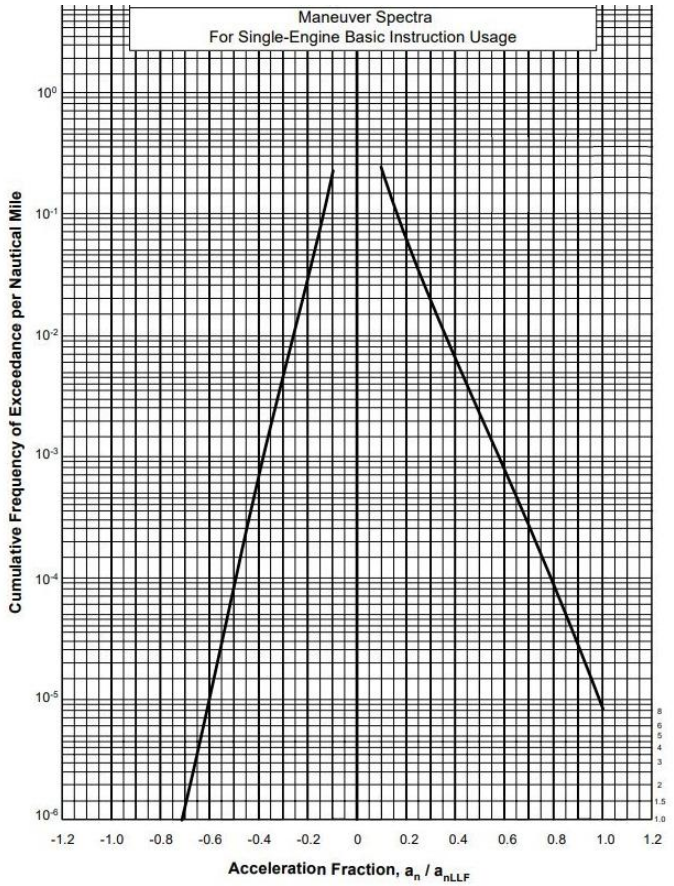
$$\frac{a_n}{a_{nLLF}} = \frac{Incremental\ Load\ Factor\ at\ Operating\ Weight}{Incremental\ Limit\ Load\ Factor\ at\ Maximum\ Gross\ Weight}$$

$$n_z = a_n + 1$$

Exceedance frequencies are provided as cumulative occurrences per nautical mile.

Cumulative Gust & Maneuver Load Exceedance Information

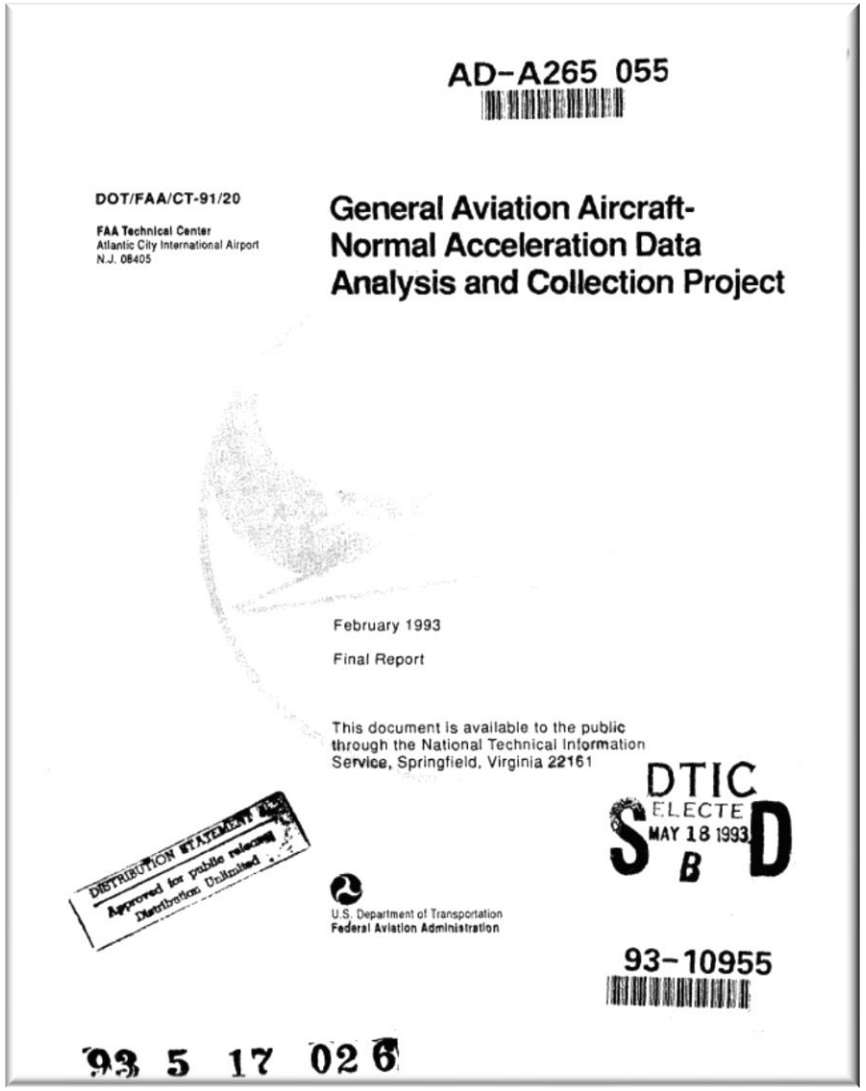




While positive and negative load cycles are considered to occur randomly in service, the high positive and negative loads of a given type of repeated loading tend to occur at the same time. For testing and analysis purposes, the high positive load cycles are typically combined with the high negative load cycles of the same frequency. **FAA AC 23-13A**

Cumulative Gust & Maneuver Load Exceedance Spectra

This reference contains an extensive amount of normalized acceleration data for general aviation aircraft. These data may also be helpful for other similar aircraft



AD-A265 055

DOT/FAA/CT-91/20

FAA Technical Center
Atlantic City International Airport
N.J. 08405

General Aviation Aircraft-Normal Acceleration Data Analysis and Collection Project

February 1993

Final Report

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

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Code of Federal Regulations
CFR Title 14

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Airworthiness Part 23 Categories

Low Speed: Vno <= 250 kts
High Speed: Vno > 250 kts

Normal: -1.52 <= Nz <= 3.8

Utility: -1.76 <= Nz <= 4.4

Aerobatic: -3 <= Nz <= 6

Often a function of gross weight for a given aircraft and gust limits may be provided by the manufacturer

Calculating the Incremental Gust Limit Load Factor

$$a_{nLLF} = \frac{U\ K\ V\ m}{498\ \frac{W}{S}}$$

U = 30.0, nominal gust velocity in feet per second

$$K = \frac{1}{2}\left(\frac{W}{S}\right)^{\frac{1}{4}} \quad \text{for } W/S < 16 \text{ lbs / ft}^2$$

$$K = 1.33 - \frac{2.67}{\left(\frac{W}{S}\right)^{\frac{3}{4}}} \quad \text{for } W/S > 16 \text{ lbs / ft}^2$$

W / S = Wing loading at maximum weight, lbs / ft^2

V = Airplane structural design cruise speed, V_C, KEAS

m = Wing lift curve slope, $C_{L\alpha}$, rad^{-1}

Note: m may be approximated as 6AR/(2+AR), where AR = (wingspan)^2/(wing area)

Example Case

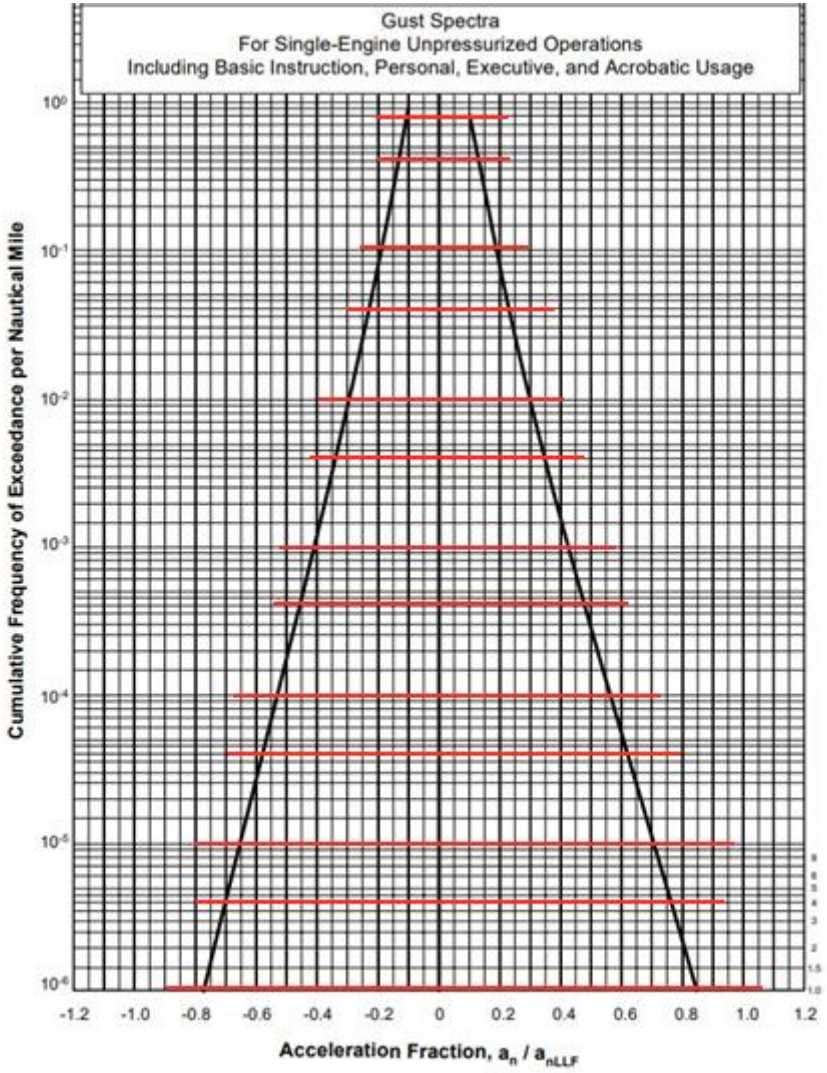
Cessna 172

Cruise Speed: 110 kts at S/L
Max Gross Wt: 2400 lbs
Wingspan: 35 ft, 8 in
Wing Area: 174 ft^2
AR: 7.345

W/S: 13.8 lb/ft^2
K: 0.964
m: 4.715

Gust Limit Load Factor (a_{nLLFg}): +/-2.183 (from equation)
Gust Limits: -1.183 <= Nz_g <= 3.183
Assume Utility Category (pilot + instructor)
Maneuver Limits: -1.76 <= Nz_m <= 4.4

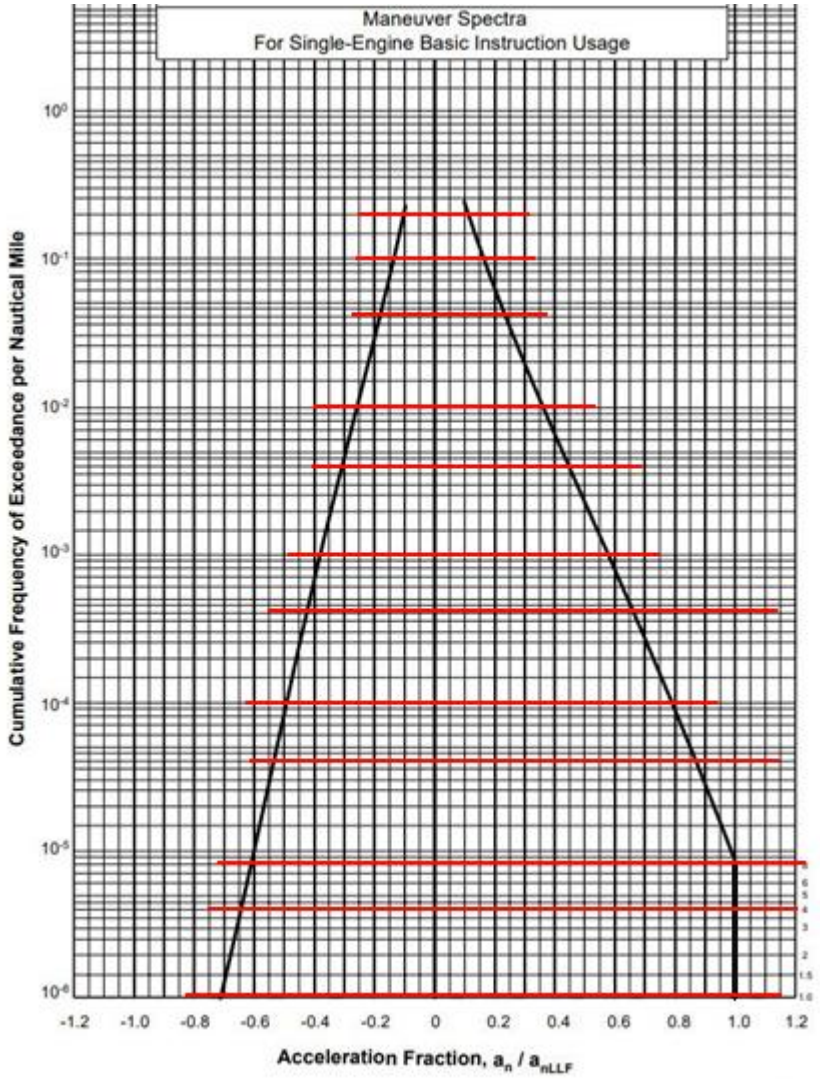
Cumulative Gust Exceedance Spectra



Cummulative Exceedances (nautical mile)$^{-1}$	Cummulative Occurances (1E6 nautical miles)	Maximum Acceleration Fraction	Minimum Acceleration Fraction
1.00E-06	1	0.850	-0.775
4.00E-06	4	0.772	-0.706
1.00E-05	10	0.721	-0.660
4.00E-05	40	0.644	-0.590
1.00E-04	100	0.593	-0.544
4.00E-04	400	0.516	-0.475
1.00E-03	1000	0.465	-0.429
4.00E-03	4000	0.388	-0.359
1.00E-02	10000	0.337	-0.313
4.00E-02	40000	0.259	-0.244
1.00E-01	100000	0.208	-0.198
4.00E-01	400000	0.131	-0.128
7.00E-01	700000	0.100	-0.100

Speed (kts)	Hours (1E6 nautical miles)	Cummulative Occurances/hour
110	9091	77

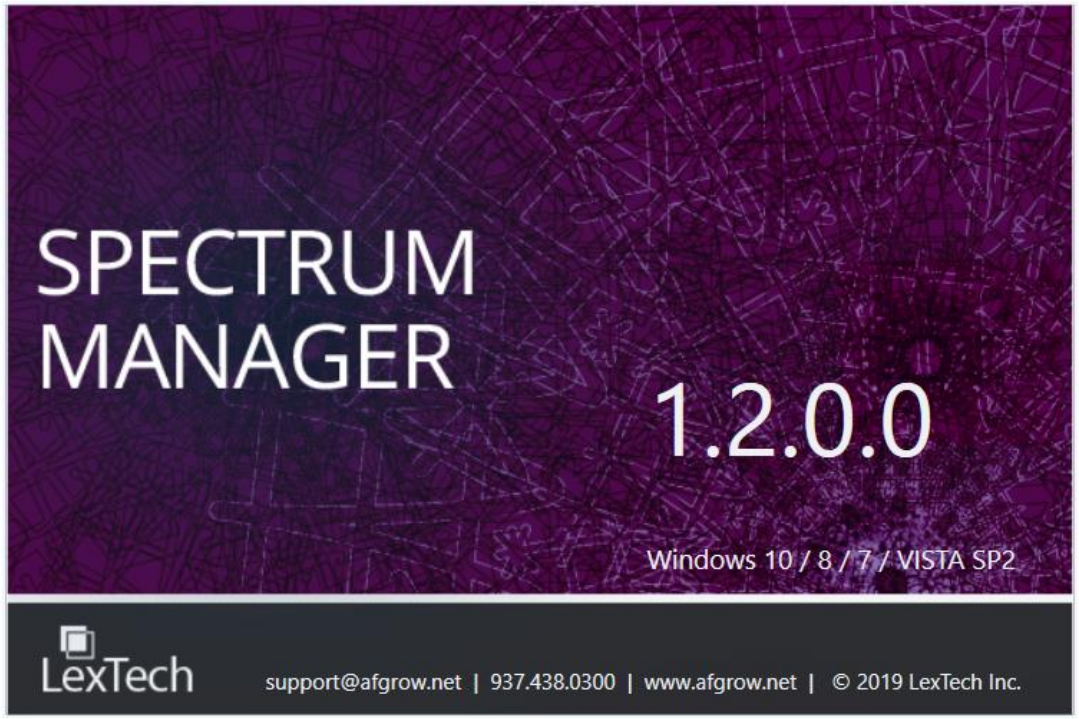
Cumulative Maneuver Exceedance Spectra

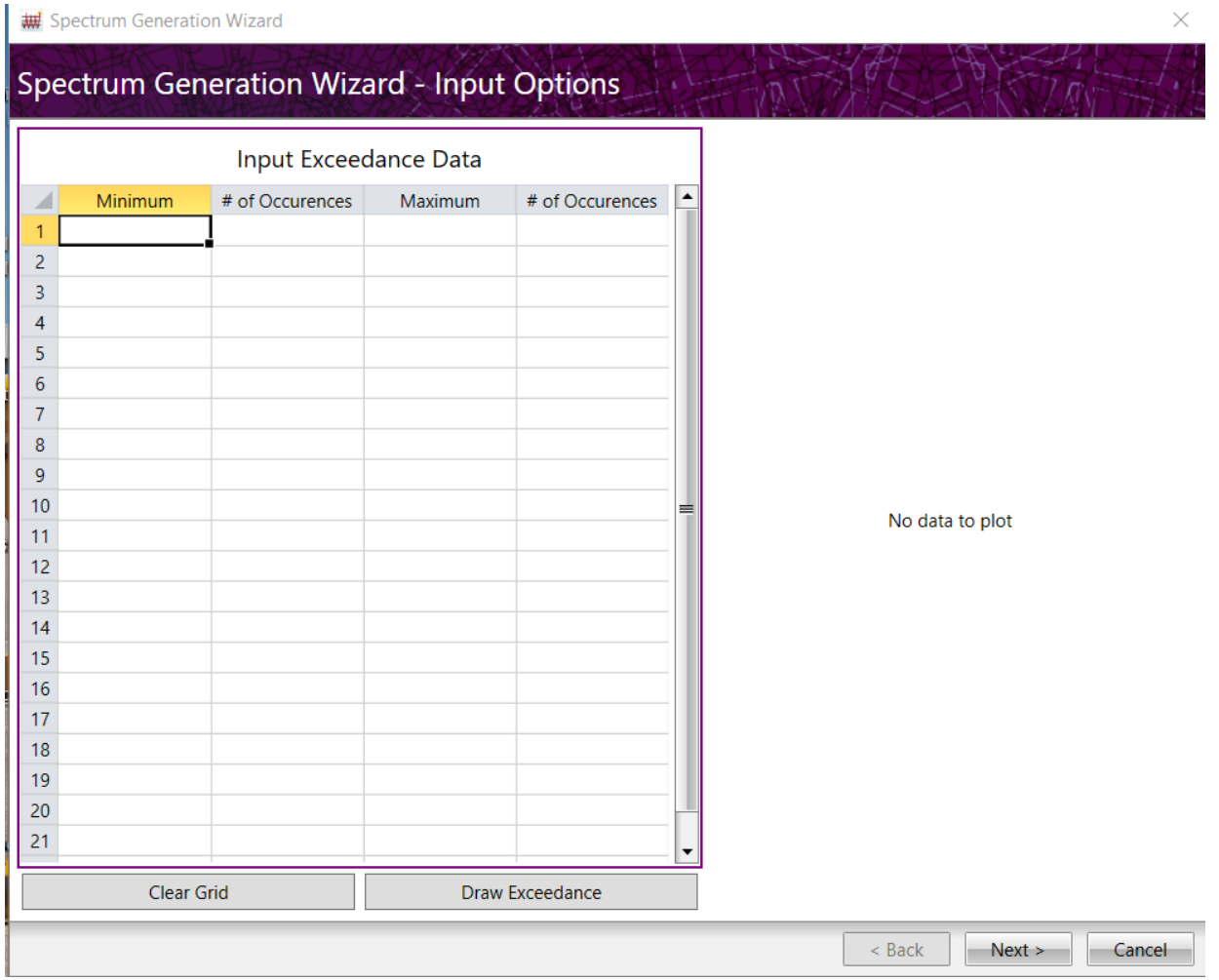


Cummulative Exceedances (nautical mile)$^{-1}$	Cummulative Occurances (1E6 nautical miles)	Maximum Acceleration Fraction	Minimum Acceleration Fraction
1.00E-06	1	1.000	-0.710
4.00E-06	4	1.000	-0.641
8.00E-06	8	1.002	-0.606
4.00E-05	40	0.858	-0.526
1.00E-04	100	0.777	-0.480
4.00E-04	400	0.653	-0.411
1.00E-03	1000	0.572	-0.365
4.00E-03	4000	0.448	-0.296
1.00E-02	10000	0.367	-0.250
4.00E-02	40000	0.243	-0.181
1.00E-01	100000	0.162	-0.135
2.00E-01	200000	0.100	-0.100

Speed (kts)	Hours (1E6 nautical miles)	Cummulative Occurances/hour
110	9091	22

Generating an AFGROW Usage Spectrum





Currently, Spectrum Manager can generate a usage spectrum from a single cumulative exceedance curve

Combining Two or More Exceedance Curves

Occurrences for more than one exceedance curve can be added, but rules would be necessary to resolve some issues

- Each individual exceedance curve must have the same number of maximum and minimum occurrences
- If different exceedance curves do not contain the same number of occurrences, null values would be assigned to curves to equalize the number of occurrences for all curves
- Randomized maximum values from one exceedance curve would be added to randomized maximum values for other exceedance curves
- Randomized minimum values from one exceedance curve would be added to randomized minimum values for other exceedance curves
- To capture GAG cycles, individual flight duration(s) must be identified
- The maximum and minimum N_z limits must be maintained (e.g. Utility category : $-1.76 <= N_z <= 4.4$)
- Etc. ?

Discussion

- Is Spectrum Manager being used in your organization to generate AFGROW usage spectra?
- Would anyone be interested in expanding the current spectrum generation capability in Spectrum Manager to allow multiple exceedance curves to be combined in Spectrum Manager?
- What types of data are available?
- Other issues/concerns/ideas?