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Life Bounding for Durability Duty Cycles

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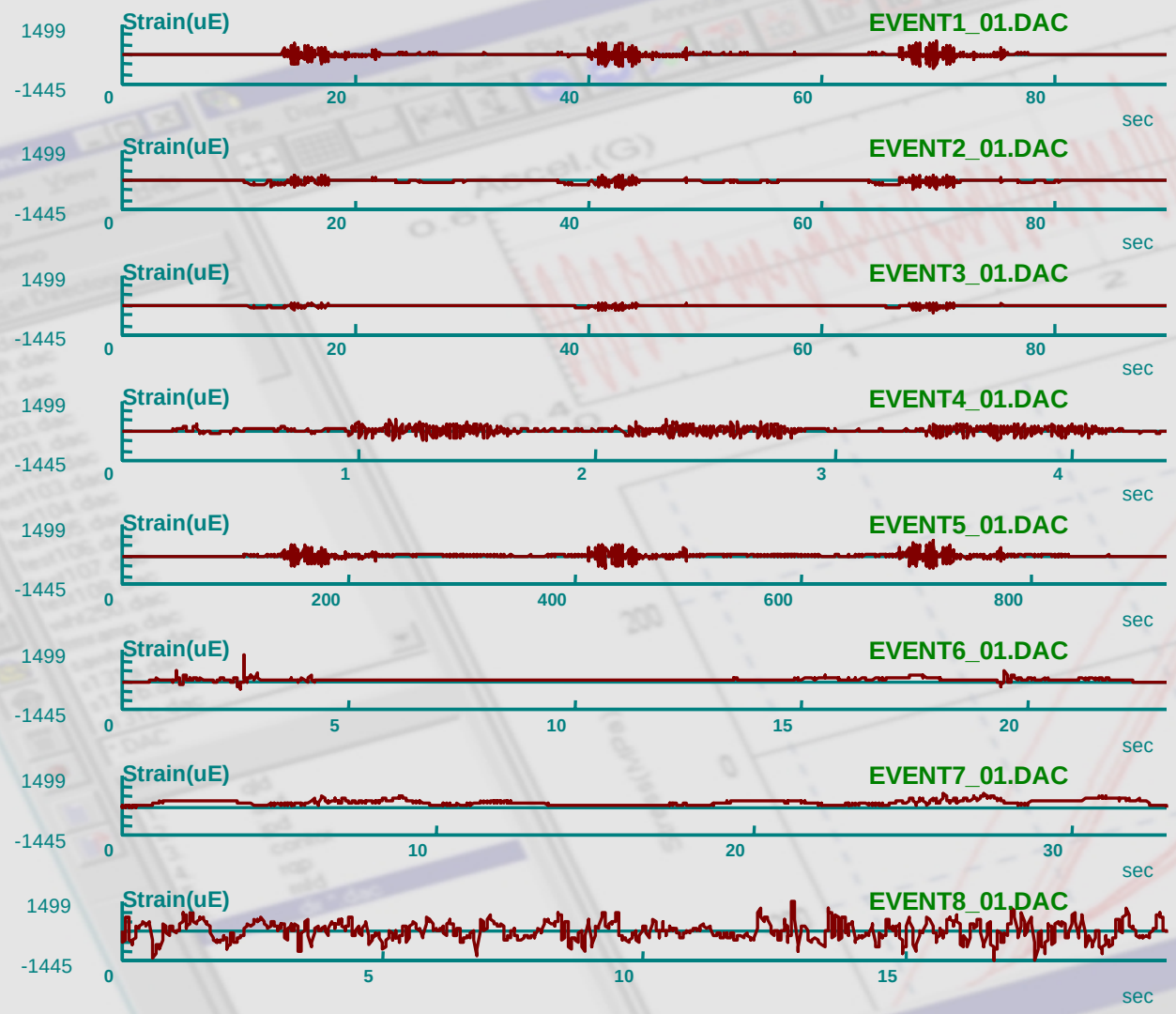
Introduction

- **Evaluate durability over a complete “life”**
  - **Proving Ground durability schedule is made up of many repeats of various events**
  - **Vehicle may run 20,000 durability miles to simulate 100,000 real-world miles**
- **Instrumented vehicle collects data over all the proving ground events**
  - **Blocks, potholes, ABS stop, bumps, etc.**
  - **Data is then used for fatigue analysis**

Fatigue Analysis Challenge

- **Due to time constraints, only 1 pass of each surface event may be collected**
  - **Ideal to have more for statistical evaluation**
- **Must take collected data and scale it by a multiplier**
  - **Multiplier is the number of repeats for each surface event that is run for an entire durability schedule (or duty cycle)**

Sample Event Files



Max Y = 716.2
Min Y = -651

Max Y = 202.8
Min Y = -424.5

Max Y = 136
Min Y = -311.8

Max Y = 575.8
Min Y = -466.8

Max Y = 710.9
Min Y = -641.2

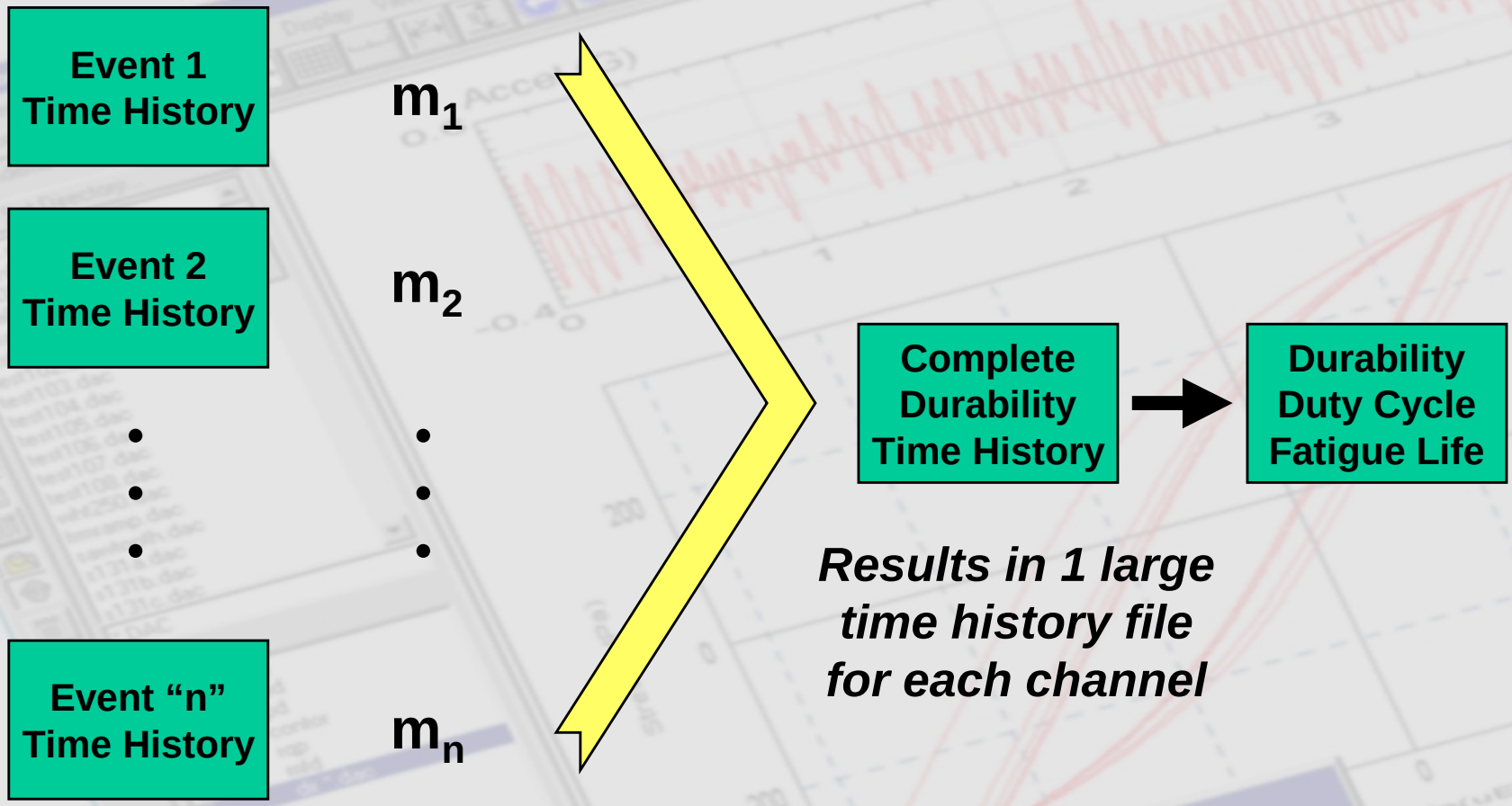
Max Y = 1301
Min Y = -392.3

Max Y = 589.8
Min Y = -0.344

Max Y = 1499
Min Y = -1445

Durability Fatigue Life Analysis

- **Concatenate all events (each with their own multiplier)**



Drawbacks with Time History

- **Large files for each channel**
- **Massive data storage needed**
- **Slower fatigue calculations**

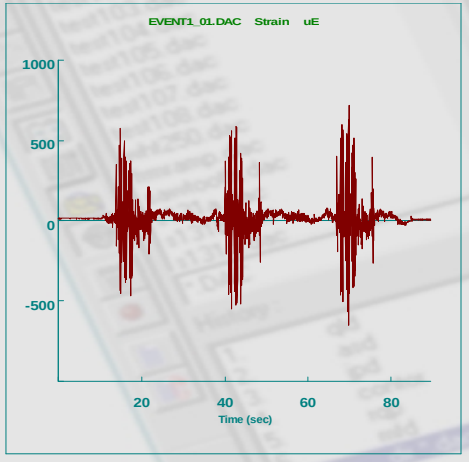
Life Bounding Analysis

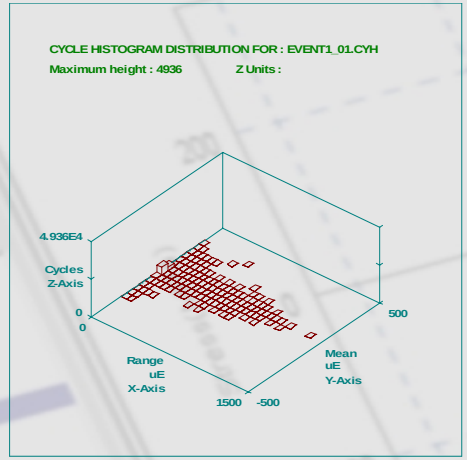
- Create rainflow cycle matrix for each event
  - Must be same size!
- Multiply each event matrix by multiplier
- Add scaled matrices to form complete durability duty cycle matrix
- Perform fatigue calculations using rainflow matrices for each channel

Create Rainflow Matrices

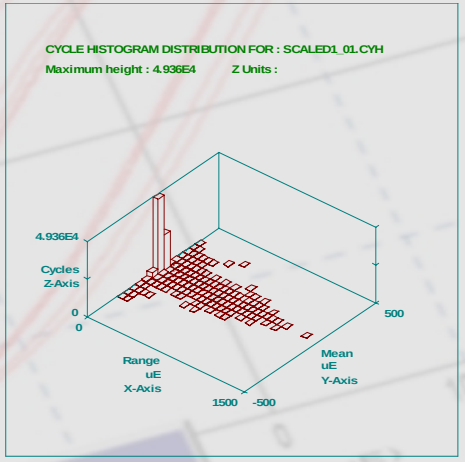
- **For each event, create a rainflow cycle matrix and scale the matrix by the duty cycle multiplier**

Event 1 Time History → **Event 1 Rainflow Matrix** * m_1 → **Event 1 Scaled Matrix**

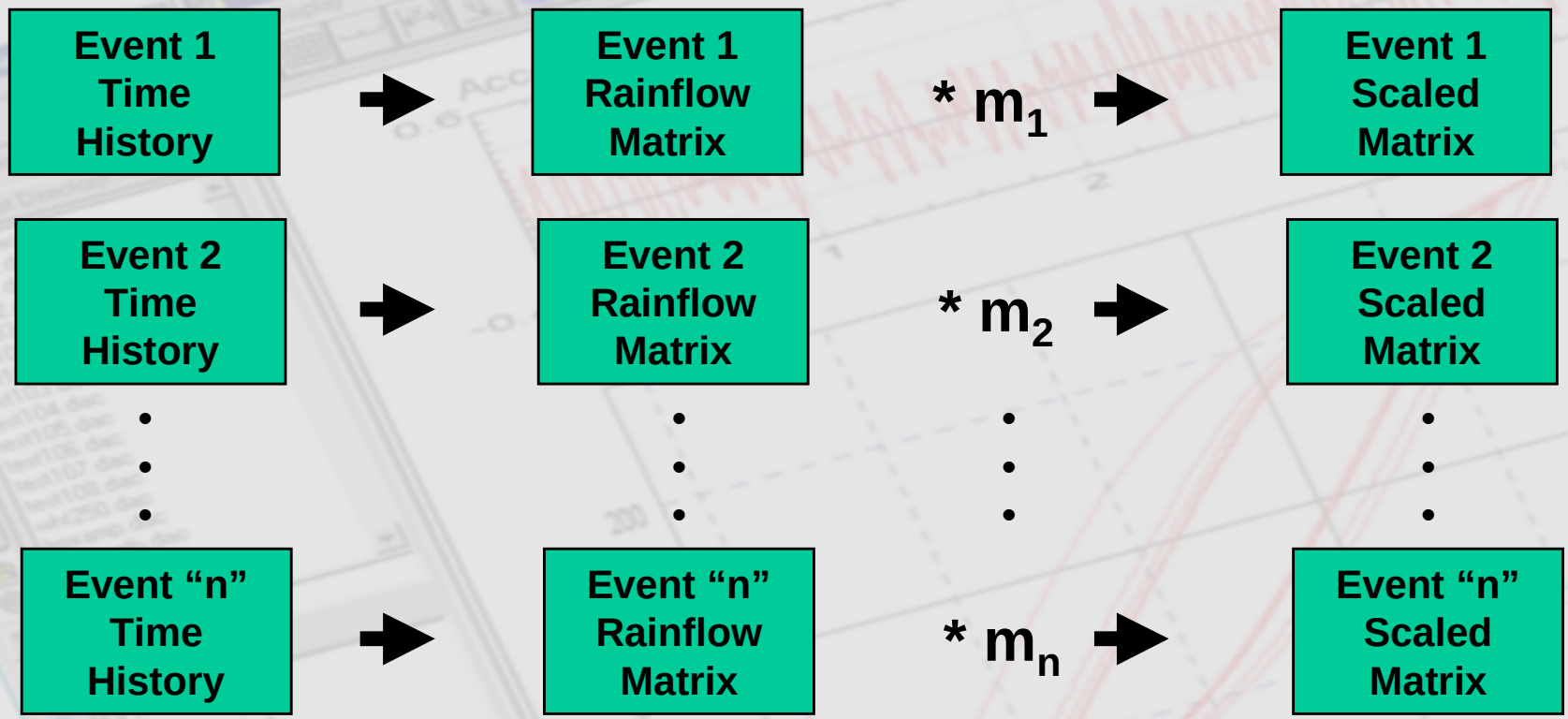




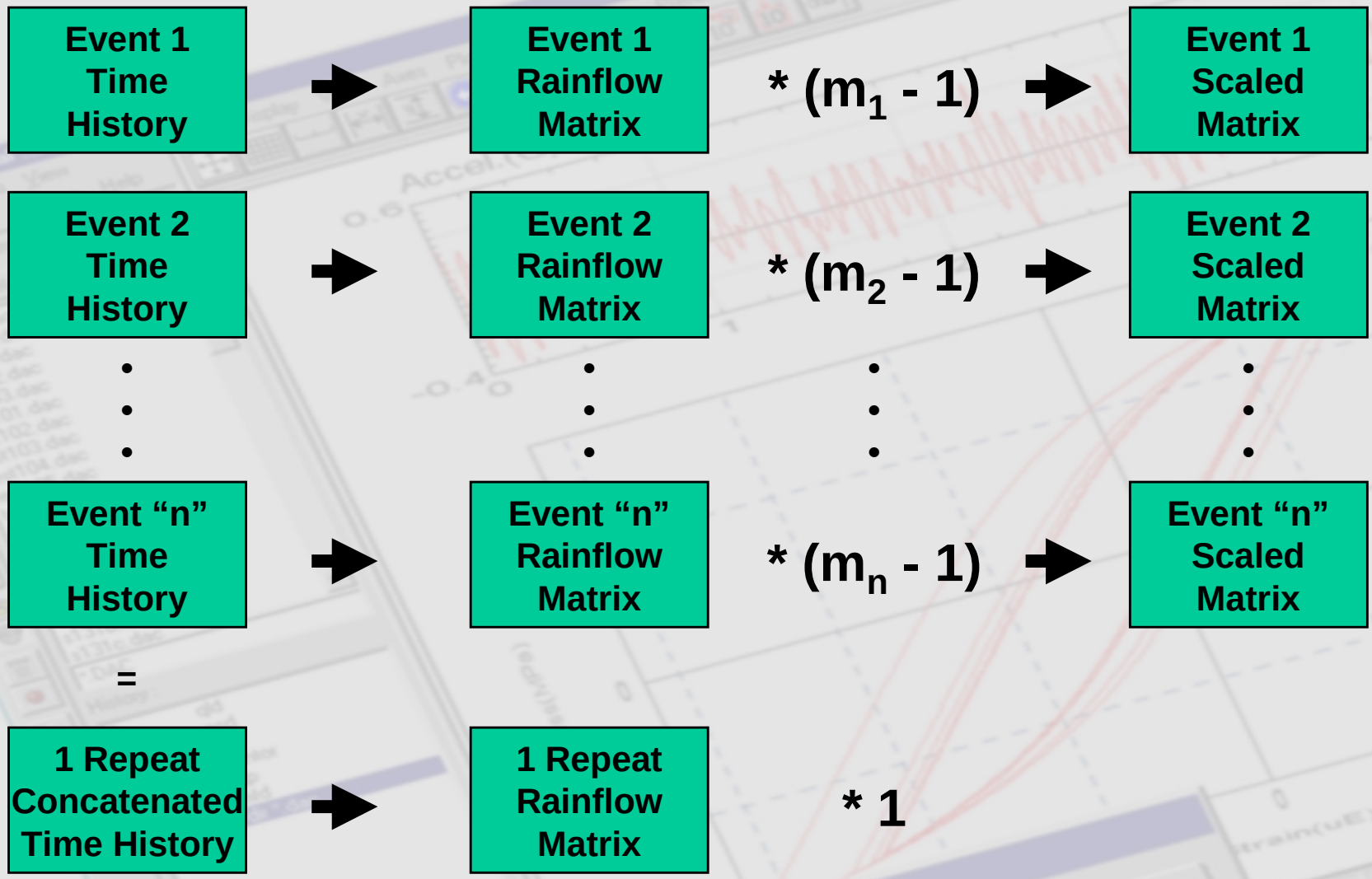
* m_1 →



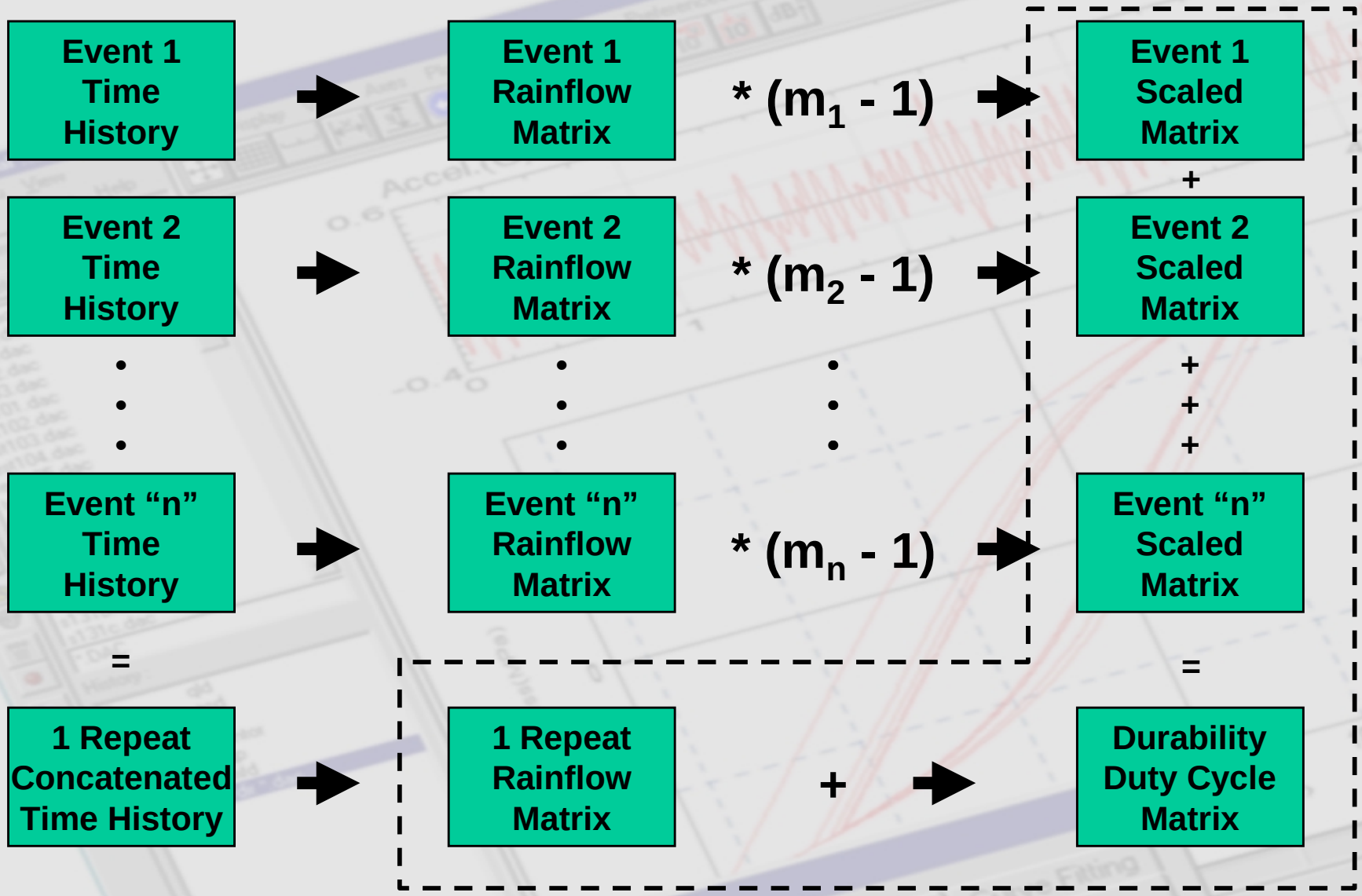
Repeat for Every Event



Account for Largest Cycle



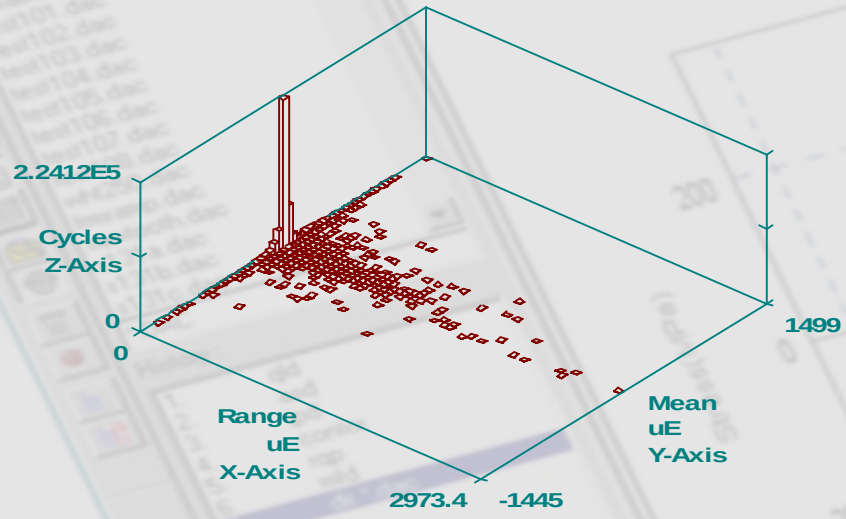
Assemble Complete Matrix



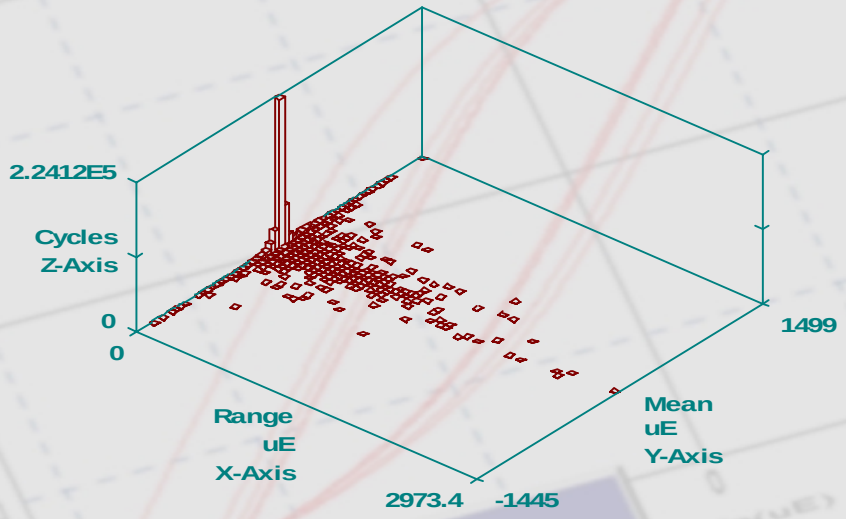
Life Bounding Results - 1

- **Compare 2 methods:**

Concatenate time histories, then rainflow count



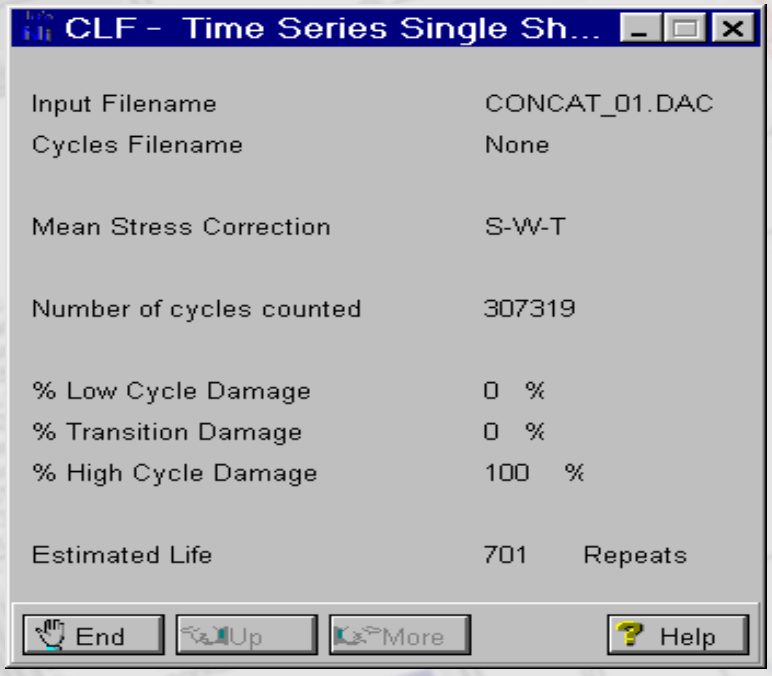
Rainflow count, multiply, then add matrices



Life Bounding Results - 2

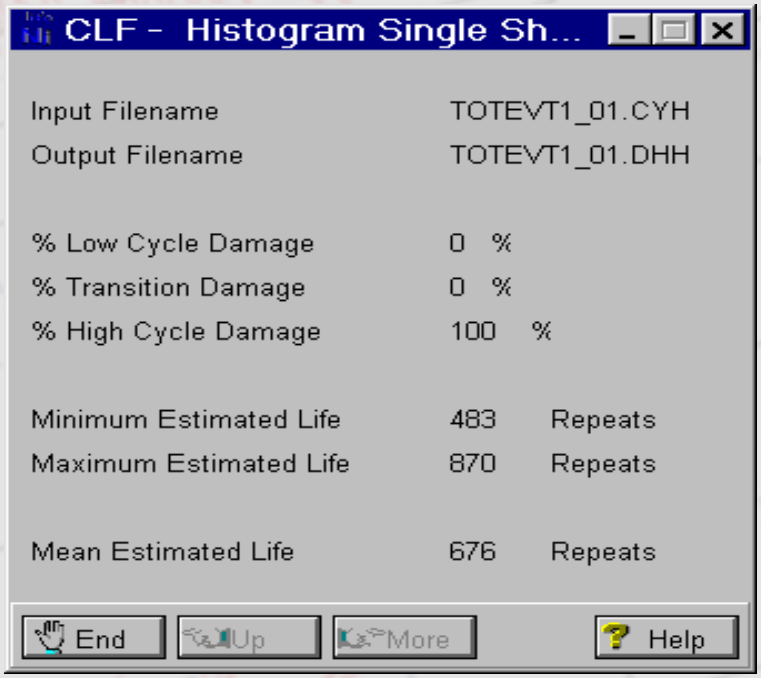
- **Compare fatigue results:**

Concatenate time histories, then calculate fatigue



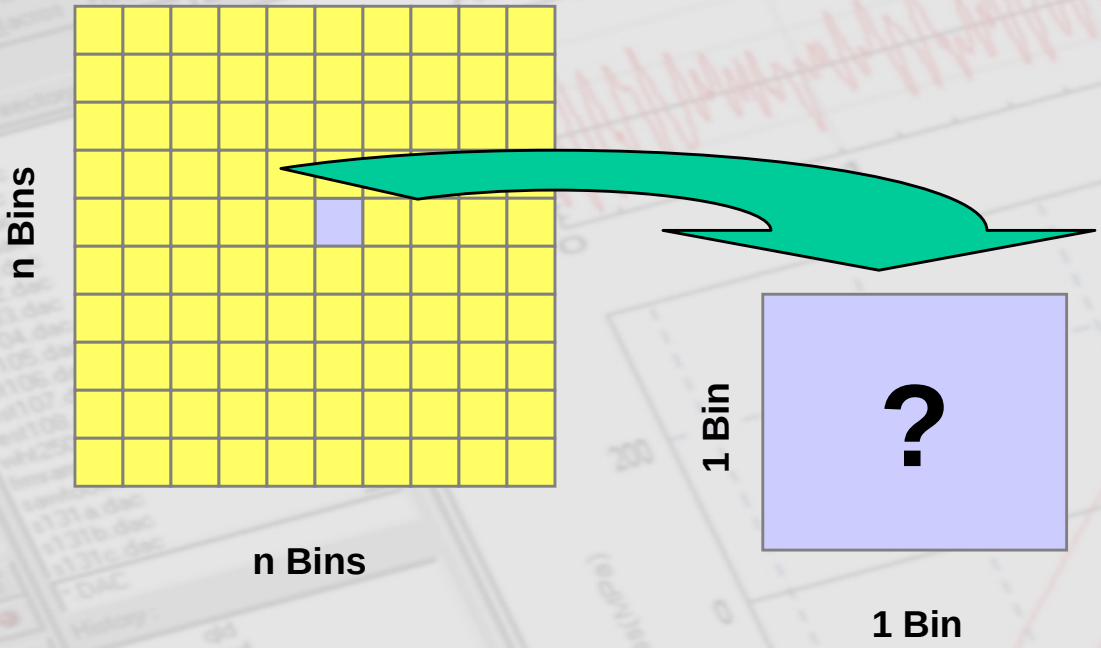
Life = 701 repeats

Rainflow count, multiply, add matrices, then calculate fatigue



Mean Life = 676 repeats
Min Life = 483
Max Life = 870

Life Bounding Results



- Uncertainty in actual data value
- Should a bin value be taken as the minimum, mean, or maximum value in the bin?
- Life Bounding calculates results for all bins values
  - Time history results should fall within bounds

Issues to Consider

- Must have all matrices same size
  - Historical reference
- Matrices are much smaller to store
- Not for multiaxial loading
  - Other methods can be applied
- Be careful of mean stress levels
  - Data validation
- Statistical extrapolation
  - How many passes were collected
- Automation

Automated Routine

- **Input multiplier file, channels**
  - **Can calculate duty cycle matrix, % damage for events, overall damage, other**