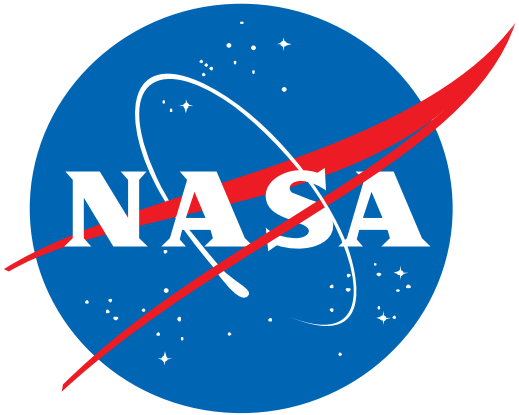

Assessing Engine Hot Fire Data for Human Spaceflight Applications

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J. Davis Hunter – NASA MSFC ER12 – Davis.Hunter@nasa.gov

Contents

Introduction

Hot Fire Data Assessment Goals

Data Analysis Components

- Access the experience base
  - Find historical data from large sets and use it for comparison
- Interpret test data
  - Visualize and manipulate data for effective assessment, then succinctly summarize assessments to answer stakeholders' questions

The Seven Elements of Flight Rationale

#	Element	Element Expanded
1	**Solid technical understanding**	Physics-based or root cause understanding of issue, based on engineering data
2	**Condition relative to experience base**	Experience base includes full-scale flight, ground test, or qualification-level tests
3	**Bounding case established**	Using physics-based understanding, determine the bounding case
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5	**Margins understood**	Adequate margins, ideally not substantially reduced from baseline
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7	**Interactions with other elements and conditions addressed**	Address interactions with other conditions (MRB, changes, technical issues), and vehicle elements

WinPlot

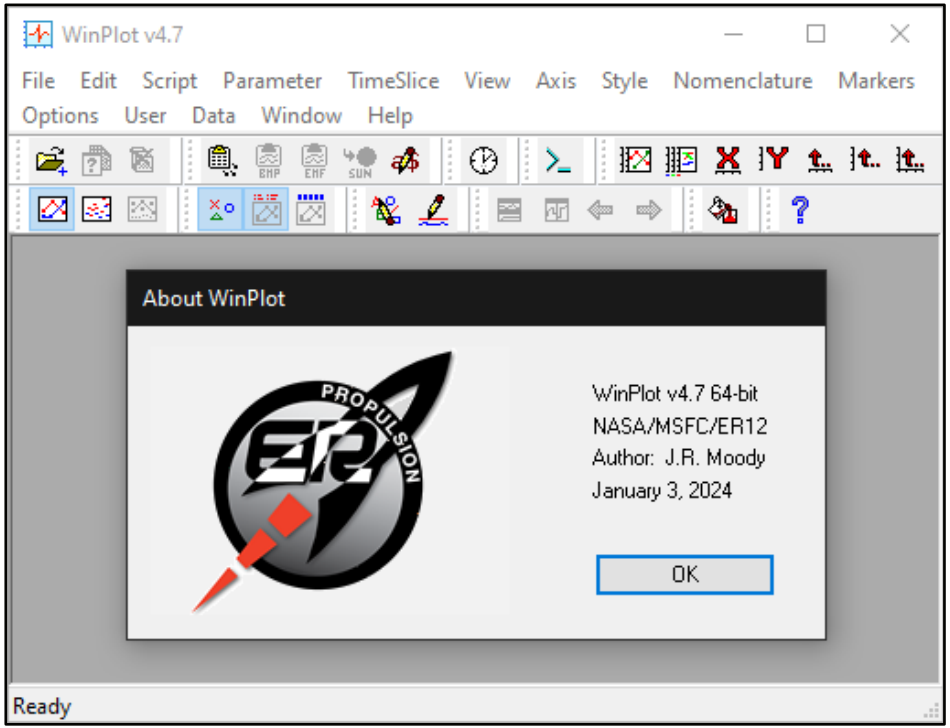
- Created in 1994 as “UCPlots”

  Developed to fulfill the need for fast and easily managed graphical displays of NASA test articles and facilities

  Generates displays of unrestrictive amounts of data seamlessly integrating real-time and post-test data from multiple sources with event-time synchronization

- Publicly available through the NASA Software Catalog

  Ref. MFS-31664-1



Data Access

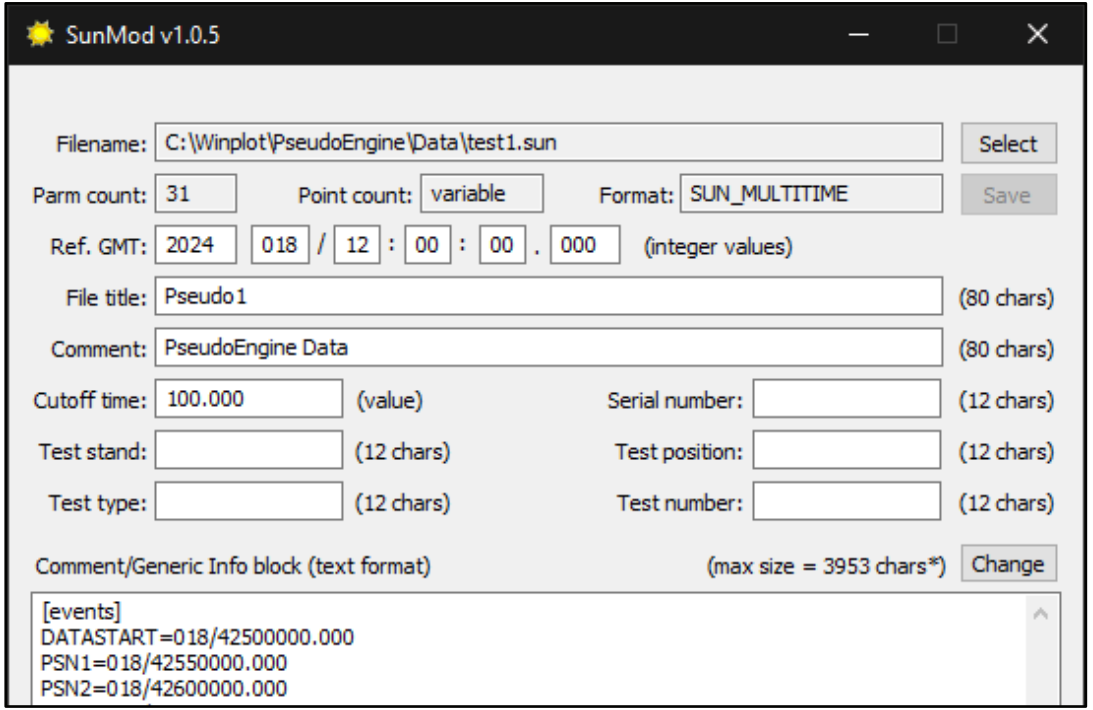
Data access capabilities are primarily judged on the speed that data can be utilized and the relevancy of that data.

WinPlot File Formats

Sun Files

- Fast retrieval
- High compression
- Multiple data acquisition systems
- Microsecond precision
- Parameter and file metadata
- Event based and absolute timing

File Format	Compressed	Sample Rate
CSV	No	Variable
Sun Common Time	Yes	Single
Sun Multi Time	Yes	Variable



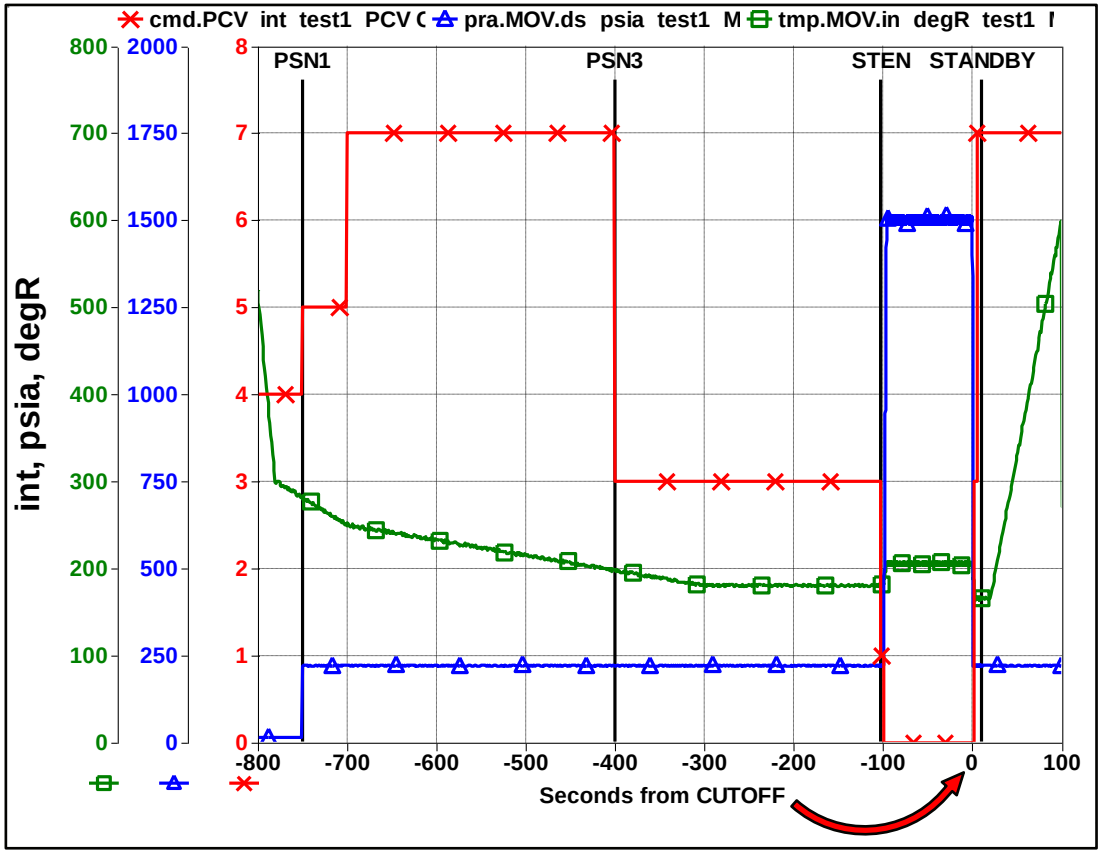
Event Based Time Alignment

Event Functions

- Synchronize files and databases
- Define timeframes
- Trigger scripts real-time

Event Definitions

- Measurement-based insertion
- ECU phase and mode
- Manual insertion



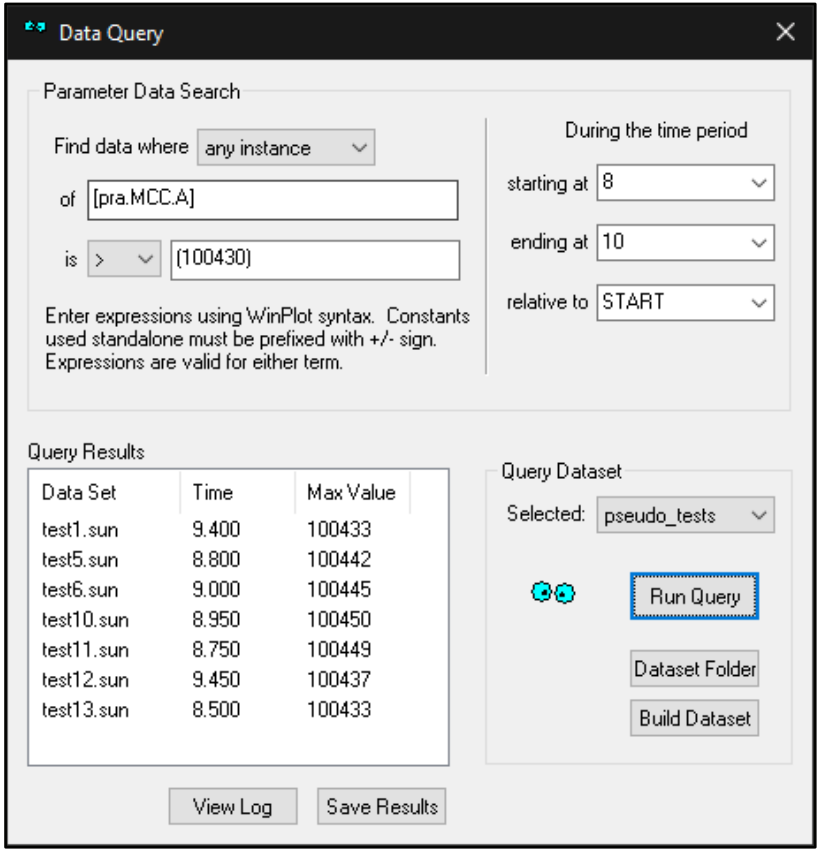
General Data Access Methods

Database Directories

- Text files referencing data files in absolute paths or predefined search paths
- Allows users to easily access multiple files from different sources and treat them as a unified database

Query

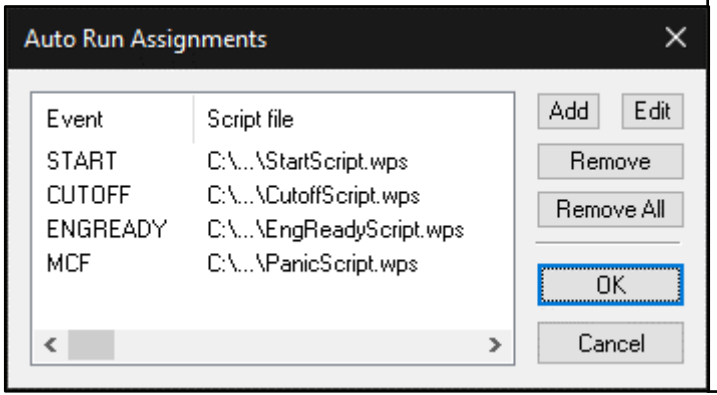
- Built-in function that returns a data subset based on binary evaluation of an expression
- Input data set size is unrestricted

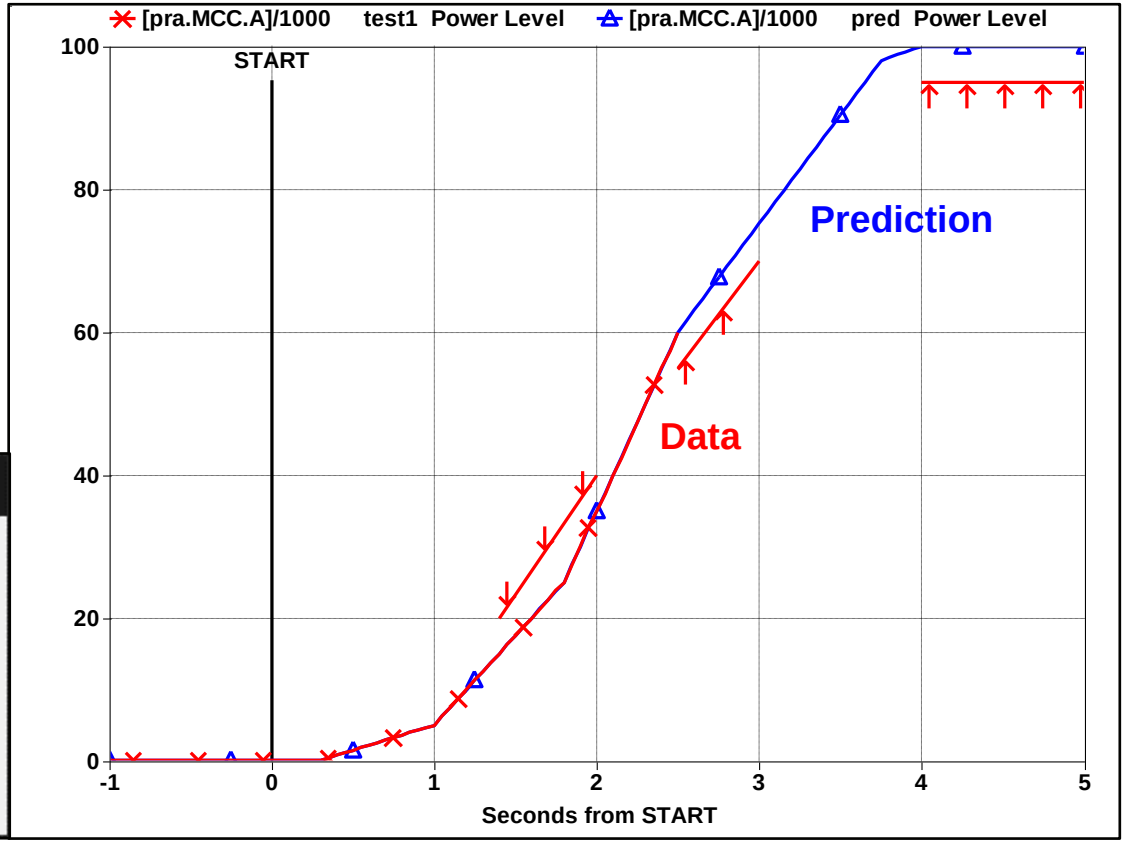


Real-Time Assessment

Real-Time WinPlot

- Auto Runs
  - Event-based script execution
- Seamless co-plotting





Data Interpretation

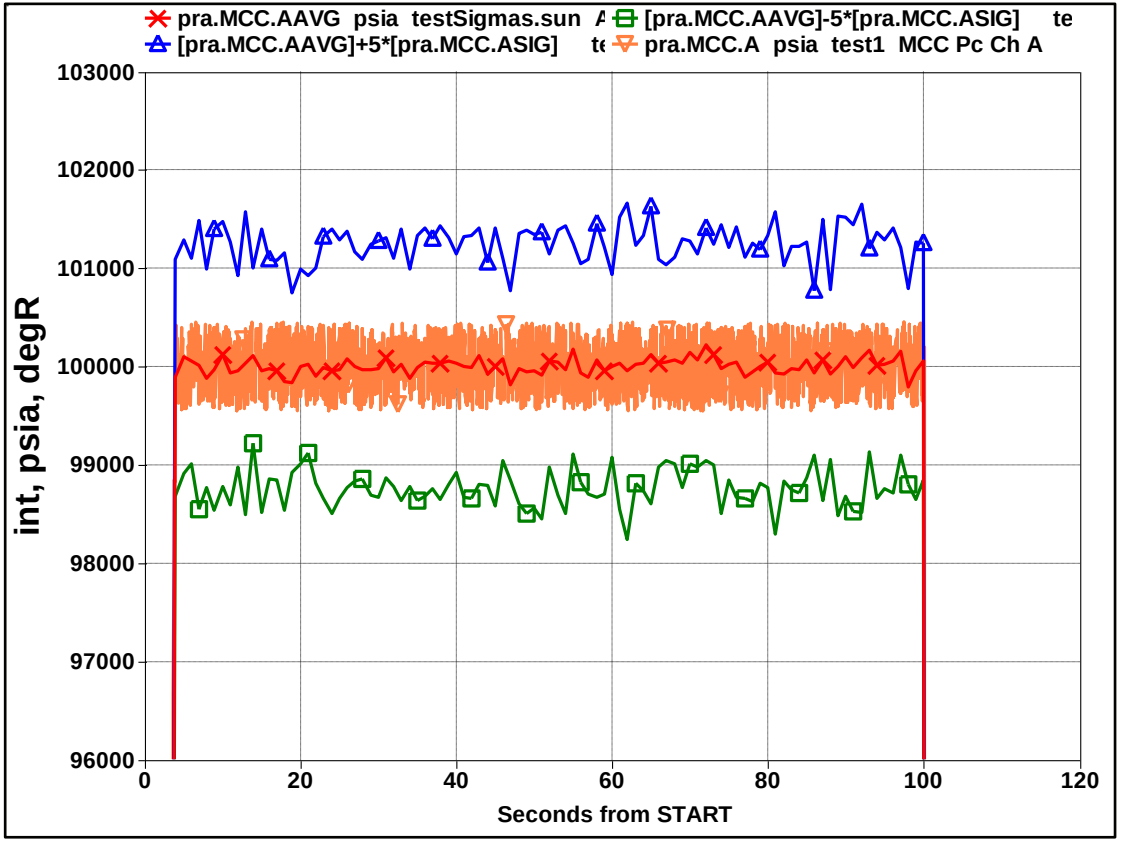
Effective interpretation happens in the context of fundamental physical laws and is built upon effective visualization.

Statistical Characterization

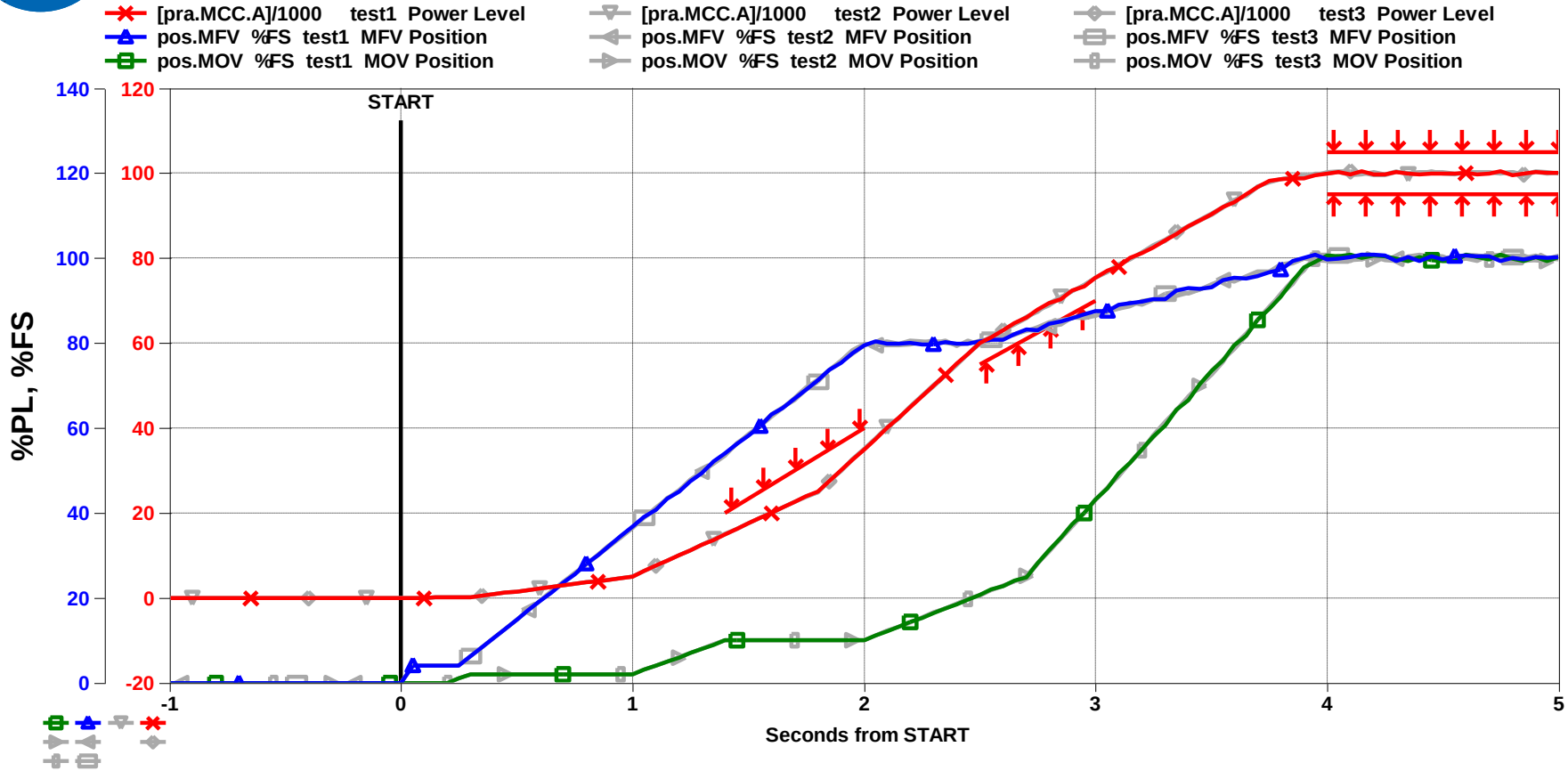
Once a sufficient population of a repeatable profile is built, historical comparisons are better made with statistical parameters than large data sets.

WinSig

Generates statistical parameters for each input parameter in a defined data set



Pseudo-Engine Start Sequence



WinPlot Scripting

Simple database loading

```
open test1
open test2
open test3
```

Time slice relative to event

Custom parameter description

Calculated parameter

```
time -100,200,START

plot [pra.MCC.A]/1000"Power Level",pos.MFV,pos.MOV
```

Add event and limit markers

```
marker 1,EVENT,0,0,0,0,GRID,START\Y0
marker 2,REDLINE,2.5,55,3,70,1,MIN\Y0
marker 3,REDLINE,1.4,20,2,40,1,MAX\Y0
marker 4,REDLINE,4,95,5,95,1,MIN\Y0
marker 5,REDLINE,4,105,5,105,1,MAX\Y0
```

Formatting options

```
legend columns 3
symbols 8
fontsize 3
linesize 3
ynomen name + units + dbname + desc
```

Axis definitions

```
fixx -1,5,1
xtitle
multiy groupby_units
fixy multi -20,120,20,0,140,20
ytitle %PL, %FS
```

Format individual traces

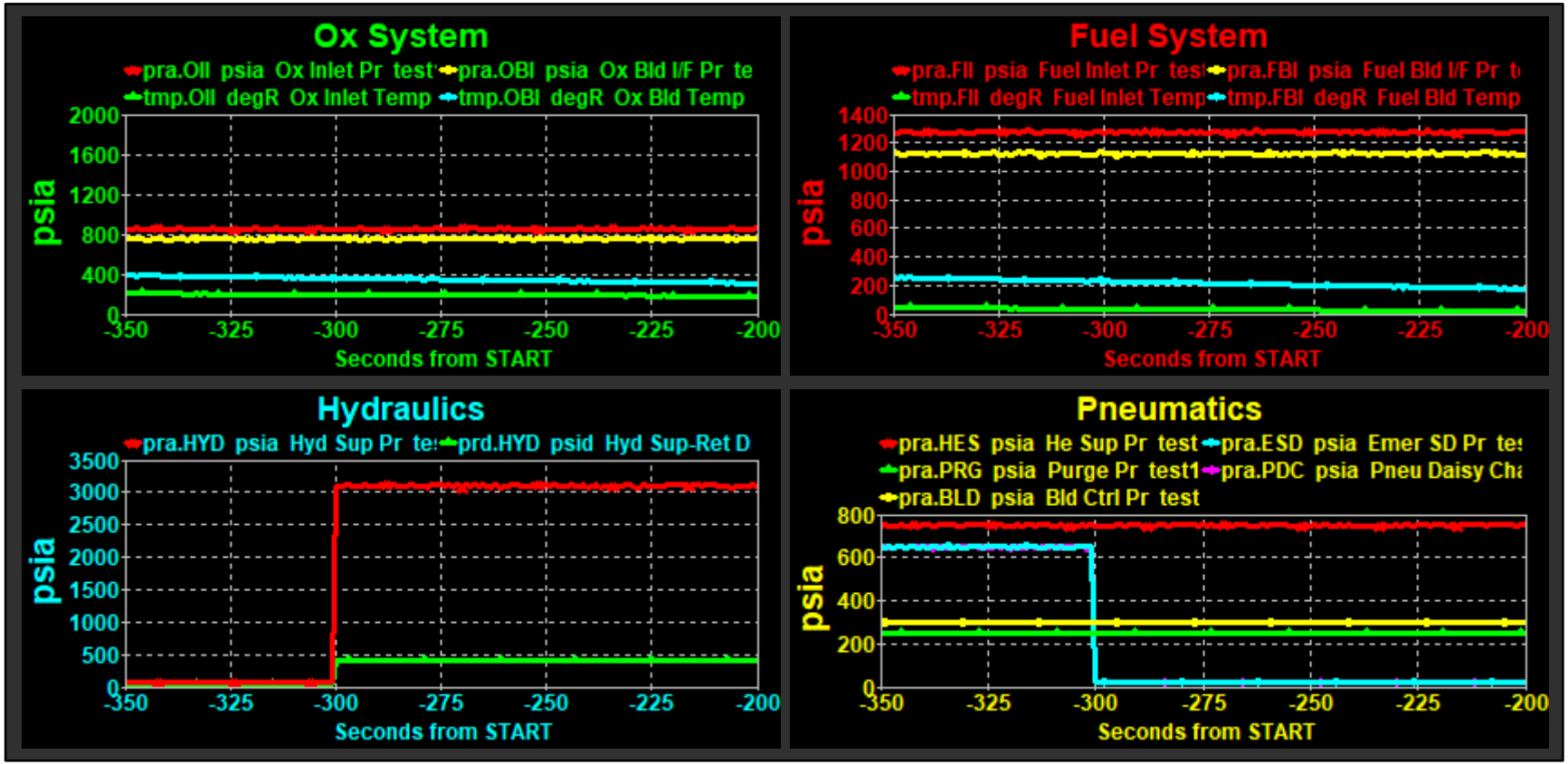
```
set color 99,169,169,169
set trace 4,COLOR_INDEX=99
set trace 5,COLOR_INDEX=99
set trace 6,COLOR_INDEX=99
set trace 7,COLOR_INDEX=99
set trace 8,COLOR_INDEX=99
set trace 9,COLOR_INDEX=99
```

Calculated Parameters

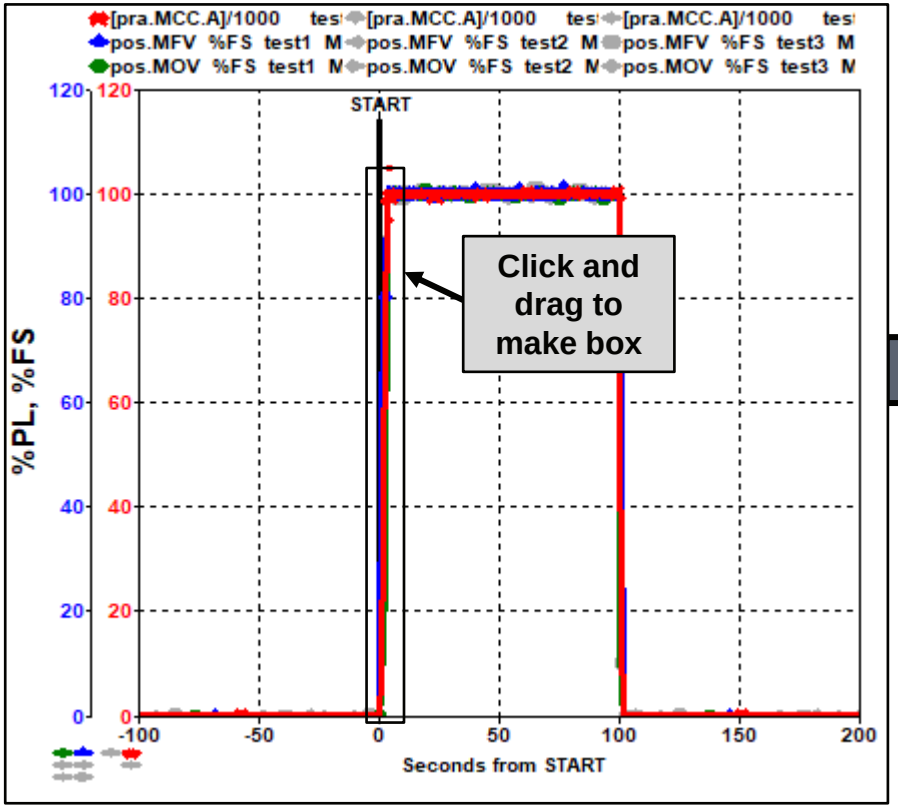
Intuitive physics-based interpretation requires both on-the-fly and scripted calculations

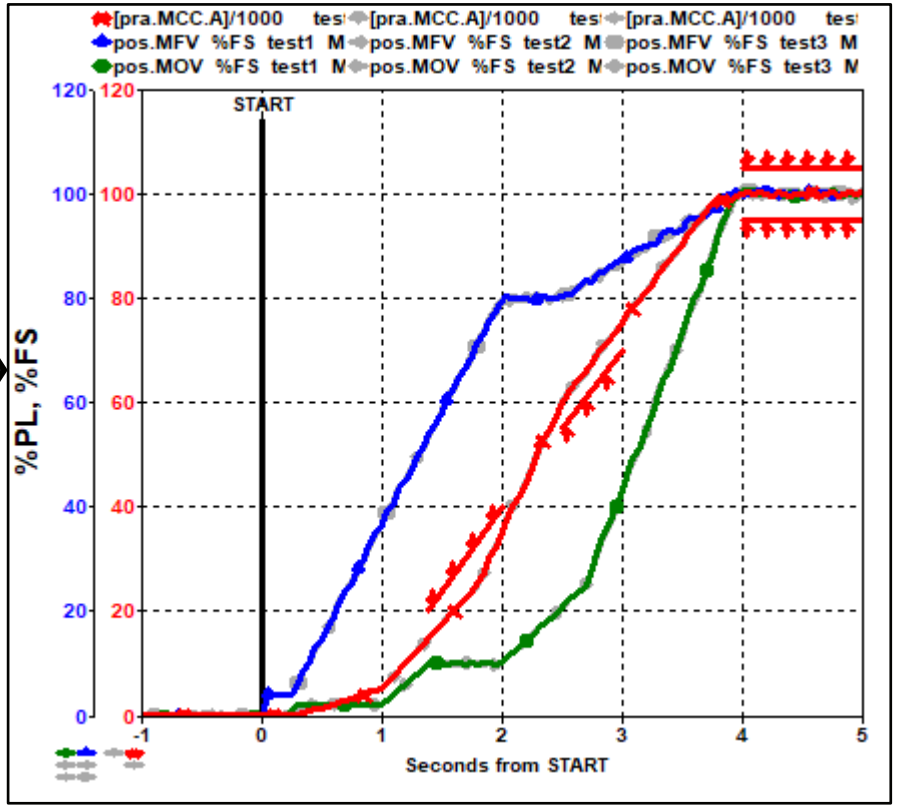
- WinPlot math expressions
  - Arithmetic operations, bit operations, Boolean logic statements
- WinPlot math functions
  - Trigonometric, logarithmic, temporal, rounding, smoothing/extrapolating, curve fitting
- External functions
  - REFPROP integration, user-defined (typically Python, MATLAB, or C programs)
- SunAcc
  - Library for working with Sun files in non-WinPlot applications
- SunCalc
  - Specify a set of calculated parameters and input data to create a new Sun file

Enhancing Readability



Active Analysis – User Interaction





Conclusion

Data Analysis Components

- Access the experience base
  - Facilitated by efficient event-based file formats and supporting tools
- Interpret test data
  - Use calculated parameters for a physics-based understanding
  - Scripting enables extensive automation and control over visualization

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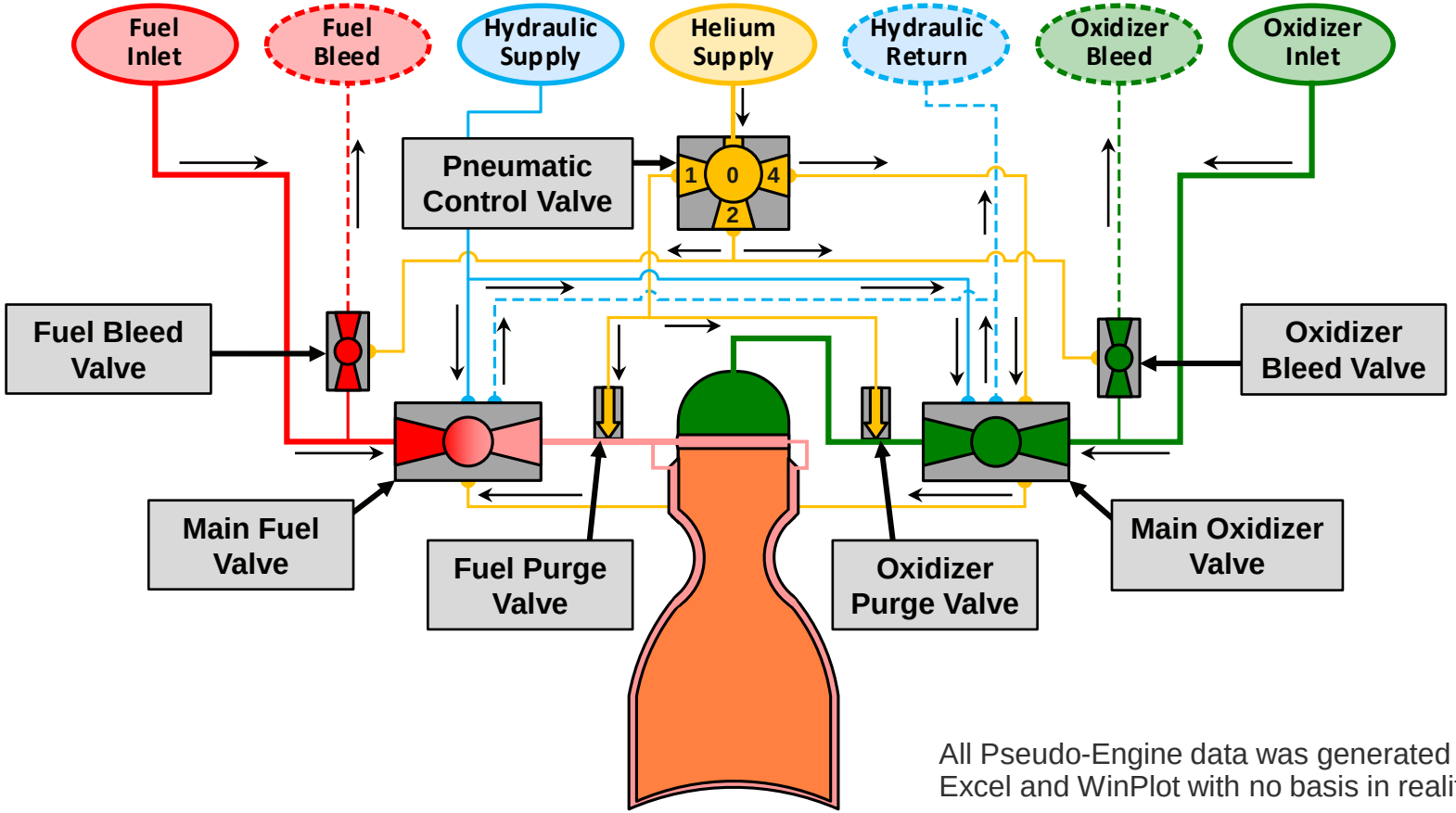
Backup

The Pseudo-Engine



All Pseudo-Engine data was generated in Excel and WinPlot with no basis in reality.