PNNL-SA-121730

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Oscillation Baselining and Analysis Tool

PAVEL ETINGOV, FRANK TUFFNER, JAMES FOLLUM, JAMES O'BRIEN
Pacific Northwest National Laboratory

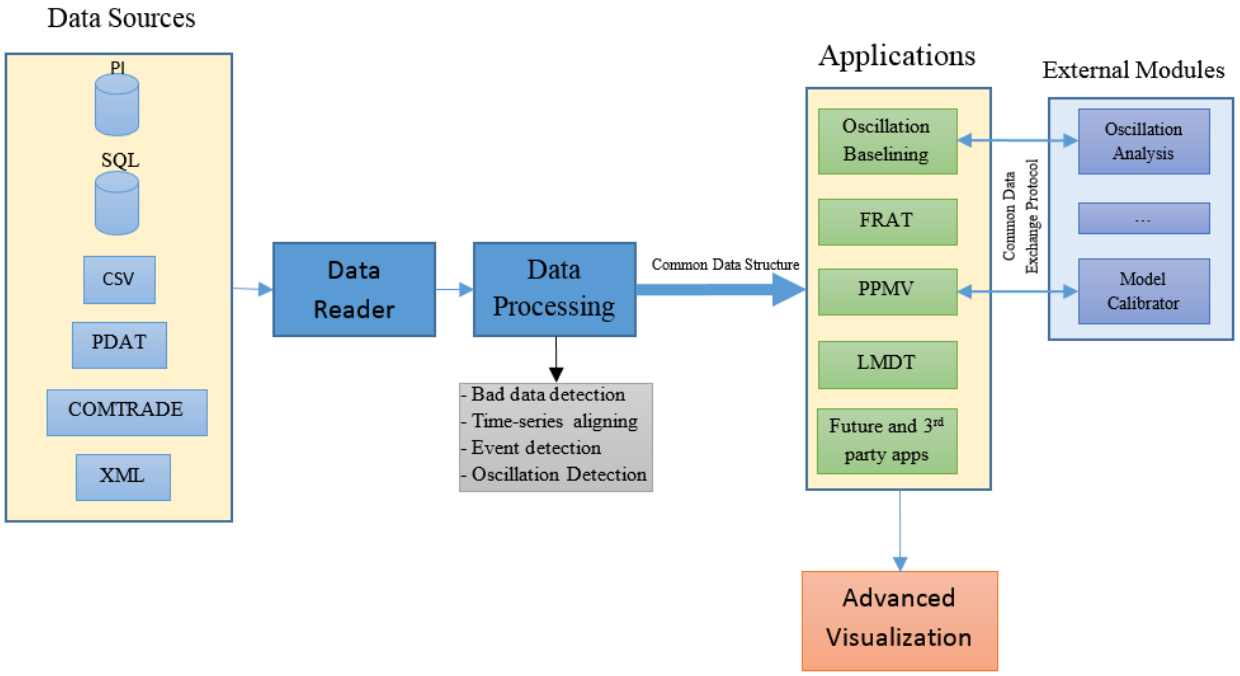
DMITRY KOSTEREV, GORDON MATTHEWS
Bonneville Power Administration

BERNIE LESIEUTRE
University of Wisconsin-Madison

NASPI Work Group Meeting, Seattle, October 19-20, 2016

Open Platform for Engineering Applications

- Development is funded by the DOE through GMLC program and by Bonneville Power Administration
- Based on Open Source Components
  - Extended WPF Toolkit™
  - OxyPlot
  - Math.NET
- Create building blocks and solutions for future and 3rd party applications
- Common data structure and data exchange protocols
- Support external modules/solvers
  - Oscillation Analysis
  - Model Calibration

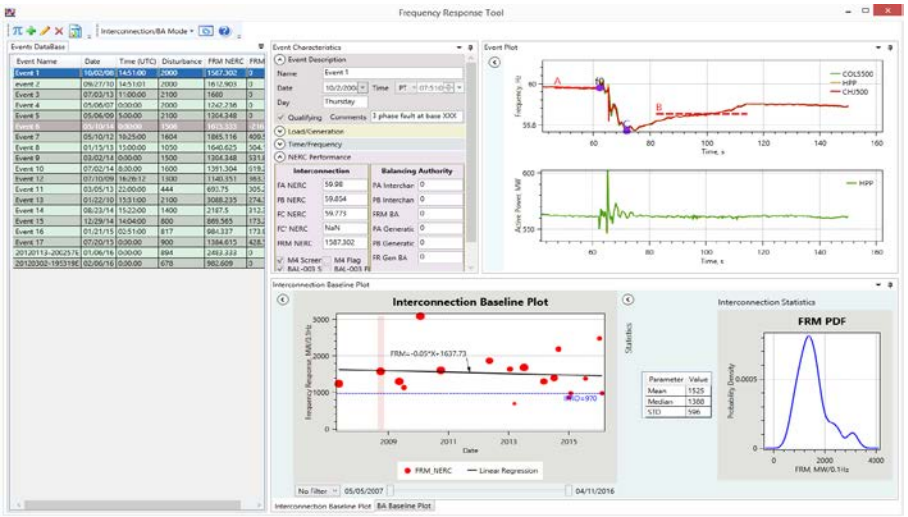


Applications based on the Open Platform for Engineering Applications

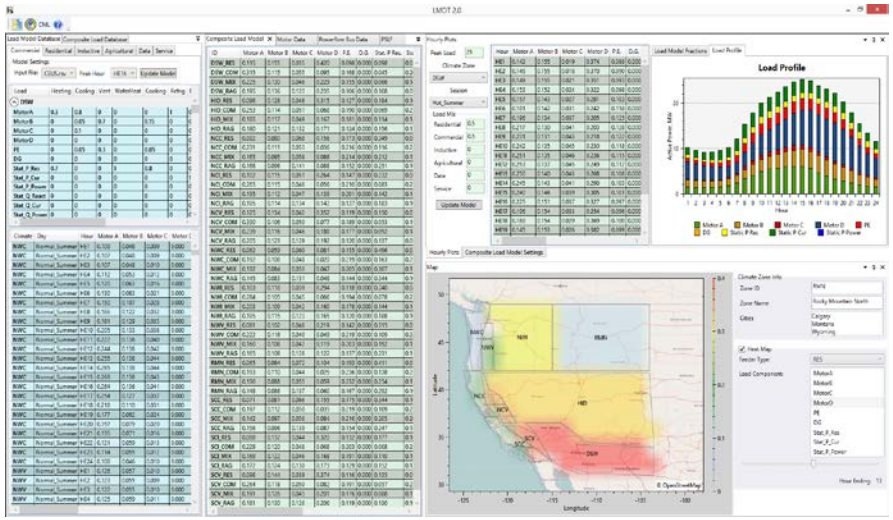
Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle Since 1965

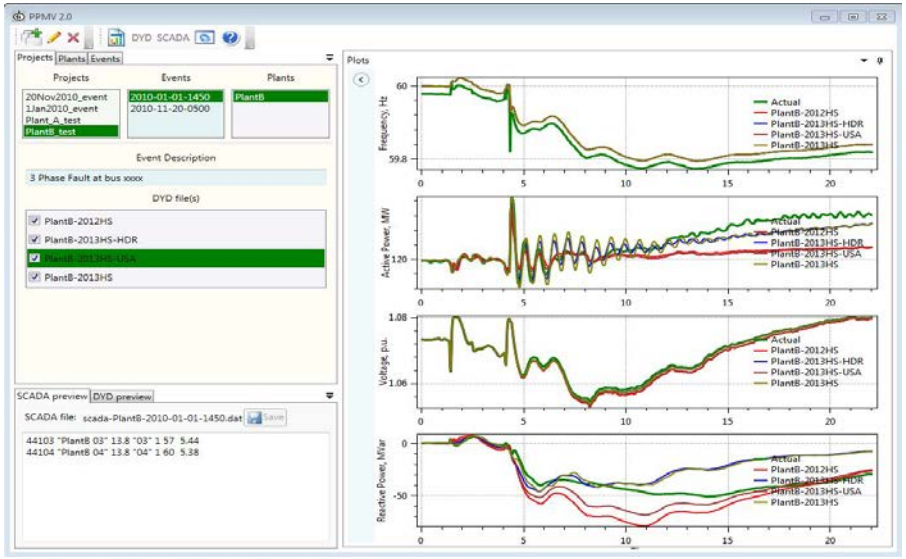
- Frequency Response Analysis Tool (FRAT 2.0)



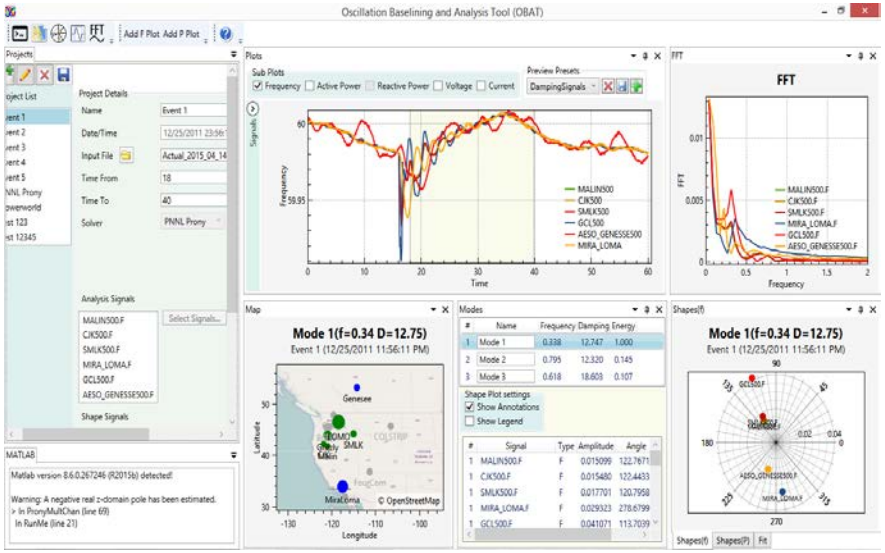
- Load model Data Tool (LMDT 2.0)



- Power Plant Model Validation Tool (PPMV 2.0)



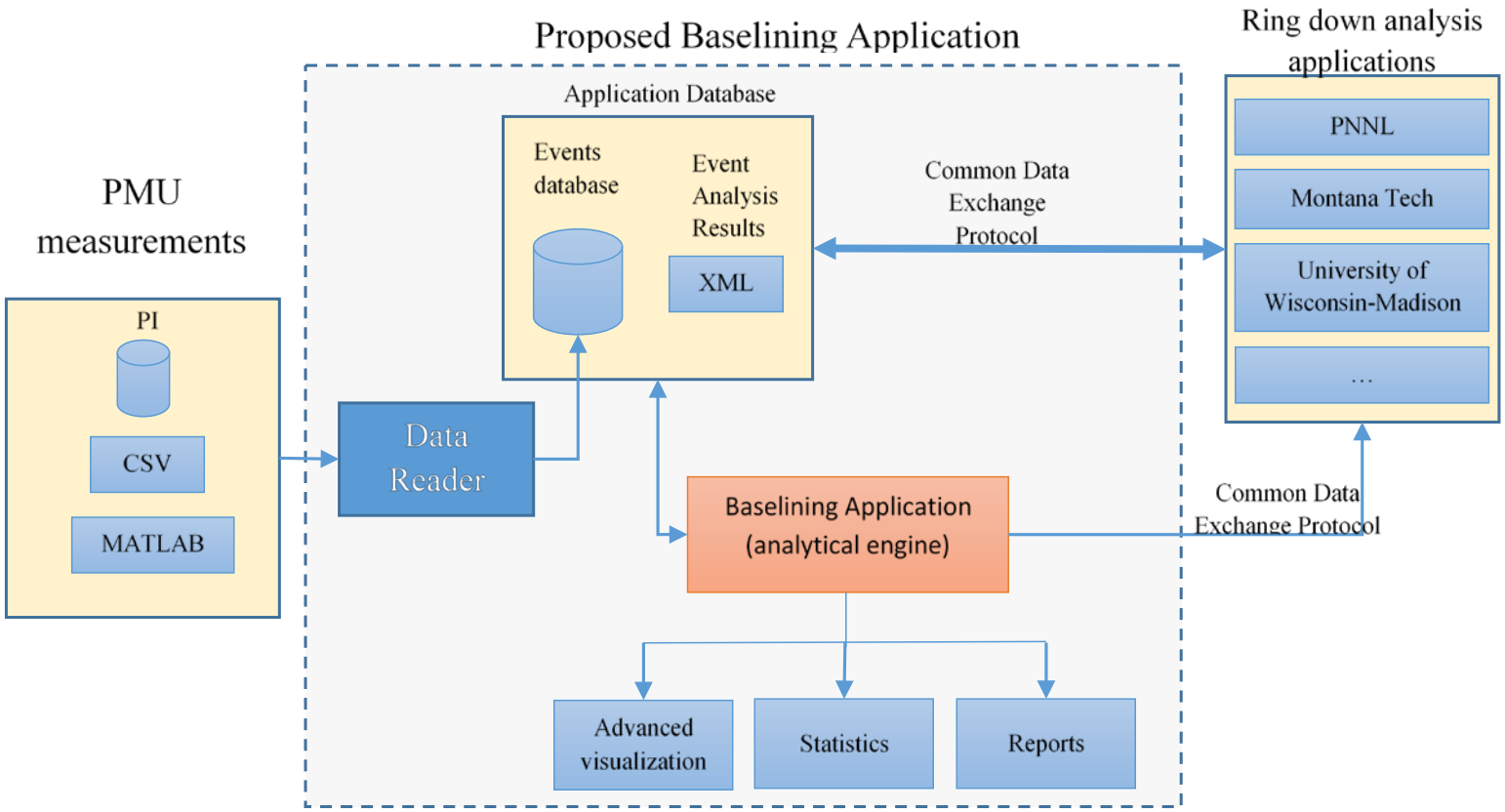
- Oscillation Baselining and Analysis Tool (OBAT)



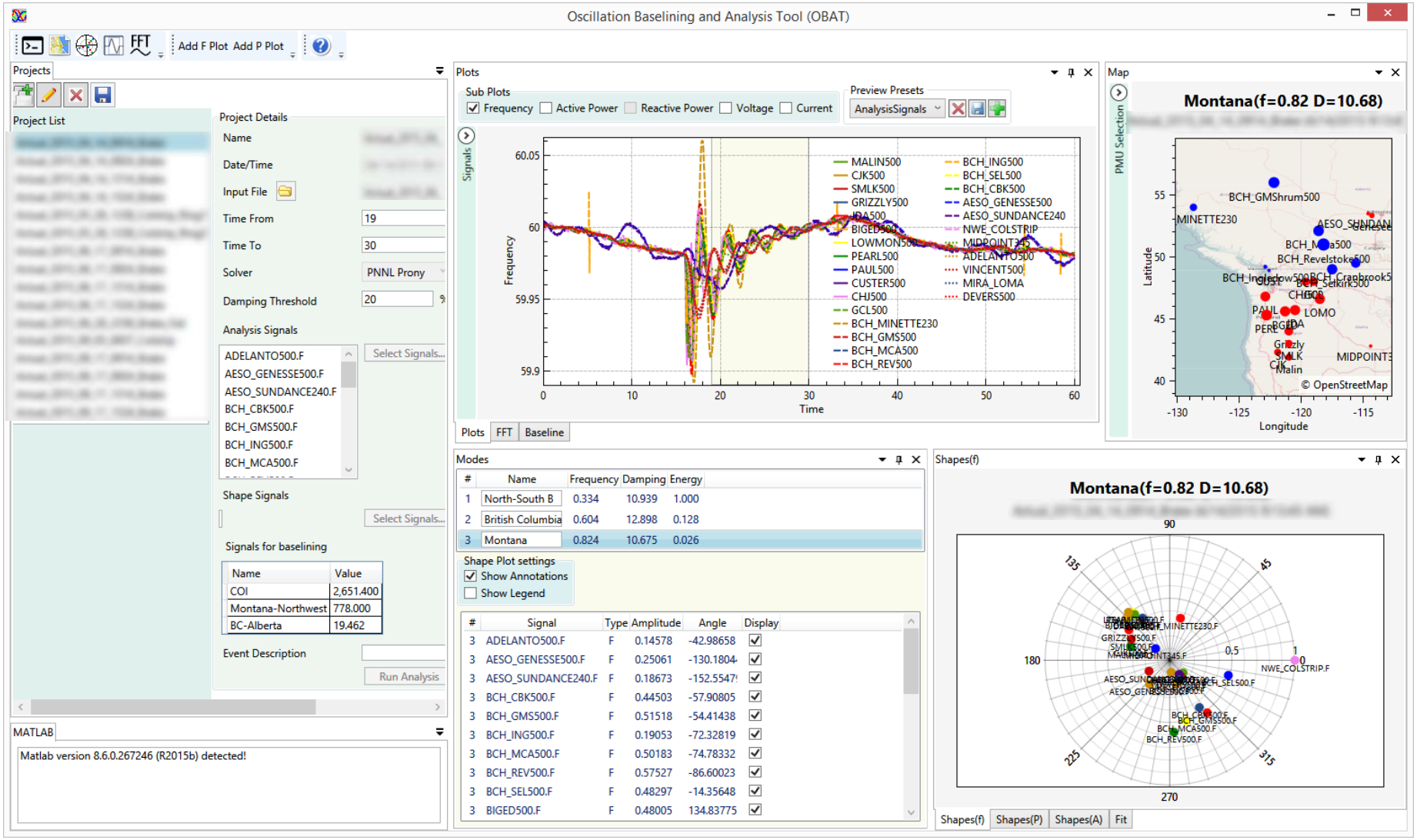
Oscillation Baselining and Analysis Tool

- Standalone Windows application
- Will be released under an open source license
- Based on the open platform for engineering application
- Interaction with external MATLAB analytical modules for oscillation analysis (e.g., VARPRO and Prony) through MATLAB COM interface
- Connectivity to different data sources
- Database of events
- Event baselining
- Advanced visualization
- Automatic reporting

OBAT Conceptual Design

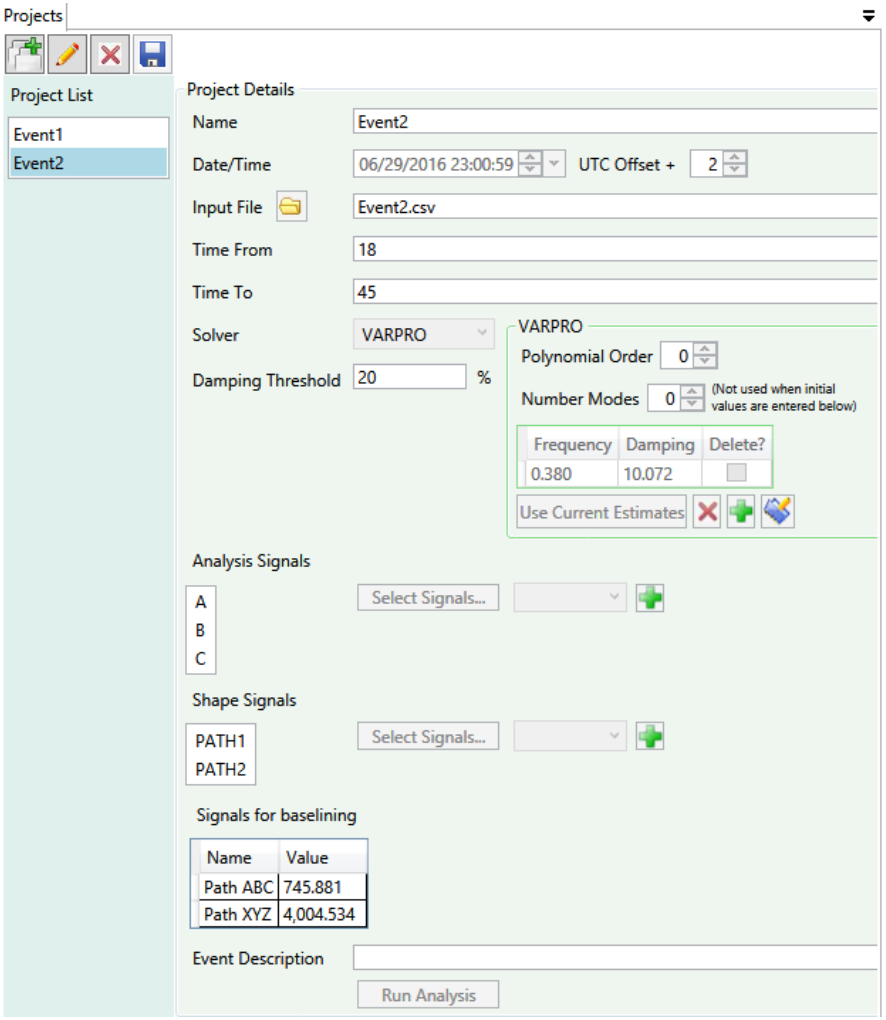


OBAT Graphical User Interface (GUI)



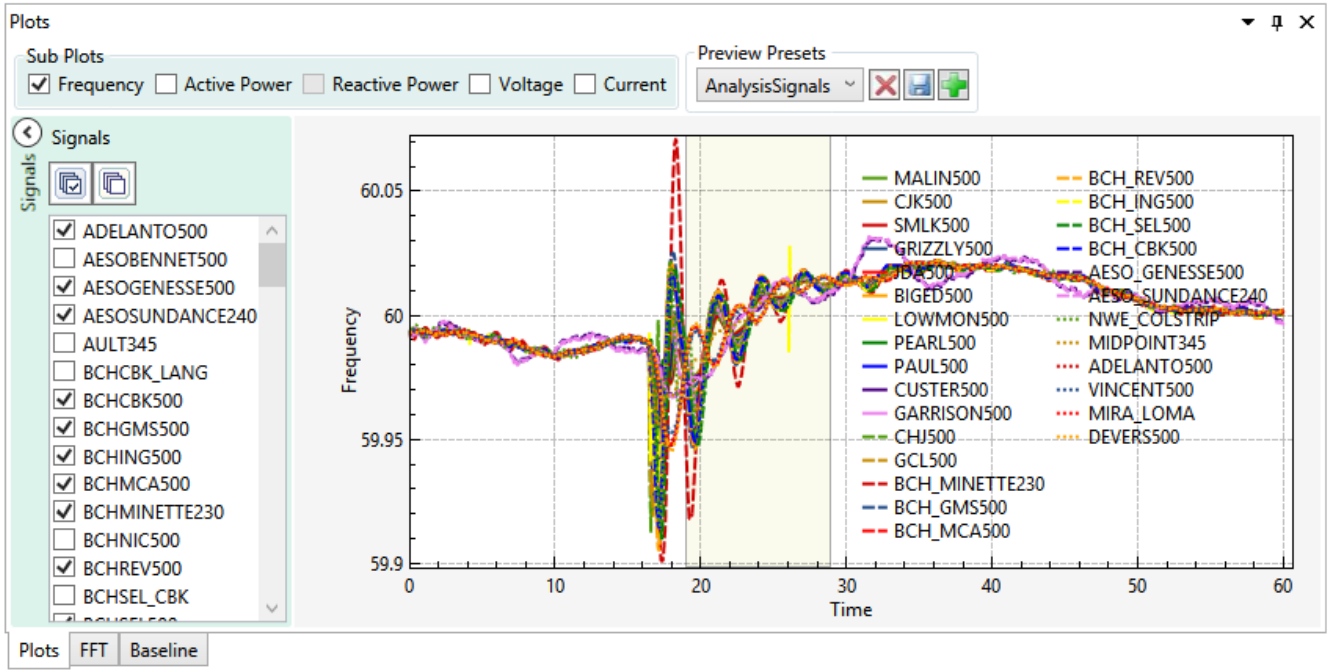
GUI – Projects panel

- List of events
- Add/modify/delete events
- Event info
- Starting/Ending time
- Oscillation Analysis Method (Solver)
- List of signals for mode analysis
- List of signals for mode shape calculation
- List of signals for baselining



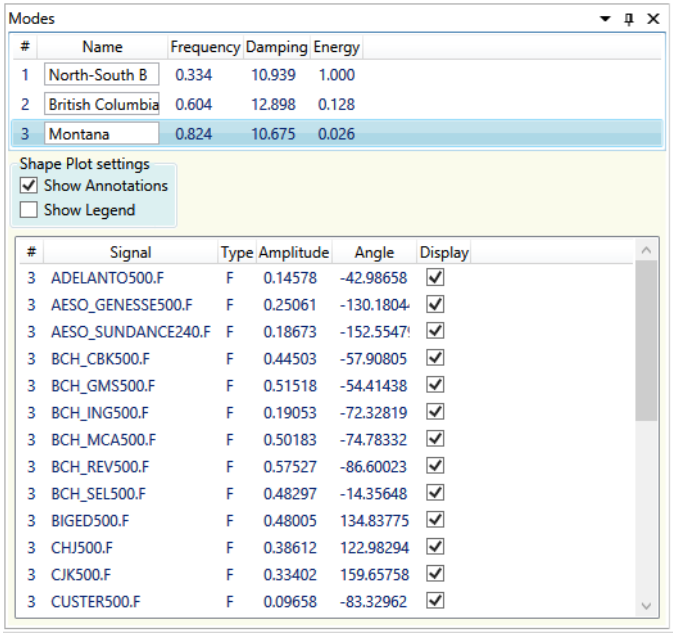
GUI – Event Preview

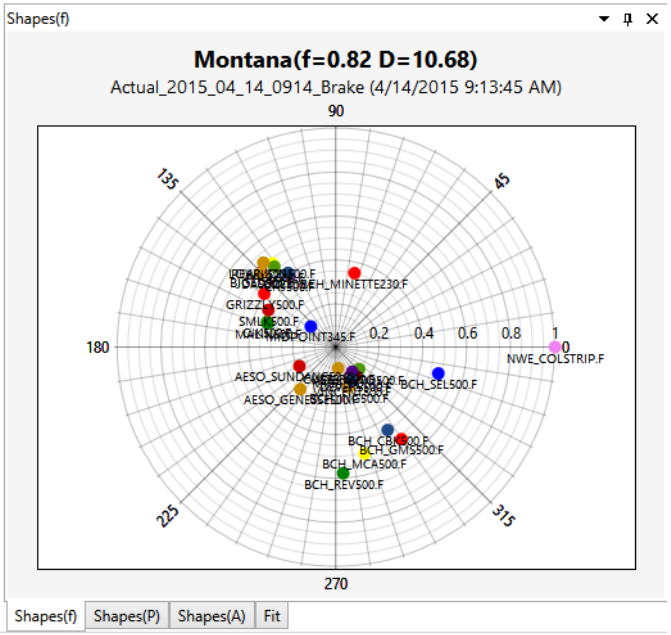
- Subplots for F,P,Q,V,I
- Configurable preview presets
- List of available signals
- Multiple subplots

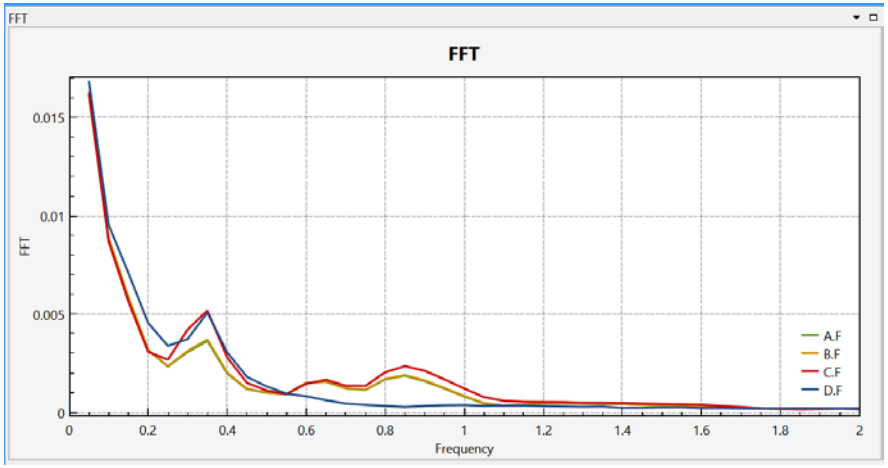


GUI – Modes & Mode Shapes

- Modes list
  - Name
  - Frequency
  - Damping
  - Energy
- Mode shapes
  - Amplitude
  - Angle
- FFT analysis

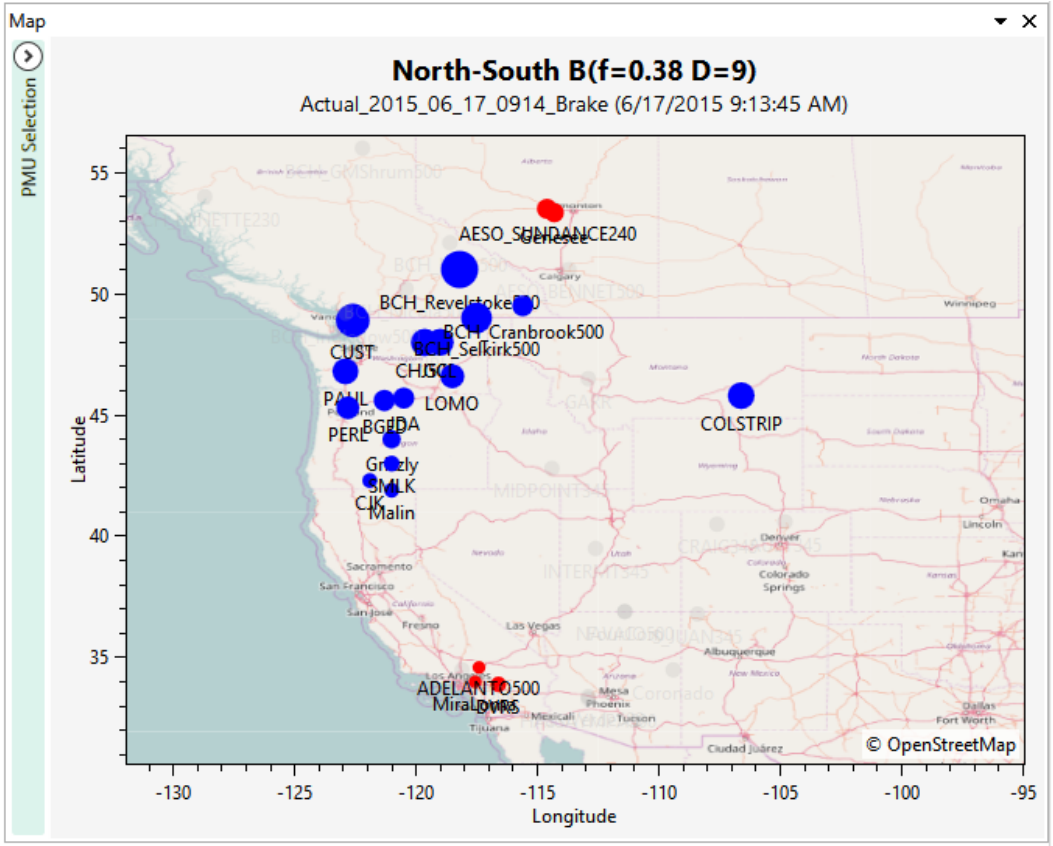






GUI – Map

- Display information for user selected mode
- PMU location
- Size of circles is proportional to mode shape magnitude
- Color depends on mode shape phase



Oscillation event description

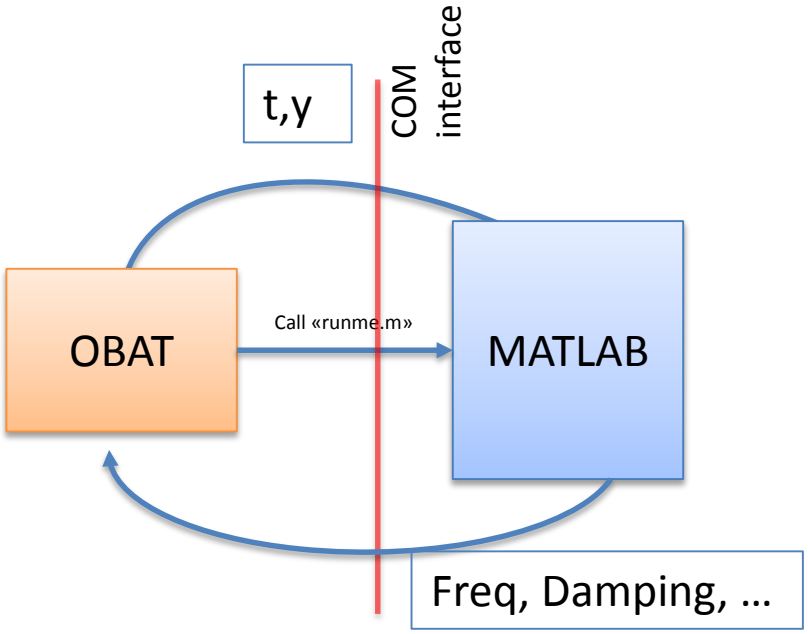
- Based on XML
- Parameters list can be extended
- Simplifies oscillation event information exchange between different organizations

- Will include the following information:
  - Event basic information (name, time, input file name, etc.)
  - List of signals used for analysis
  - Modes(name, frequency, damping, mode shapes, etc.)

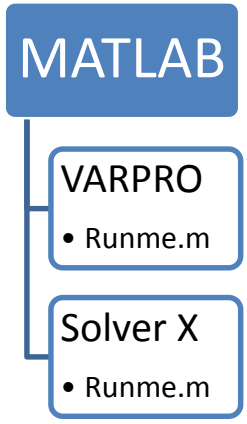
```
- <Event Name="Event2">
    <Tstart>5</Tstart>
    <Tend>45</Tend>
    <InputFile>Event2.csv</InputFile>
    <Solver>VARPRO</Solver>
  - <Signals>
      <Signal>A</Signal>
      <Signal>B</Signal>
      <Signal>C</Signal>
    </Signals>
  - <Modes>
    - <Mode>
        <ID>1</ID>
        <Name>Mode 1</Name>
        <Frequency>0.37802</Frequency>
        <Damping>1.03616</Damping>
      - <ModeShapes>
        - <Signal Name="A">
            <Amplitude>0.00389</Amplitude>
            <Angle>66.38118</Angle>
          </Signal>
        - <Signal Name="B">
            <Amplitude>0.00391</Amplitude>
            <Angle>66.41947</Angle>
          </Signal>
        - <Signal Name="C">
            <Amplitude>0.00419</Amplitude>
            <Angle>67.69662</Angle>
          </Signal>
        </ModeShapes>
      </Mode>
    - <Mode>
        <ID>2</ID>
        <Name>Mode 2</Name>
        <Frequency>0.06316</Frequency>
        <Damping>3.0263</Damping>
      - <ModeShapes>
        - <Signal Name="A">
            <Amplitude>0.01537</Amplitude>
            <Angle>199.65433</Angle>
          </Signal>
        - <Signal Name="B">
            <Amplitude>0.01537</Amplitude>
            <Angle>199.6545</Angle>
          </Signal>
        - <Signal Name="C">
            <Amplitude>0.01531</Amplitude>
            <Angle>199.61553</Angle>
          </Signal>
        </ModeShapes>
      </Mode>
    </Modes>
</Event>
```

Integration with MATLAB

- Define naming convention for input/output parameters
- Input parameters:
  - t- Time (vector)
  - y – measurement values (matrix)
- Output parameters:
  - Freq – frequency values (vector)
  - Damping – damping values (vector)
  - A – mode shape amplitude values (matrix)
  - theta – mode shape phase values (matrix)



Folders structure



[Freq,Damping,A, theta] = callVarpro (t, y)

[Freq,Damping,A, theta] = callSolverX (t, y)

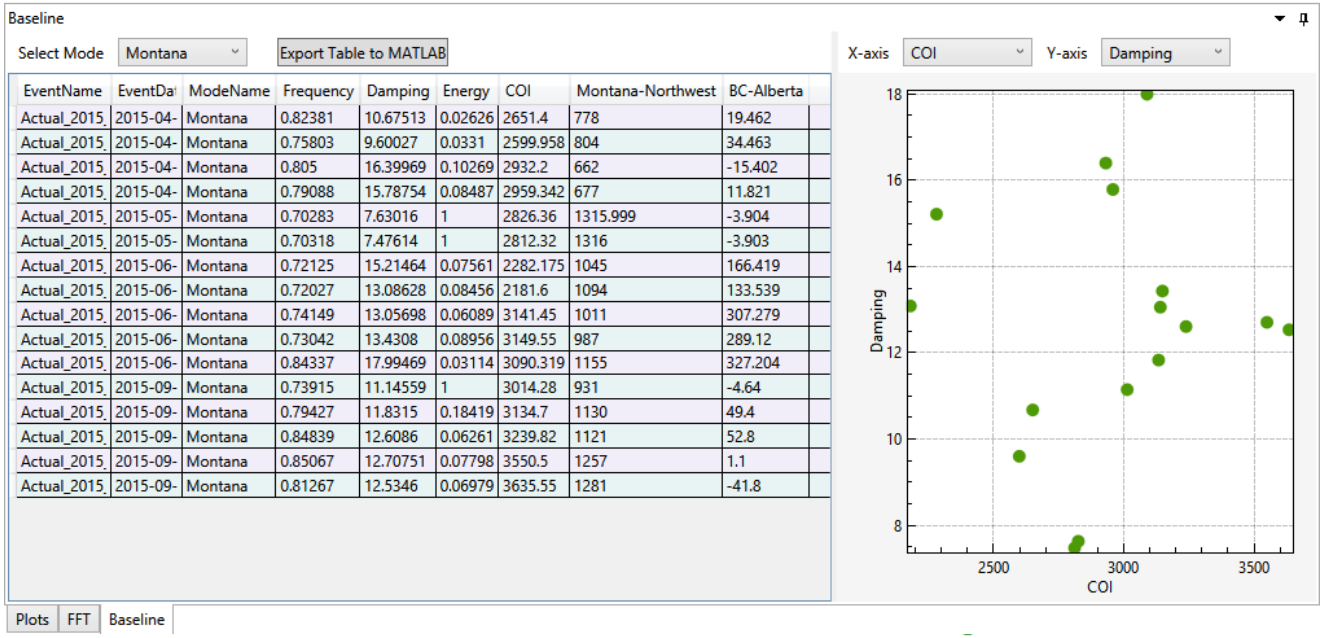
Mode identification

- Configurable presets for automatic mode identification
  - Mode shape based on a set of signals
  - Frequency range

```
<Mode Name="Montana">
  <fmin>0.65</fmin>
  <fmax>0.85</fmax>
  <Cluster1>
    <SetA>
      <PMU>NWE_COLSTRIP</PMU>
      <PMU>GARRISON500</PMU>
    </SetA>
    <SetB></SetB>
  </Cluster1>
  <Cluster2>
    <SetA>
      <PMU>CHJ500</PMU>
      <PMU>GCL500</PMU>
      <PMU>JDA500</PMU>
      <PMU>BIGED500</PMU>
    </SetA>
    <SetB></SetB>
  </Cluster2>
</Mode>
```

Oscillation Baselining

- Configurable set of signals used for baselining
- Select events in the database with particular mode
- Export results to MATLAB for analysis
- Plot oscillation characteristics vs. system operating conditions

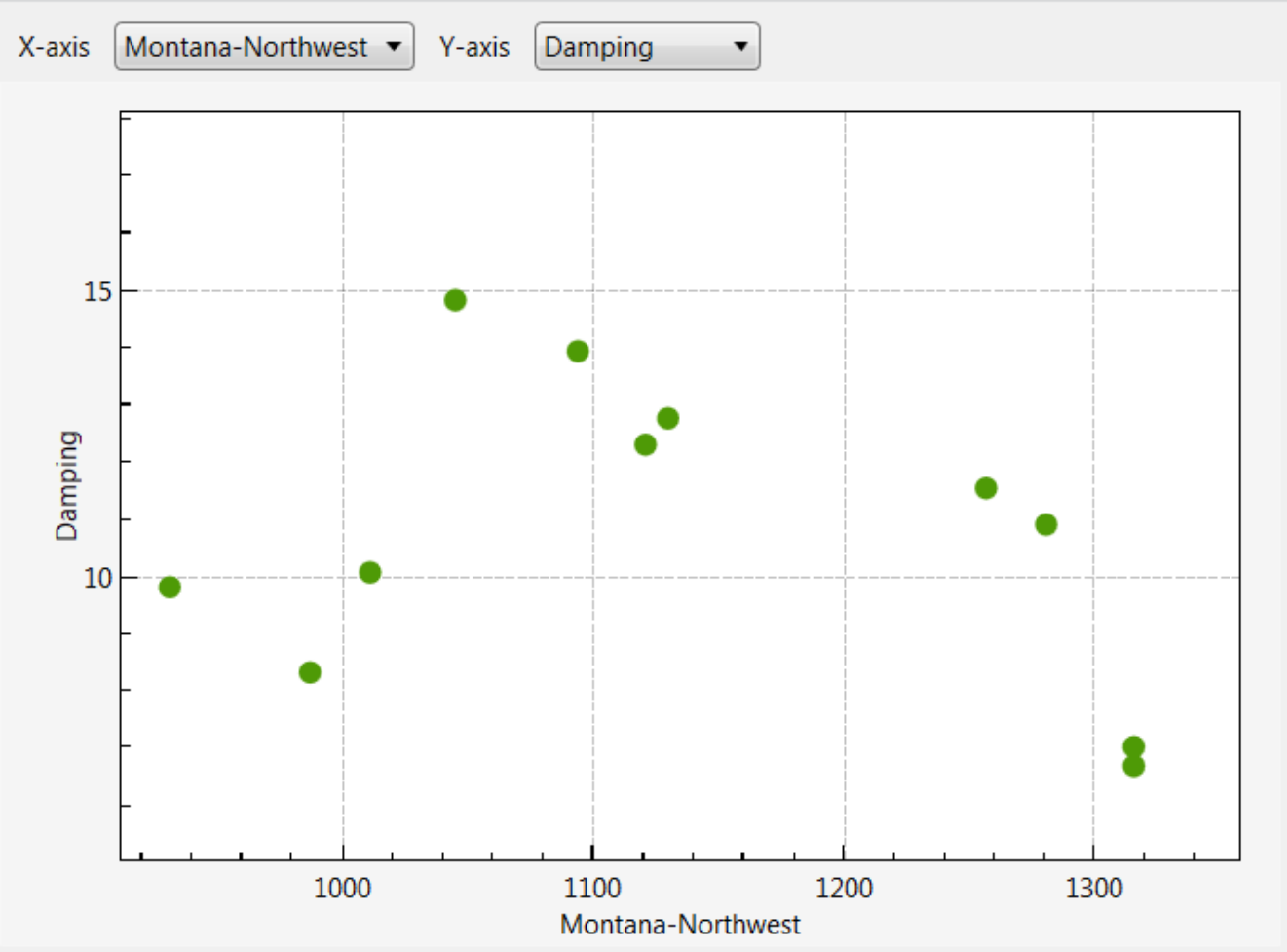


EventName	EventDat	ModeName	Frequency	Damping	Energy	COI	Montana-Northwest	BC-Alberta
Actual_2015_	2015-04-	Montana	0.82381	10.67513	0.02626	2651.4	778	19.462
Actual_2015_	2015-04-	Montana	0.75803	9.60027	0.0331	2599.958	804	34.463
Actual_2015_	2015-04-	Montana	0.805	16.39969	0.10269	2932.2	662	-15.402
Actual_2015_	2015-04-	Montana	0.79088	15.78754	0.08487	2959.342	677	11.821
Actual_2015_	2015-05-	Montana	0.70283	7.63016	1	2826.36	1315.999	-3.904
Actual_2015_	2015-05-	Montana	0.70318	7.47614	1	2812.32	1316	-3.903
Actual_2015_	2015-06-	Montana	0.72125	15.21464	0.07561	2282.175	1045	166.419
Actual_2015_	2015-06-	Montana	0.72027	13.08628	0.08456	2181.6	1094	133.539
Actual_2015_	2015-06-	Montana	0.74149	13.05698	0.06089	3141.45	1011	307.279
Actual_2015_	2015-06-	Montana	0.73042	13.4308	0.08956	3149.55	987	289.12
Actual_2015_	2015-06-	Montana	0.84337	17.99469	0.03114	3090.319	1155	327.204
Actual_2015_	2015-09-	Montana	0.73915	11.14559	1	3014.28	931	-4.64
Actual_2015_	2015-09-	Montana	0.79427	11.8315	0.18419	3134.7	1130	49.4
Actual_2015_	2015-09-	Montana	0.84839	12.6086	0.06261	3239.82	1121	52.8
Actual_2015_	2015-09-	Montana	0.85067	12.70751	0.07798	3550.5	1257	1.1
Actual_2015_	2015-09-	Montana	0.81267	12.5346	0.06979	3635.55	1281	-41.8

```
<Baseline>
    <Parameter Name="COI">
        <Signal>PATH.COI</Signal>
    </Parameter>
    <Parameter Name="Montana-Northwest">
        <Signal>PATH.MT-NW</Signal>
    </Parameter>
     <Parameter Name="BC-Alberta">
        <Signal>PATH.BC-ALB</Signal>
    </Parameter>
</Baseline>
```

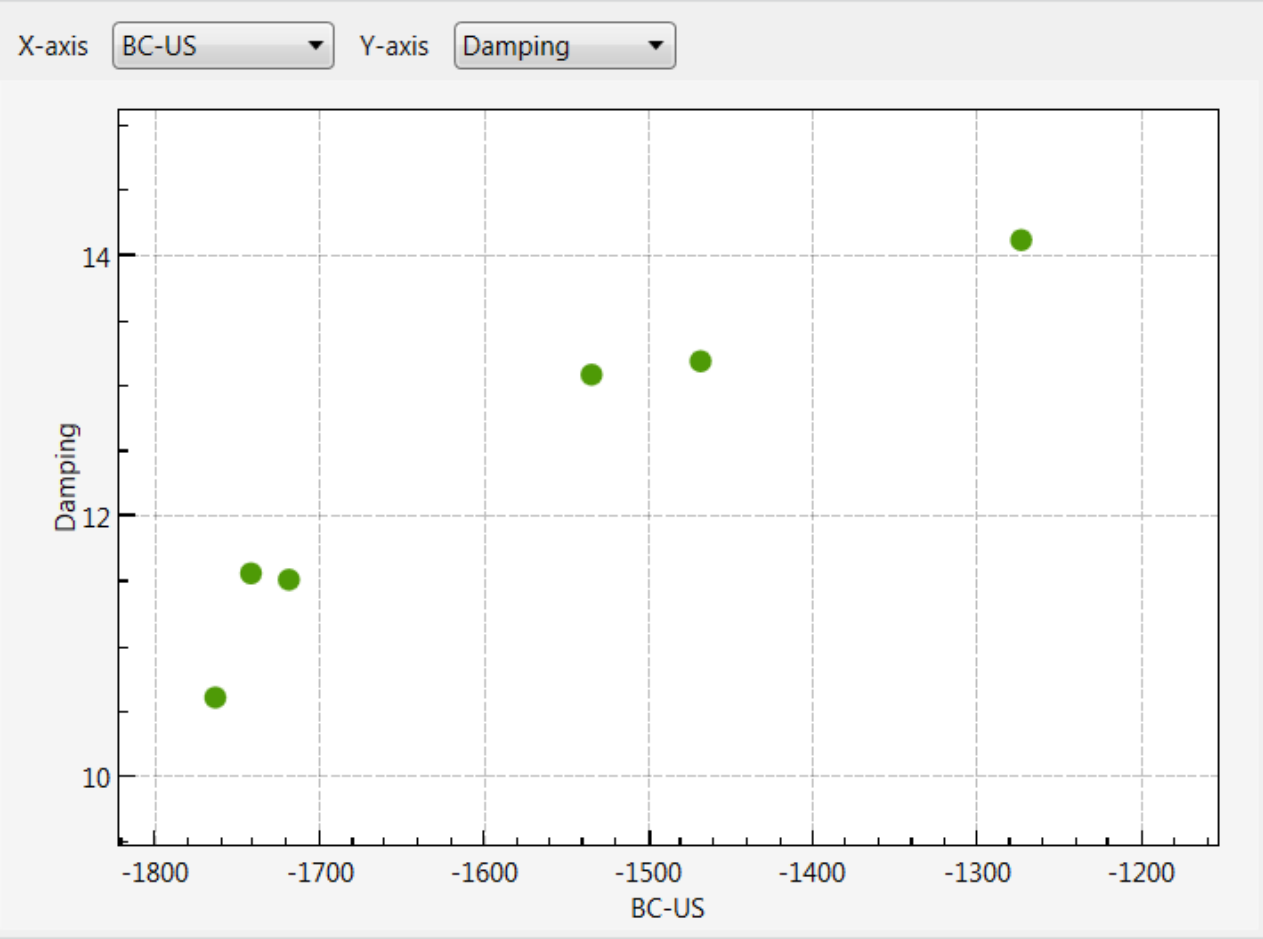
Baselining Results

- Montana mode



Baselining Results

- British Columbia mode



Contact Information

- https://svn.pnl.gov/OBAT
  - pavel.etingov@pnnl.gov
  - francis.tuffner@pnnl.gov
  - james.follum@pnnl.gov