Vibroacoustic Launch Analysis using VISPERS: Overview and Demonstration

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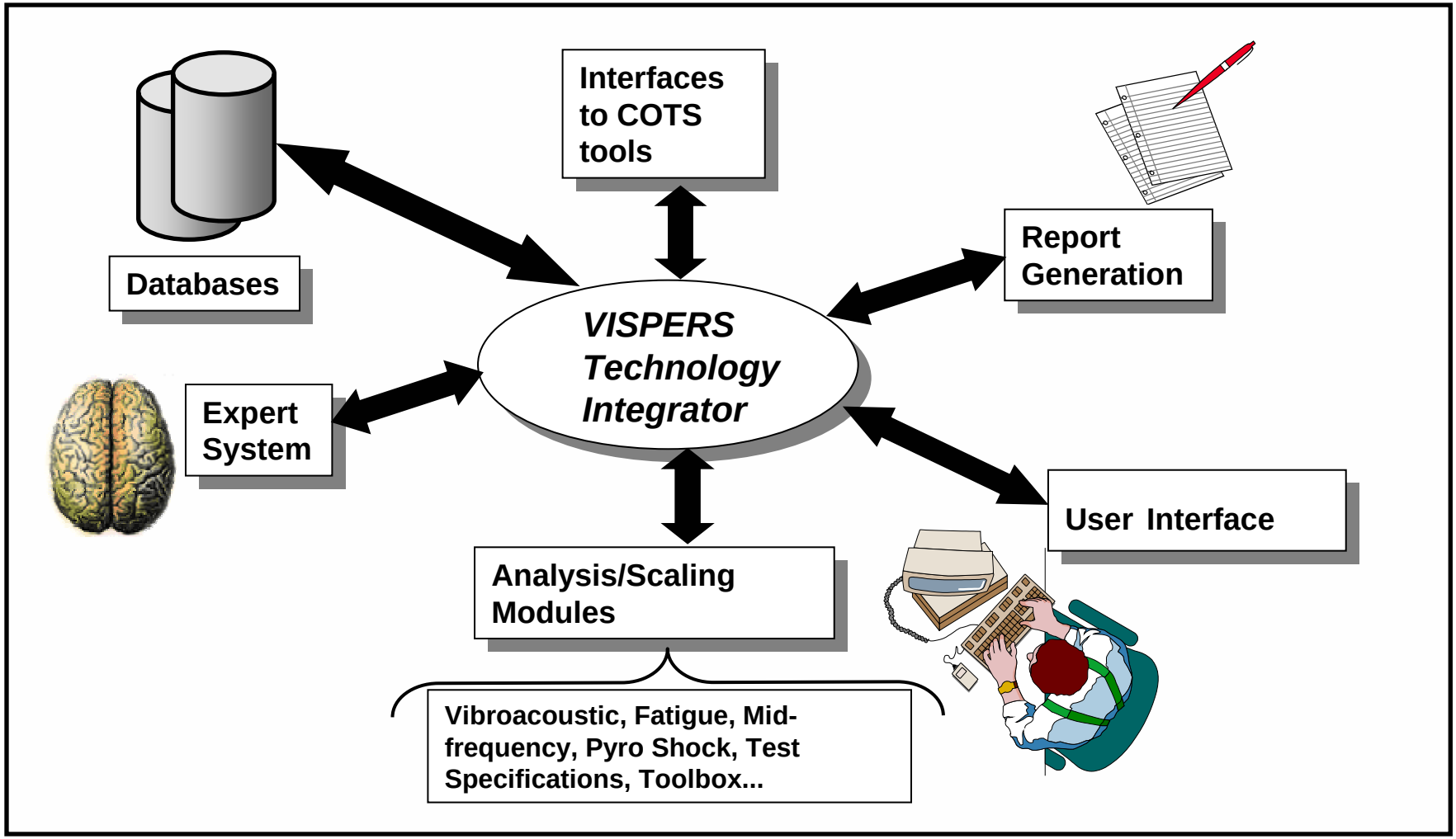
VISPERS Overview



Motivation for VISPERS

- **Reduce the cost of developing vibroacoustic specifications for space systems and components**
- **Reduce the need for component requalification and vibration isolation**
- **Captures the knowledge and wisdom of experts in vibroacoustics and shock**
- **Captures invaluable spacecraft and launch vehicle test and flight data from heritage programs**

VISPERS Uses

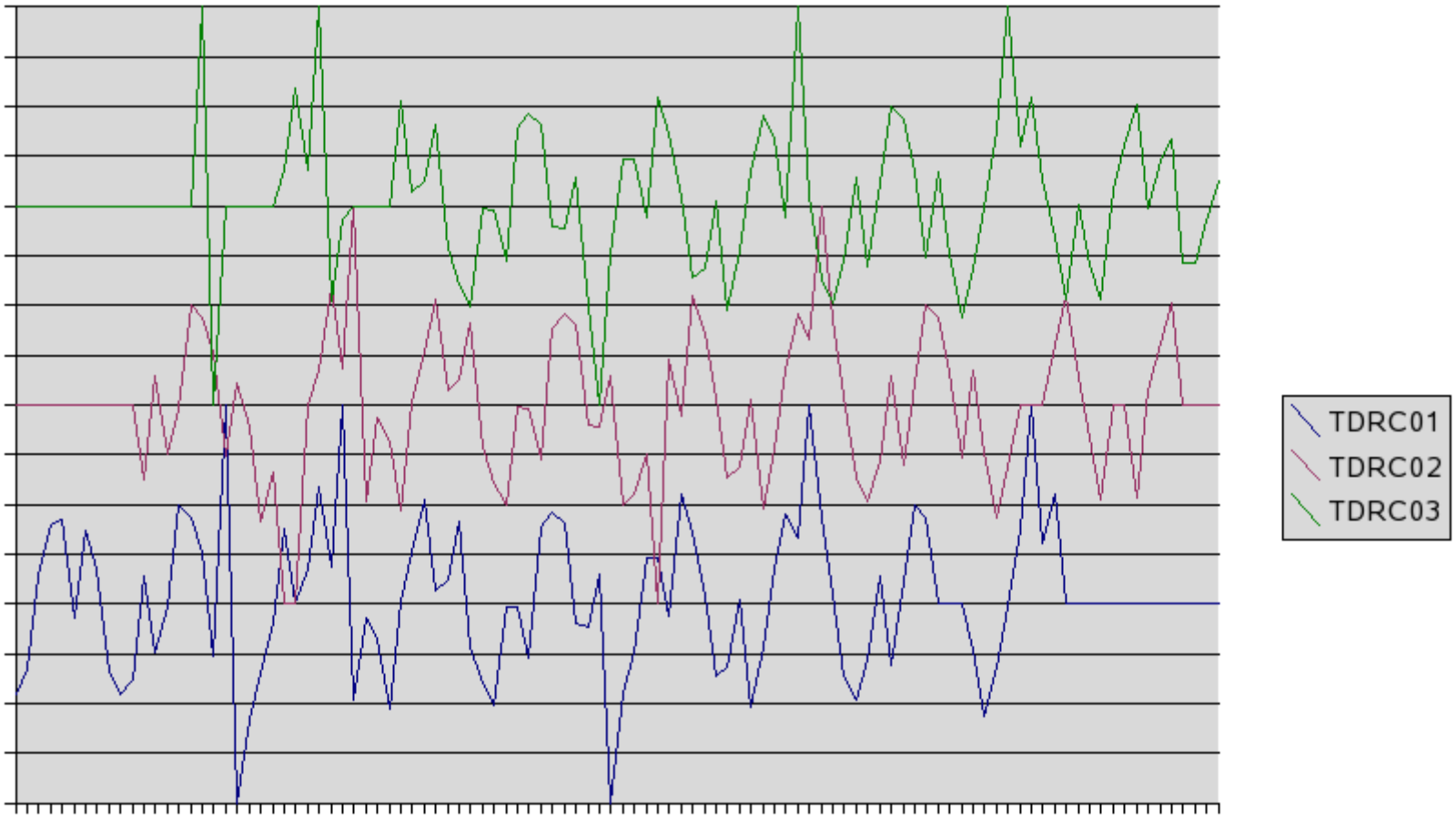
- **Design Stage**
  - External and internal acoustic & vibration predictions
  - Test specification development
- **Flight Verification**
  - Qualification test history and heritage flight data stored in database
- **Post-Flight Data Analysis**
  - Batch tool reduces time required for flight data processing
  - Can easily compare previous flight data from the VISPERS database to new flight data
  - Damage Based Analysis can be used for risk assessment
- **Validation**
  - Archived flight data can be used to test and validate new analytical tools and models

Telemetry Clean-Up
VAIL and TACT
Lead: Jorge Seidel

Telemetry Requires Clean-Up

- **It's a fact: Telemetry data received from spacecraft will have anomalies.**
  - Data drop-out, Spikes, Saturation, DC-drift, etc.
- **Before the data can be processed, the anomalies must be removed.**
- **VISPERS provides two tools to help the analyst clean-up the waveforms:**
  - TACT: alignment and consolidation of common telemetry streams from multiple sources (TDRC)
  - VAIL: A neural-net based anomaly detection and identification tool.

TACT – misaligned, anomalies



TACT

- **Data from multiple files may not be aligned with respect to a common clock**
  - Distance: one mile of range is 6 microseconds offset
  - Clocks: one clock providing the IRIG timestamp may have an offset from another (timestamp applied at TDRC)
  - Clocks: the clock on the spacecraft may drift (timestamp applied at spacecraft).
  - Time-Step: 5000 samples-per-second may not be exactly 5000.0000+ samples-per-second

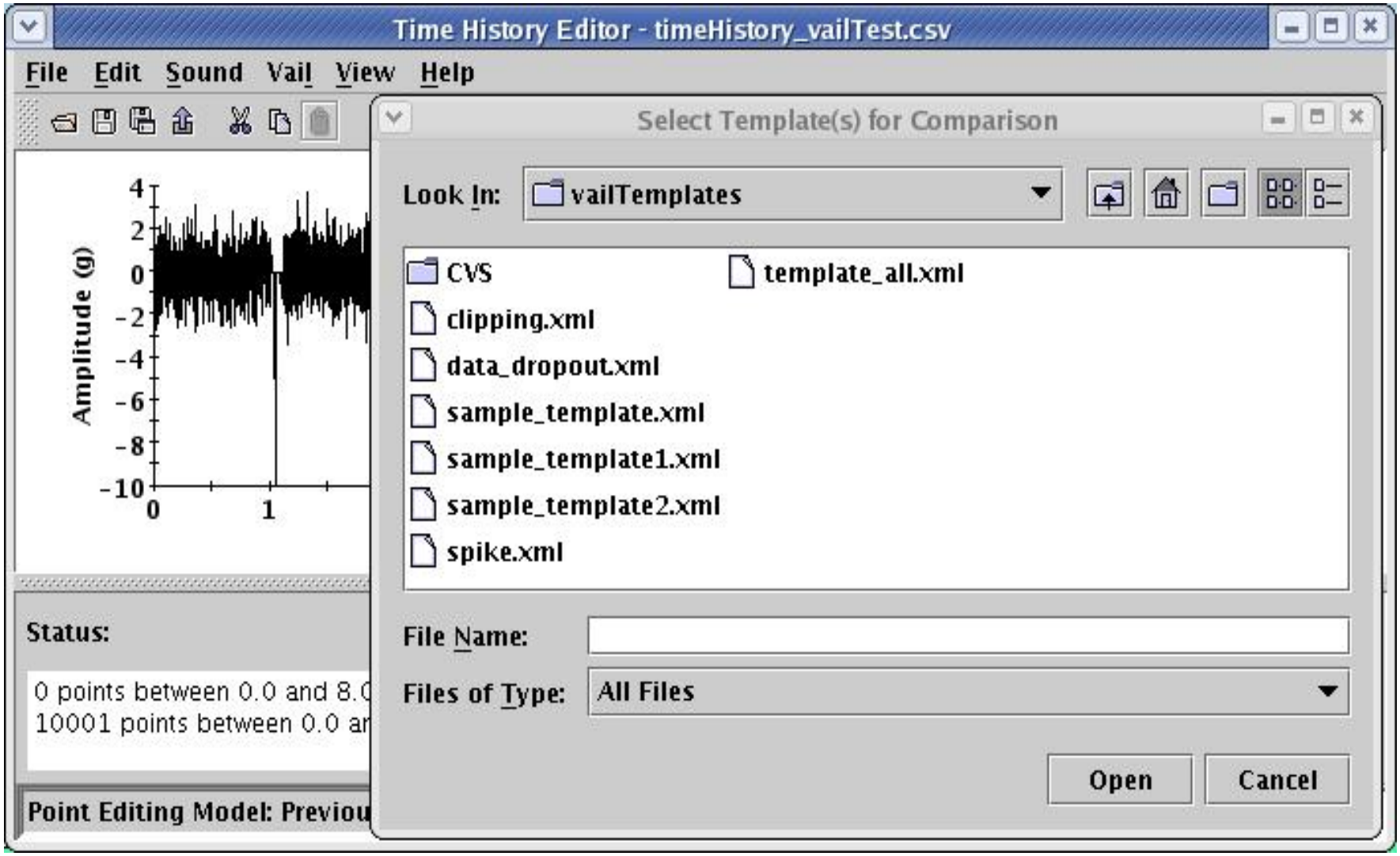
TACT

- **Tact attempts to align two waveforms:**
  - Only look at areas of overlap in data time stamps – time-codes are "close", within ± 1 second
  - Break the overlap into smaller pieces for processing
  - Method 1: Slide one wave past the other to find the minimum sum-of-absolute-differences
  - Method 2: Using several filtering techniques, find common points and determine the "best match"
  - Method 3: Allow the analyst to specify a point on each waveform, then fine tune with methods 1 and 2

VAIL

- **GOAL: Using AI techniques, identify specific anomalous points and suggest corrective actions to the user.**
- **METHOD: Simulates a Neural Net where an anomalous point is recognized and highlighted.**
- **gVail – a grid version of Vail that can be run on clusters (Fellowship) or heterogeneous computing grids (like SETI at Home)**

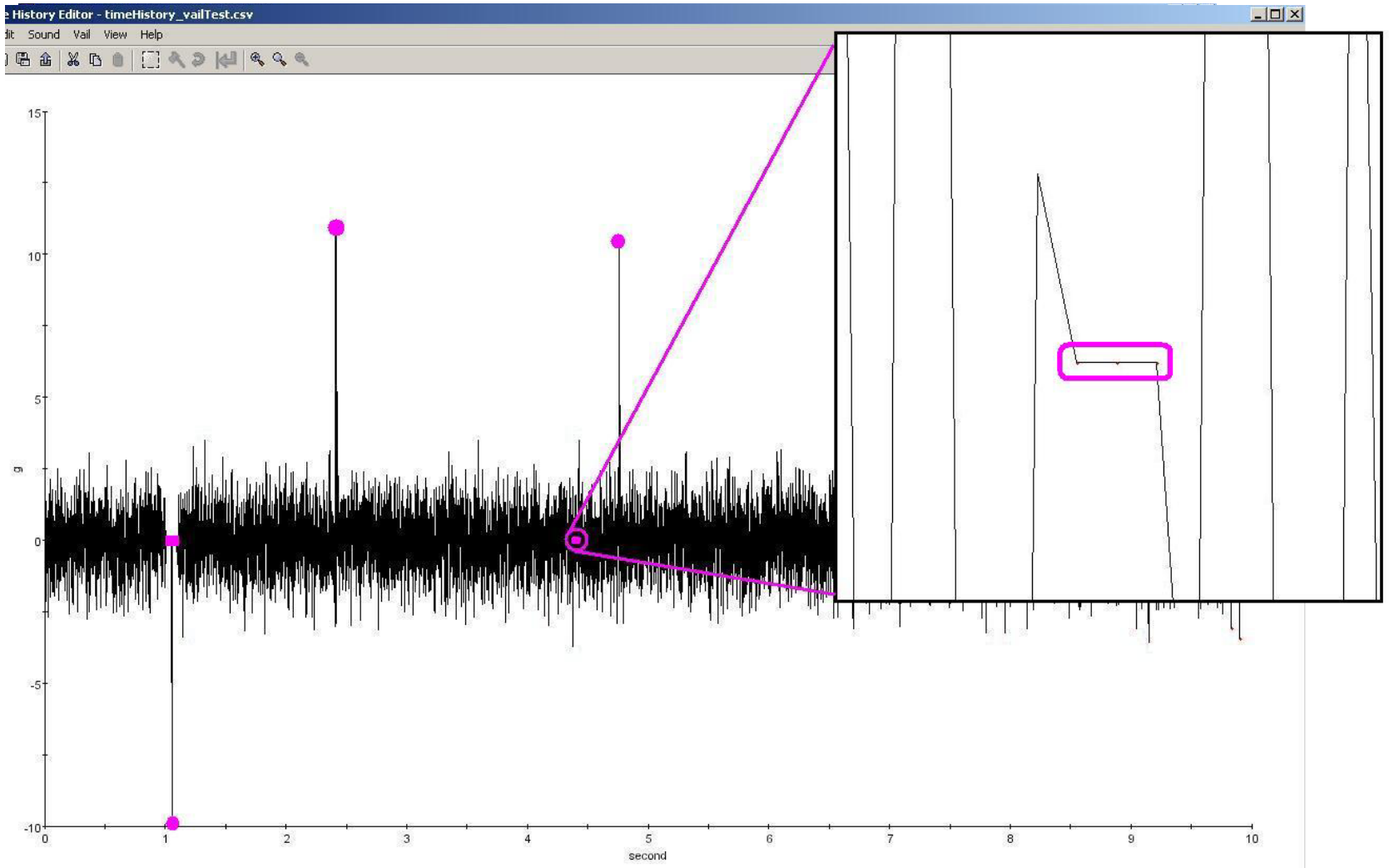
VAIL – Several Templates



VAIL - templates

- **Vail ‘looks’ at each point in the waveform and the neighborhood around that point.**
- **Each template is like a neuron**
  - If the point looks ‘normal’,then go on to the next point. This quick look makes VAIL fast
  - If the point does not look normal, then see if the firing threshold of the neuron is reached
  - If the neuron fires, the point is highlighted, and information is passed to display the ‘type’ of the anomaly and suggested corrective actions.

VAIL – Finds hidden anomalies



Time History Analysis
Lead: Jessica Jensen

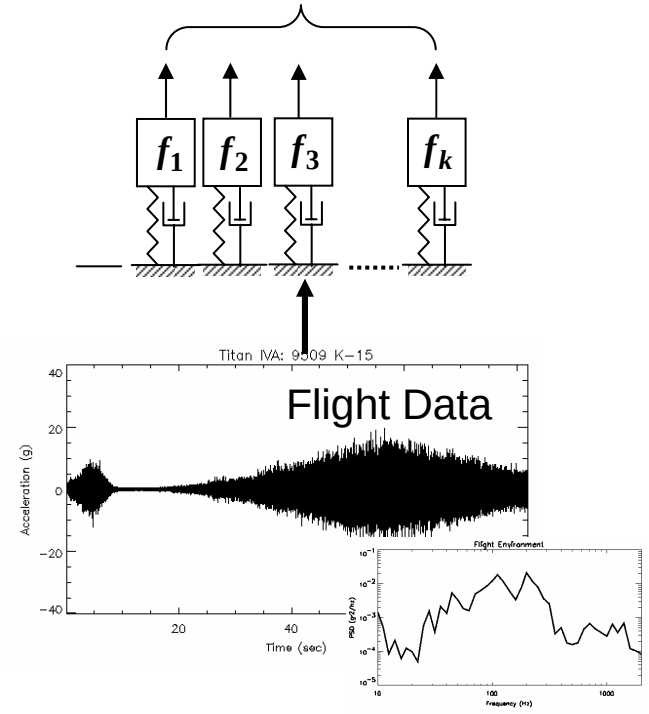
Use of Damage Potential Analysis

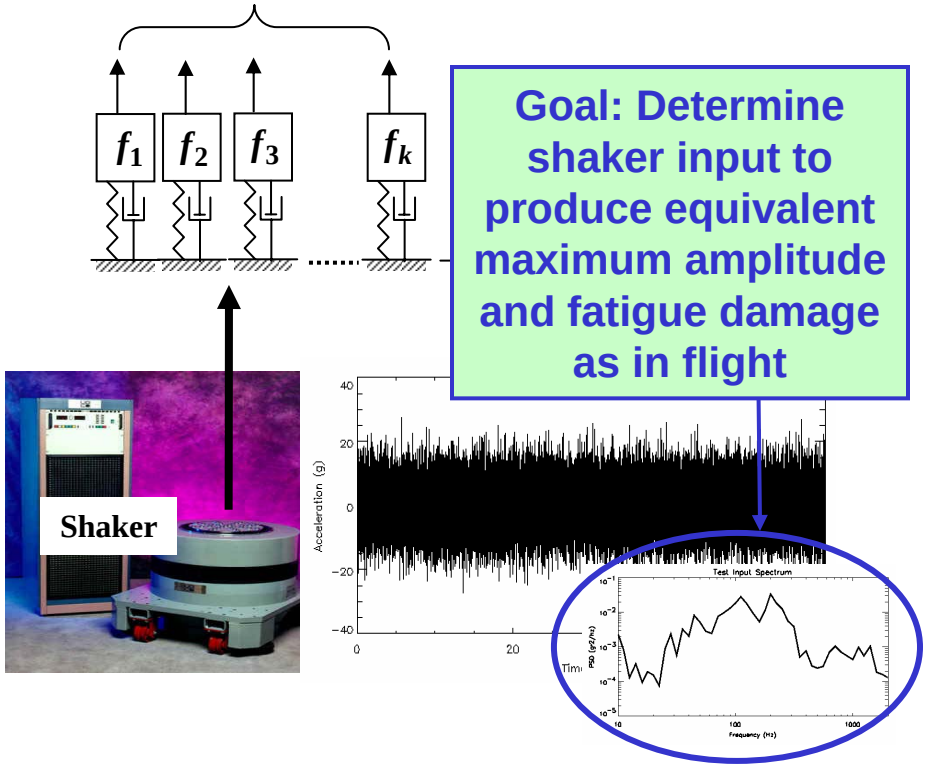
- **Launch Vehicle**
  - Traditional maximax algorithm used to evaluate flight data
    - A brief period of strong oscillation can dominate the spectrum and re-qualification may seem necessary
  - Damage Potential Analysis takes into account not only the maximum response but also the duration of peak levels (fatigue)
    - Still yields a conservative spectrum
    - May help avoid unnecessary re-qualification of hardware
- **Spacecraft**
  - Spacecraft/components tend to be over-tested when qualified on a shaker table for vibration or shock due to the rigidity of the table
  - Damage Potential Analysis can provide insight as to whether relief in the specification can be allowed

Damage Potential Analysis Theory

Flight maximum amplitude response = Test maximum amplitude response

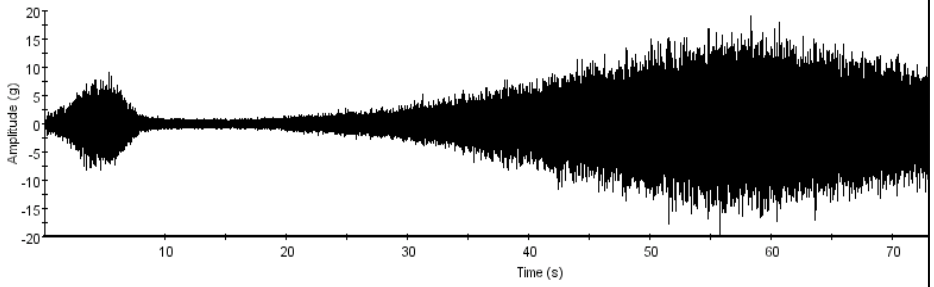
Flight fatigue damage = Test fatigue damage



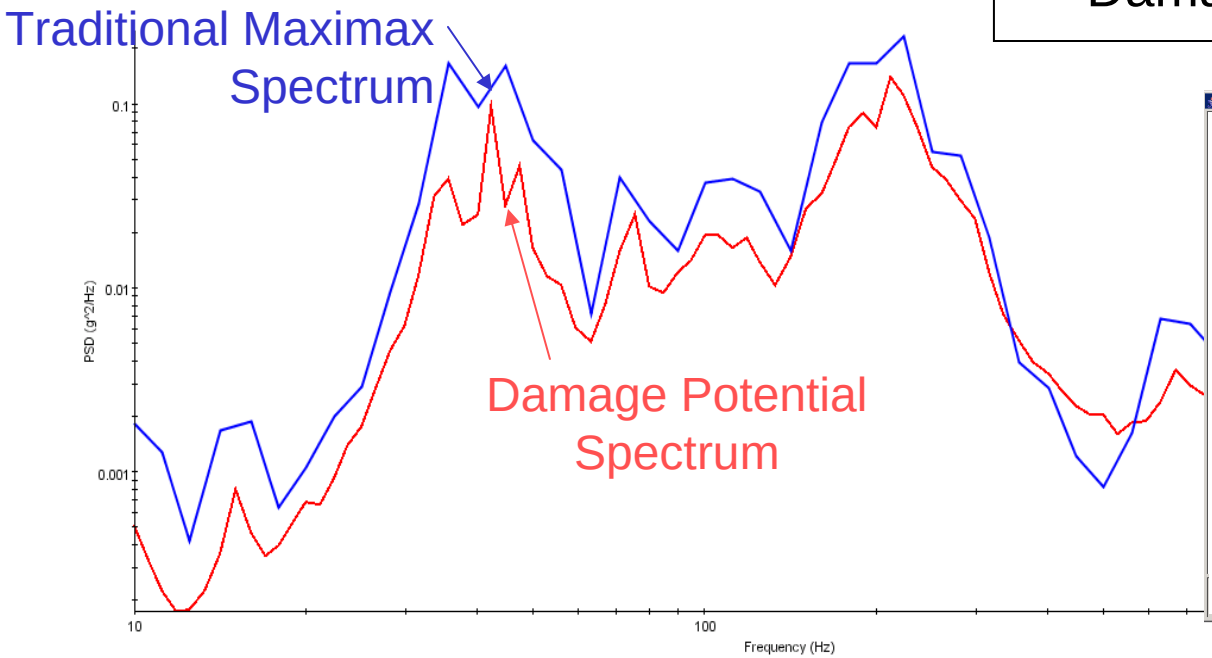


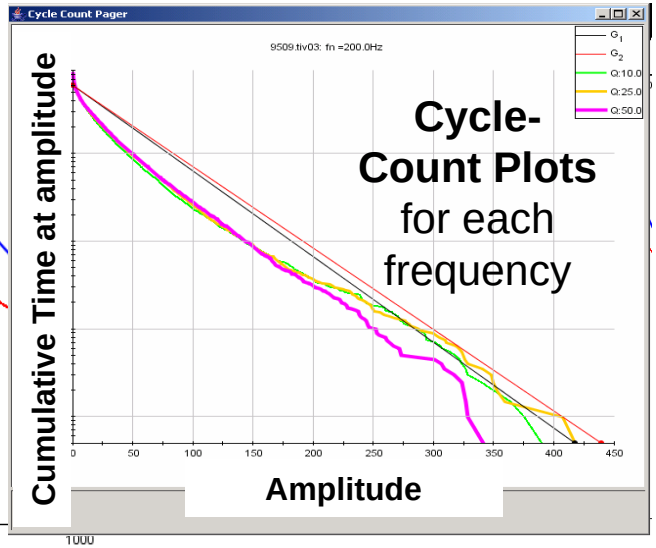
Goal: Determine shaker input to produce equivalent maximum amplitude and fatigue damage as in flight

Damage Potential Exclusively in VISPERS



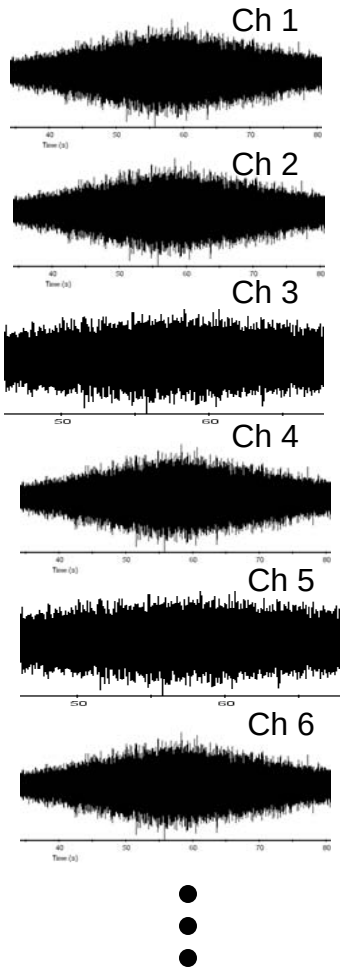
- Easy to use graphical interface
- Cycle count plots help the user understand the dynamics of the system and some of the assumptions behind the Damage Potential Algorithm



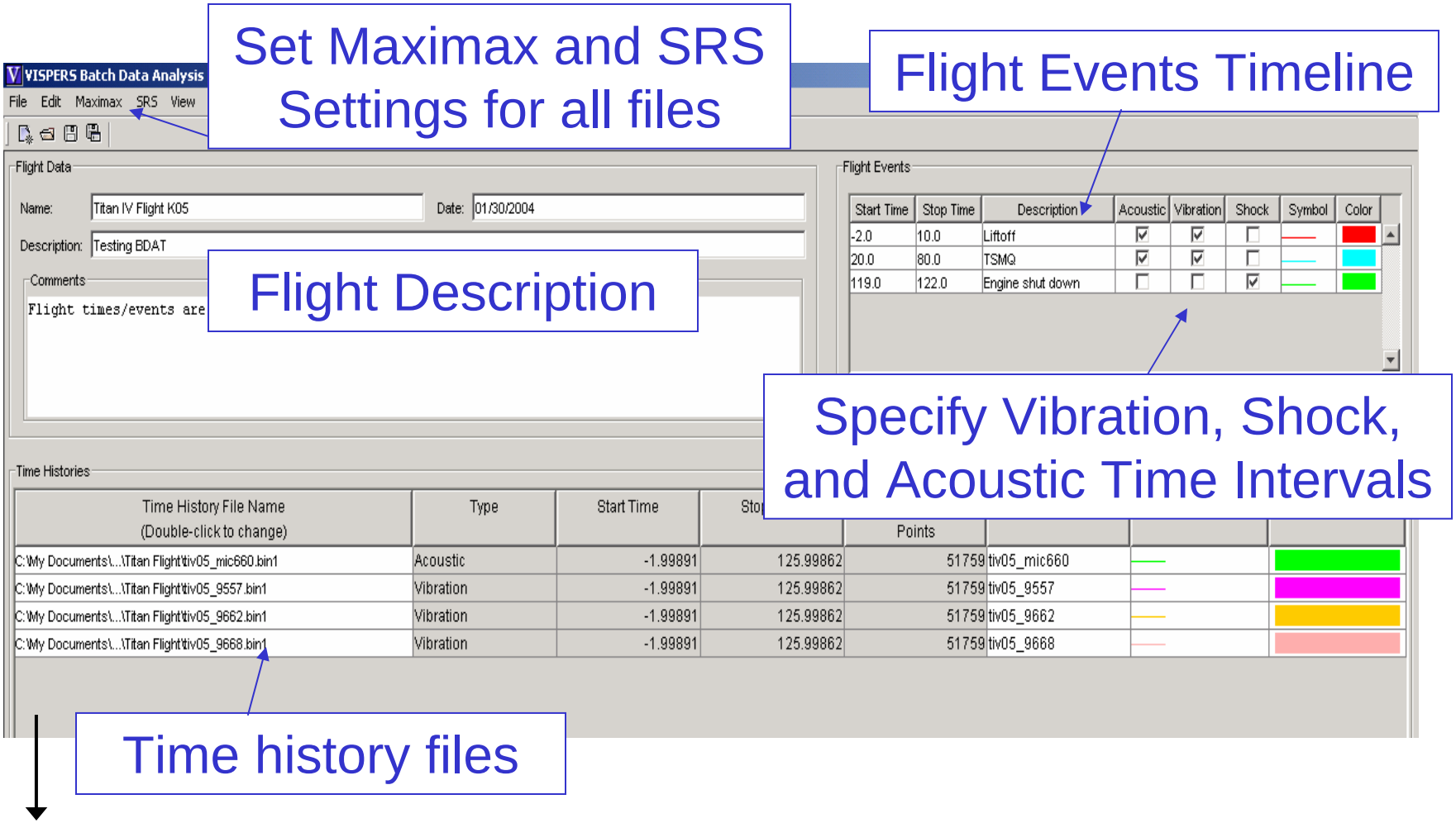


Traditional Processing Now in Batch Format

- **Allows input of flight parameters so that all vibration, shock and acoustic data from a flight can be processed simultaneously**
- **Significantly cuts down turnaround time for post-flight data analysis**
- **Can prepare and save model before flight**
- **Generates a report showing all the time histories and their corresponding vibration, shock, and acoustic environments**



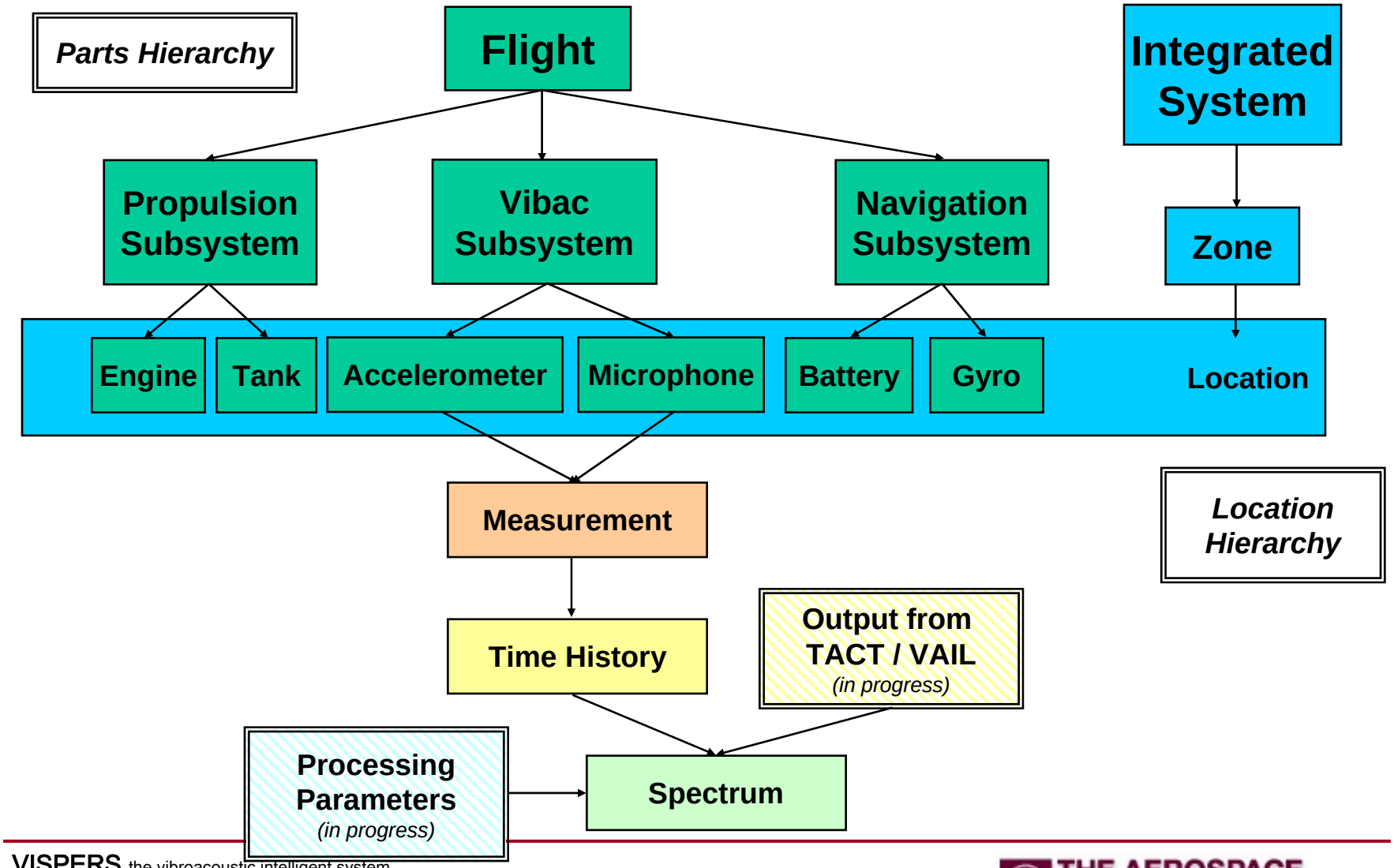
Batch Data Analysis Tool – User Interface



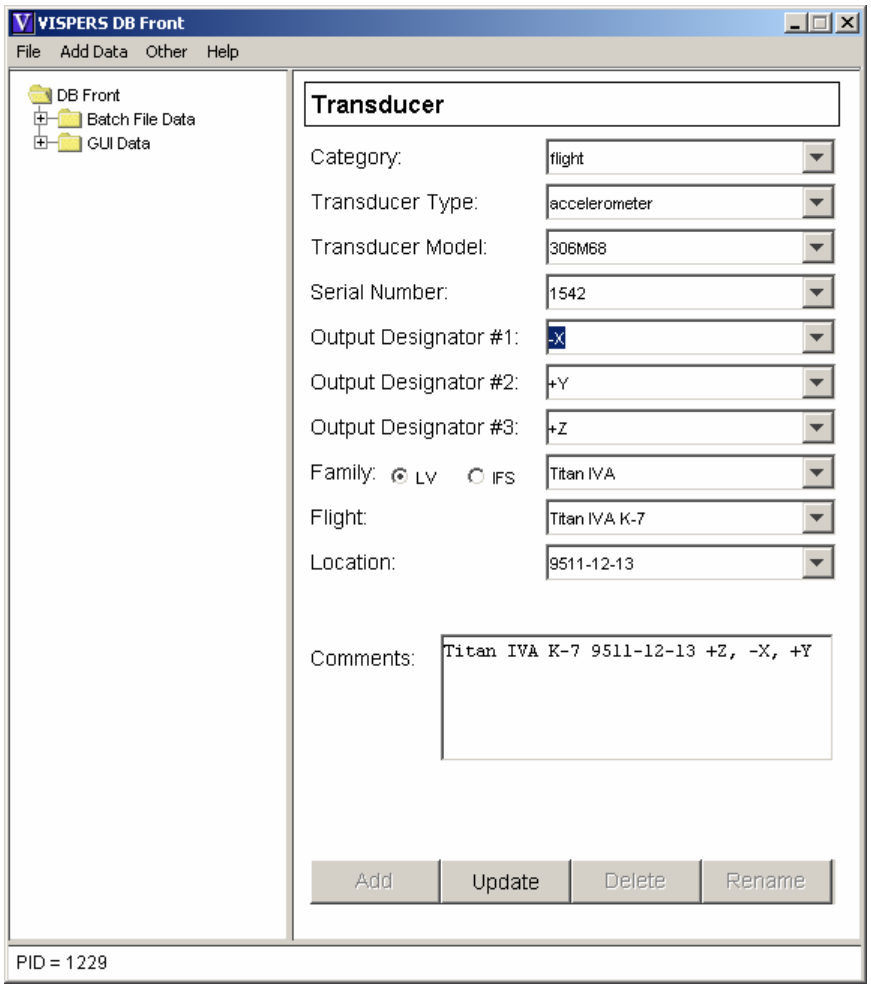
Enter Parameters ⟶ Click Process ⟶ Report (.pdf) is Generated

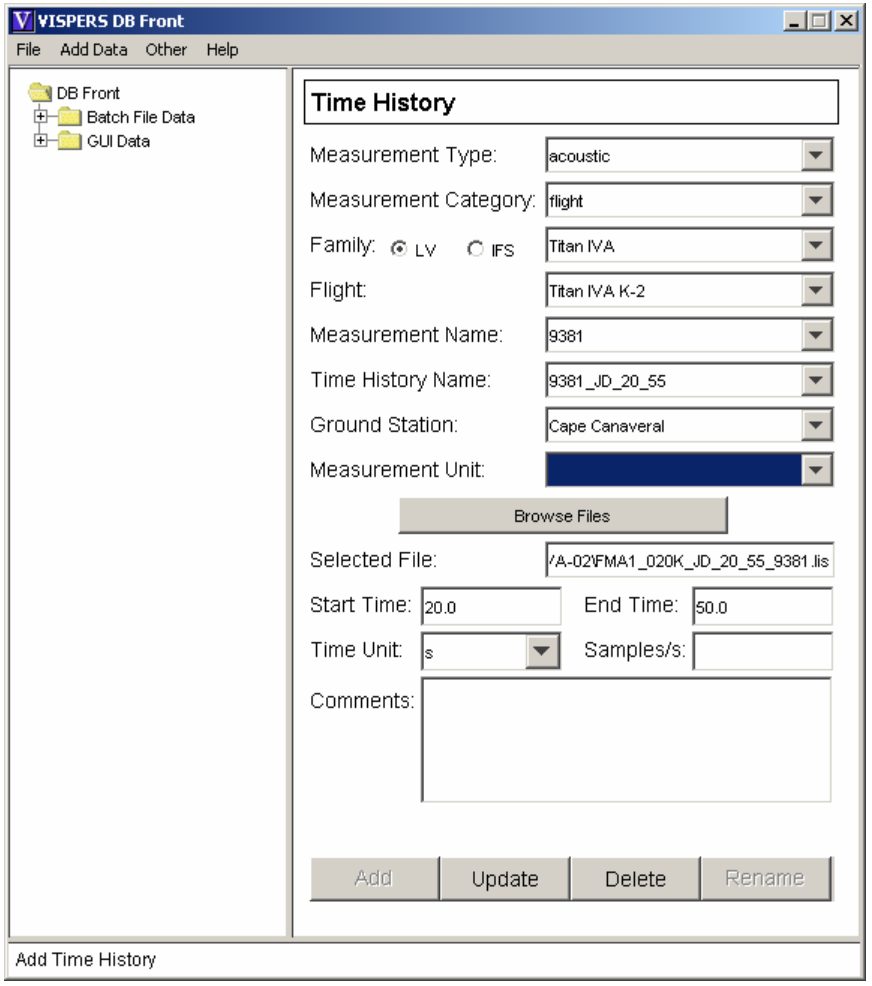
Database
Lead: Marie Boeck

Database Structure



Example Input Screens





Current Efforts

- **Expert System**
  - Integrate grid-enabled version of VAIL, developed by team of Harvey Mudd College undergraduates
  - Create templates for additional anomalies, develop tool for generating templates
  - Continue to develop TACT algorithms
- **Database**
  - Schema refinement
  - Complete database front end tool
- **Continuing Research**
  - External liftoff acoustic prediction algorithms

Summary

- **The VISPERS team has made significant progress in implementing a tool set to**
  - Efficiently process multiple time history data streams using both traditional and improved analysis techniques
  - Automatically identify common anomalies in vibration and acoustic time histories
  - Capture vibration, acoustic, and vehicle configuration data for future analysis and comparisons
- **Although VISPERS is already quite capable, much remains to be done.**

Backup

TACT – time correction

- **The analyst can select how to correct the time-stamps when the waves are not aligned**
  1. Base all times on the “best” T0, and the time step that is specified by the sample rate.
  2. Specify the time for any point, and Tact computes the times for all other points based on the time step.
  3. Specify the time of any two points and the time step will be adjusted based on those points.
  4. Specify the time step and all times will be adjusted based on that time step and the “first” time stamp.