AVEC, Inc.
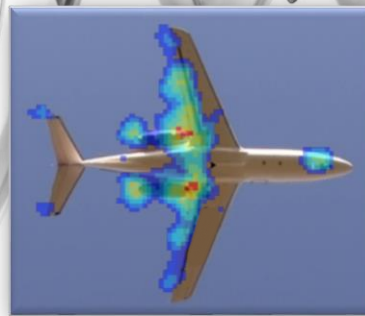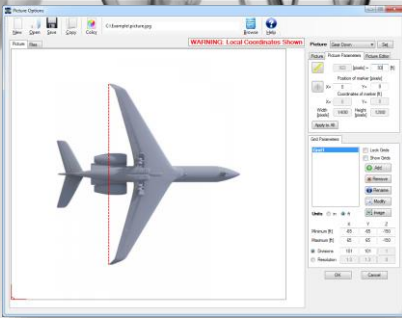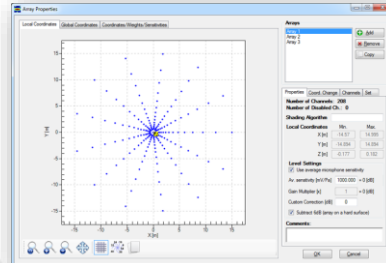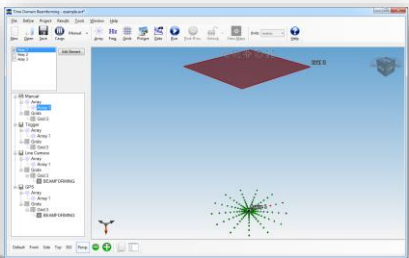## Acoustical and Vibrations Engineering Consultants

AVEC TIME DOMAIN BEAMFORMING SOFTWARE

FAST, SIMPLE, INTUITIVE, HELPFUL

AVEC's Time Domain Beamforming Software is a complete solution for flight testing using acoustic phased arrays. The package provides beamforming, deconvolution, and analysis of experimental data collected with microphone phased arrays. During flight testing, the user can quickly analyze raw data, obtain preliminary acoustic maps, integrate results, and estimate EPNL levels.

The software design philosophy is centered on the user. As long time users and developers of phased array technologies, the software engineers at AVEC have focused on the most important aspects of array processing and analysis. Our goal is to provide the user with a comprehensive environment to perform all the tasks involved in a phased array test.

Our software excels in processing speed, simplicity of setup, and intuitive access to results, among other advantages. It also provides the user with tools that help increase productivity through the automation of result documenting functions. For example, the software provides automatic report generation, the option to export data to spreadsheets, and the ability to easily copy any figure. These and several other features allow the user to focus on what matters most: data analysis.

The flight test results shown are courtesy of JAXA (Japan Aerospace Exploration Agency), or part of work done and published by NASA Langley Research Center.
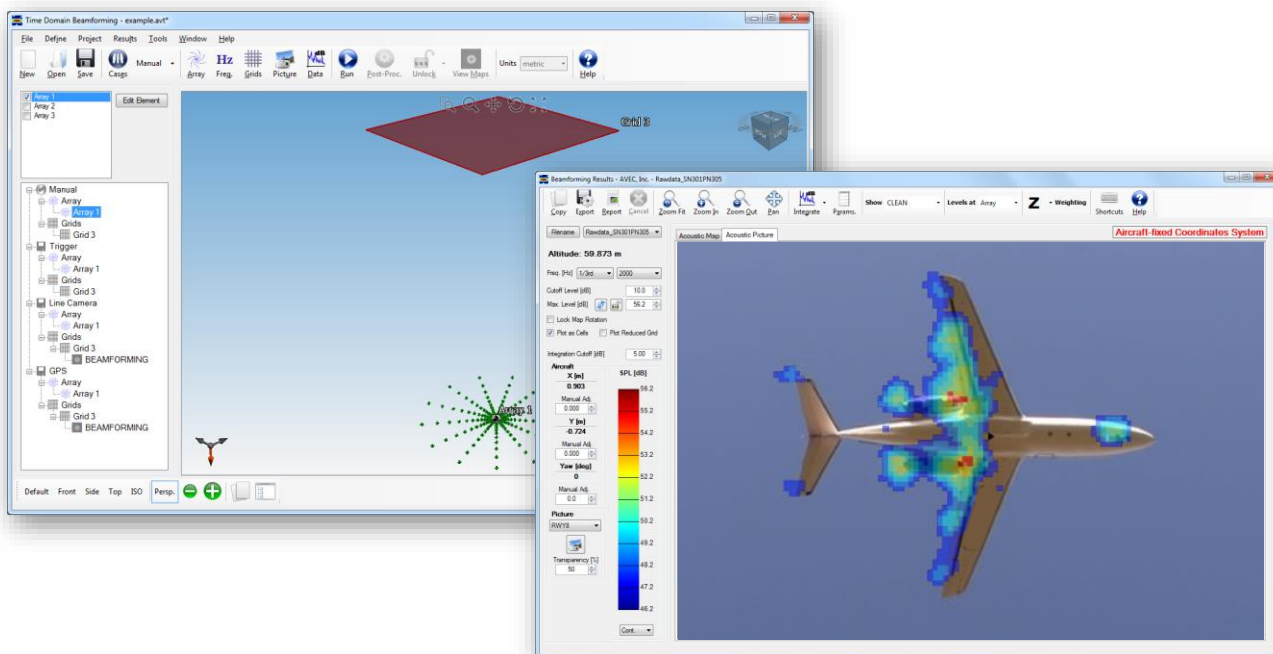
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Overview of Main Features

AVEC's software includes modules for all the typical tasks of a flight test using microphone phased arrays. Additional functions were added to aid in the data processing and analysis. Some of the features available in the software include:

➢ Fast and easy project setup through an intuitive interface design,

➢ Multi-case analysis (to compare results from different processing options or settings),

➢ Array coordinates transformation (rotation and translation),

➢ Quick raw data review (time histories and spectra),

➢ Disabling of non-working microphones (manually or programmatically),

➢ Processing with a user defined shading algorithm or microphone weights,

➢ Aircraft tracking using GPS data, line camera data, a trigger signal, or manual mode,

➢ Diagonal removal beamforming,

➢ Multiple-file beamforming and deconvolution (CLEAN or DAMAS),

➢ Integrated spectra and directivity calculation (of single or multiple regions),

➢ EPNL estimation (from single microphone spectra or integrated spectra),

➢ Results available in narrowband, 1/24th, 1/12th, and 1/3rd octave bands,

➢ Acoustic maps overlay with pictures or drawings,

➢ Automatic export/report generation for multiple files, and

➢ Hundreds of files can be part of a project and be easily batch-processed, integrated or exported.

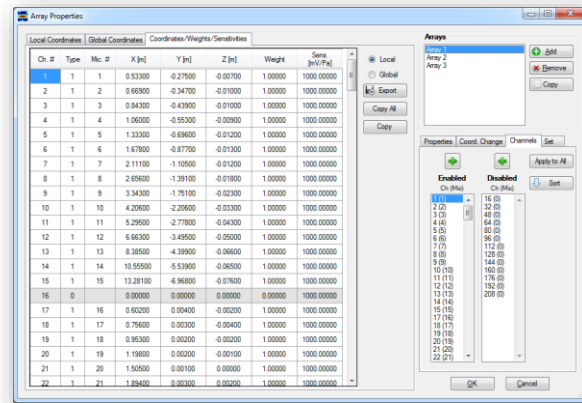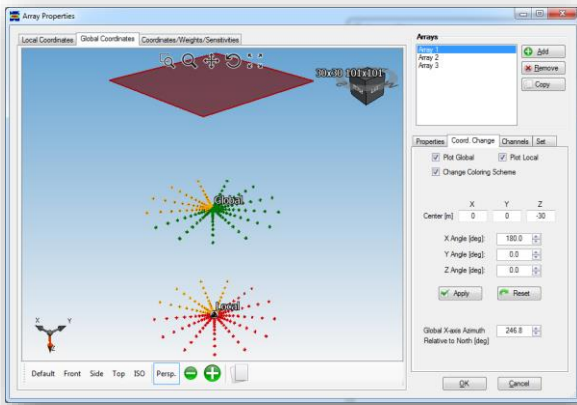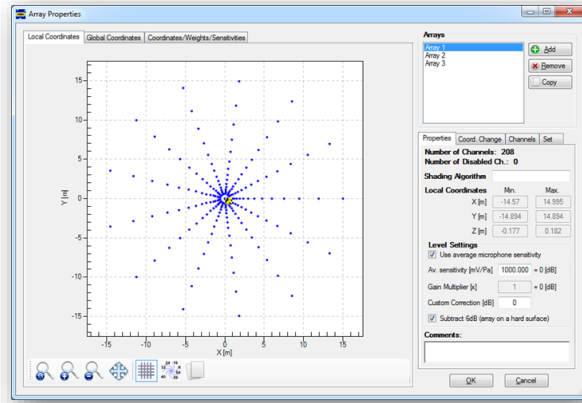Most of these and other features are described and explained in more detail in this brochure.

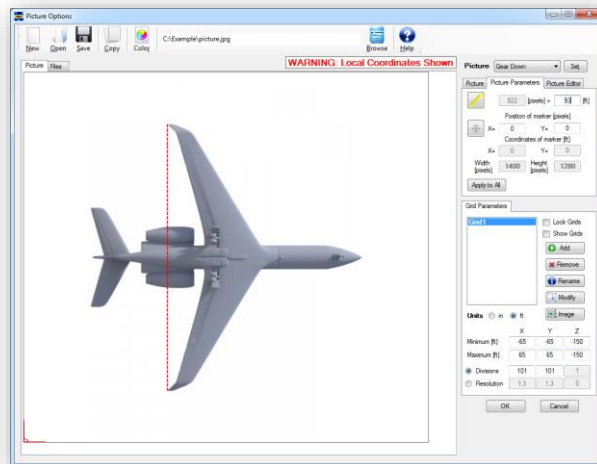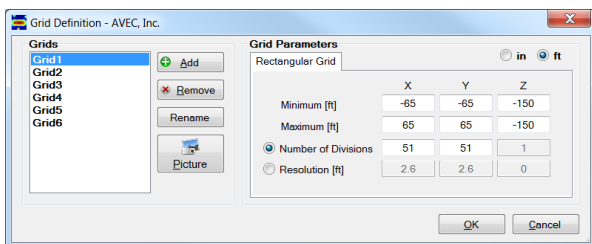**AVEC, Inc**

Array Definition Module

The software has several tools that allow defining, manipulating and modifying the arrays to be used for data processing. The array module allow the user to:

➢ Import the array coordinates and parameters (weights, sensitivities and channel type) from an text file (easily obtained from a spreadsheet).

➢ Easily rotate and translate the array to match the test setup.

➢ Independently assign the channel type, weight and sensitivity of each channel in the array.

➢ Implement custom shading algorithms.

➢ Automatically disable auxiliary channels (e.g. IRIG, synchronization, trigger, etc.) .

➢ Define and use multiple arrays in a single project.

Scanning Grid Modules

The scanning grids over which the data will be beamformed can be easily defined using its coordinates relative to the aircraft. The user can also define the grids using a picture or drawing of the aircraft. The user can then visualize the acoustic maps overlaid on these pictures.
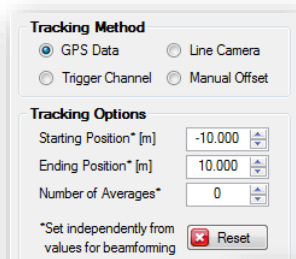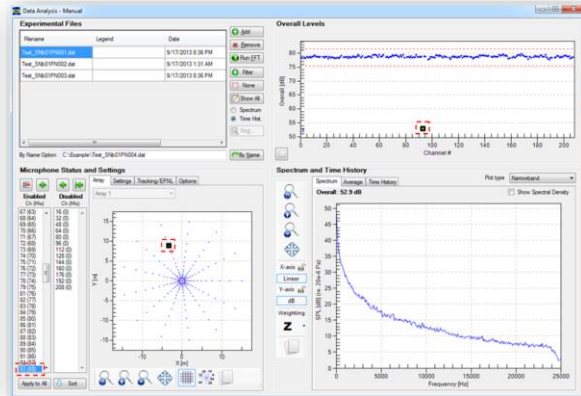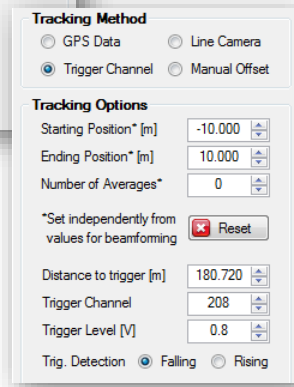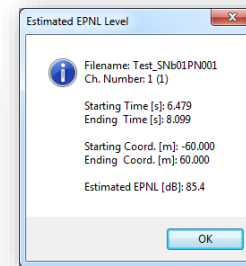
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Raw Data Analysis Module

The raw data analysis tools are used to quickly determine if all channels are working properly during the test. This information can also be used to determine if some microphones should be discarded during processing, i.e. to avoid "contaminating" the beamforming results. Some of the tools in the raw data analysis module include:
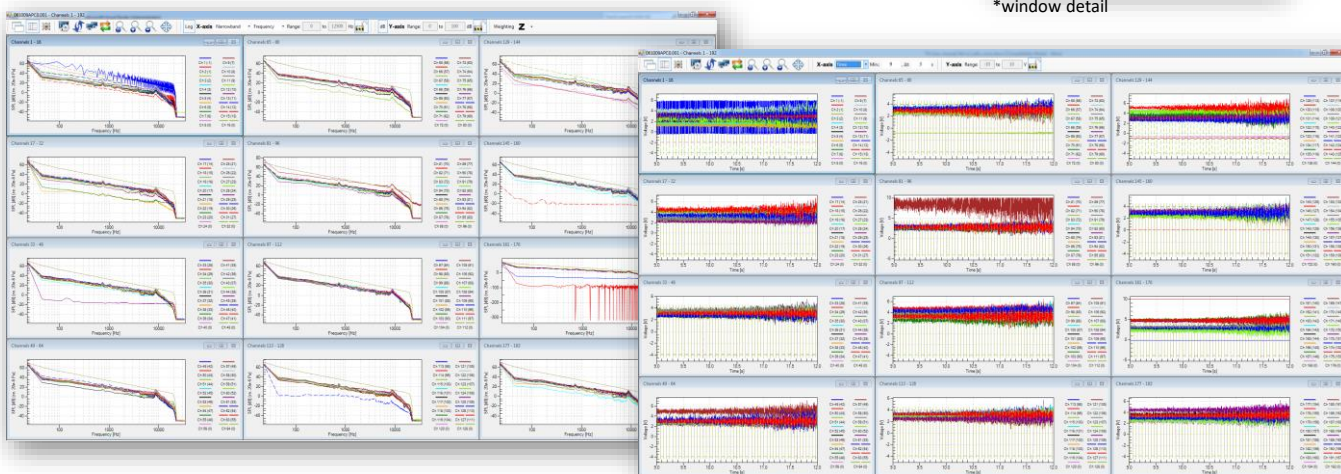
➢ Visualization of the time history or spectrum of each individual microphone. The average spectra of a subset of microphones is also available.

➢ The overall levels of all the microphones in the array can be used to easily find outliers. Also, the overall levels can be obtained above a frequency defined by the user.

➢ Non-working channels are easily identified in the figures so they can be troubleshot during the test or excluded during data processing.

➢ Microphones can be programmatically disabled based on their overall levels relative to the average value.

➢ The time range over which the spectra will be computed can be defined manually or using aircraft tracking data. This feature can be used, for instance, to compare the average microphone spectra to the integrated spectra over the same time window.

➢ EPNL estimation for single microphones using aircraft tracking information.

➢ Quick raw data review (time histories and spectra) using multiple monitors. In this tool, disabled and non-microphone channels can be easily hidden to facilitate the analysis.
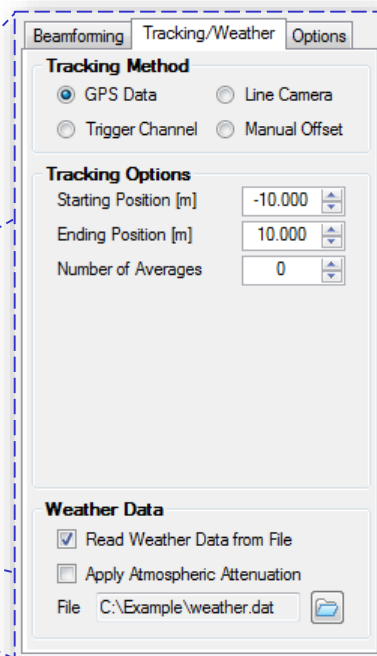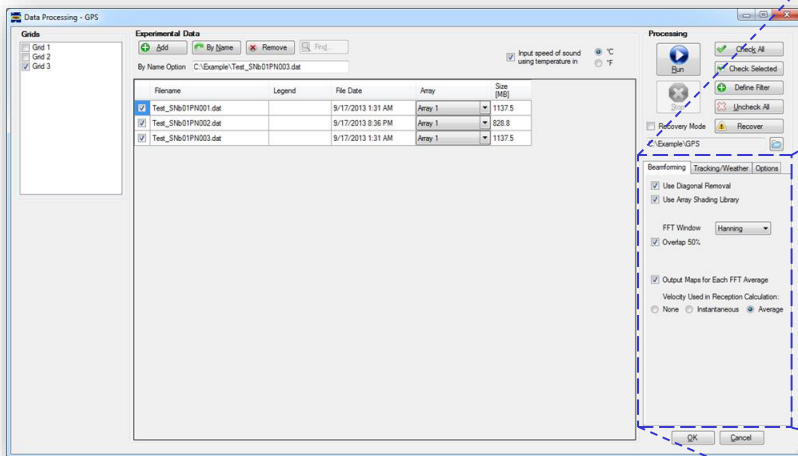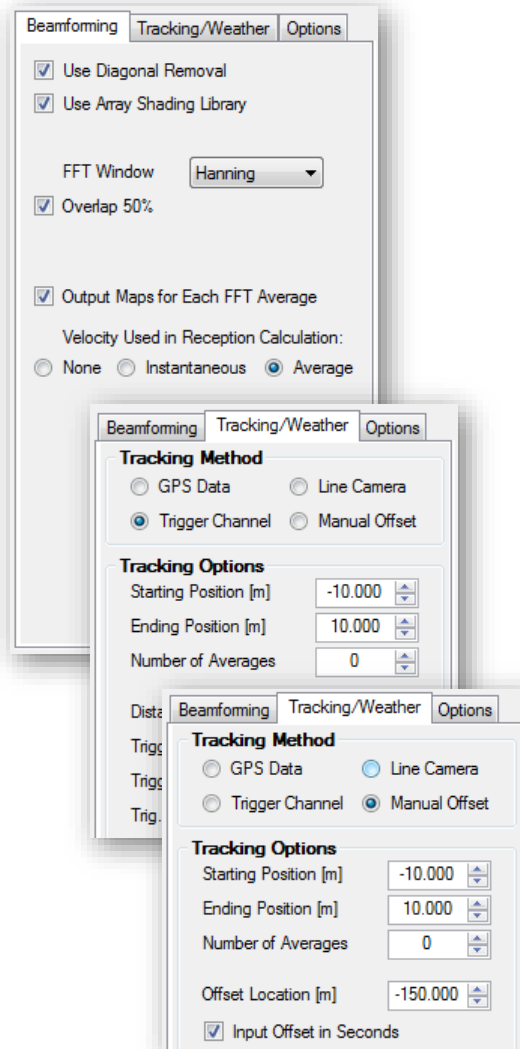
*window detail

*window detail

Beamforming Module

AVEC's software offers several beamforming options and features, including:

➢ Aircraft tracking can be achieved using GPS data, line camera data, a trigger signal, or simply a "manual" mode.

➢ The time window over which the beamforming takes place is easily defined by its coordinates relative to the array.

➢ Flight direction is automatically accounted for.

➢ Advanced time-domain beamforming with diagonal removal is available.

➢ Different FFT windows (rectangular, Hanning, Hamming, Tukey) and overlap are available.

➢ Processing with microphone weights or shading algorithms defined by the user (in a customizable library).

➢ Optimized, multi-threaded processing allows results to be obtained quickly during the flight test.

➢ Weather data can be used to account for atmospheric attenuation and wind convection.

➢ Hundreds of files can be part of the project and easily batch-processed, and later visualized and integrated.

➢ The beamforming results for each time-step can be output. The maps can be visualized or used to estimate directivity and EPNL.
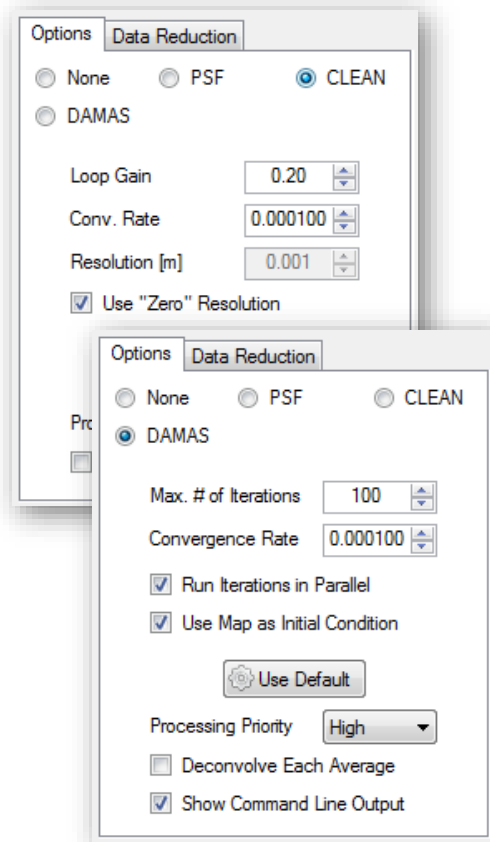
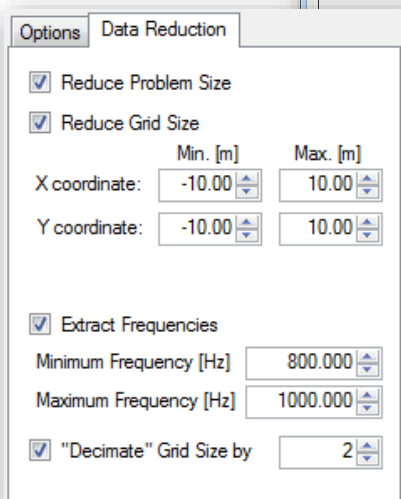# AVEC TIME DOMAIN BEAMFORMING SOFTWARE

Post-processing Module

The post-processing module includes array deconvolution, point spread functions (PSF) calculation, and data reduction tools. The main features are:

- CLEAN and DAMAS are implemented with different processing options suggested in the literature.

- The CLEAN algorithm and the PSFs calculation are parallelized (multi-threaded) to reduce computational time.

- An innovative approach for DAMAS includes a parallelized version that can be used to reduce computational time while not requiring large amounts of memory (i.e. only the PSFs for a single frequency at a time are computed/stored).

- The deconvolution can be computed for the "averaged" results (for "quick" results) or for each time-step to increase accuracy.

- The data reduction tool can be used to speed-up the deconvolution process or to obtain results only for a few desired frequencies. This is a very helpful feature during a flight test.

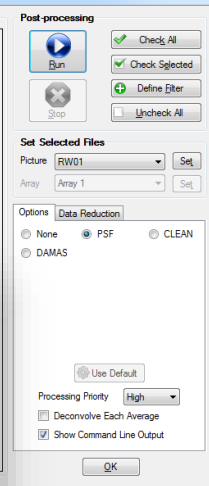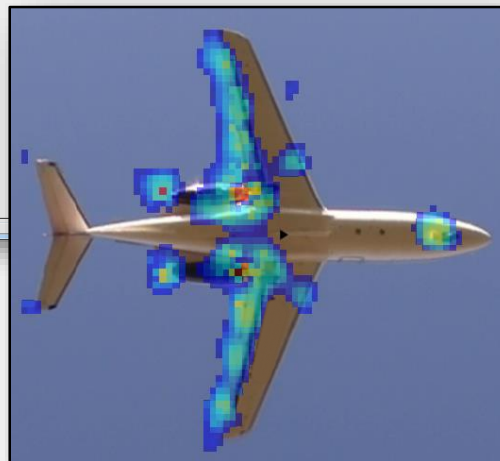- Several files can be batch-processed with a single click of a button.

*window detail

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Visualization of Acoustic Maps

The beamforming results visualization options include:

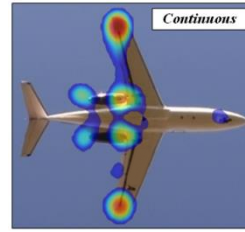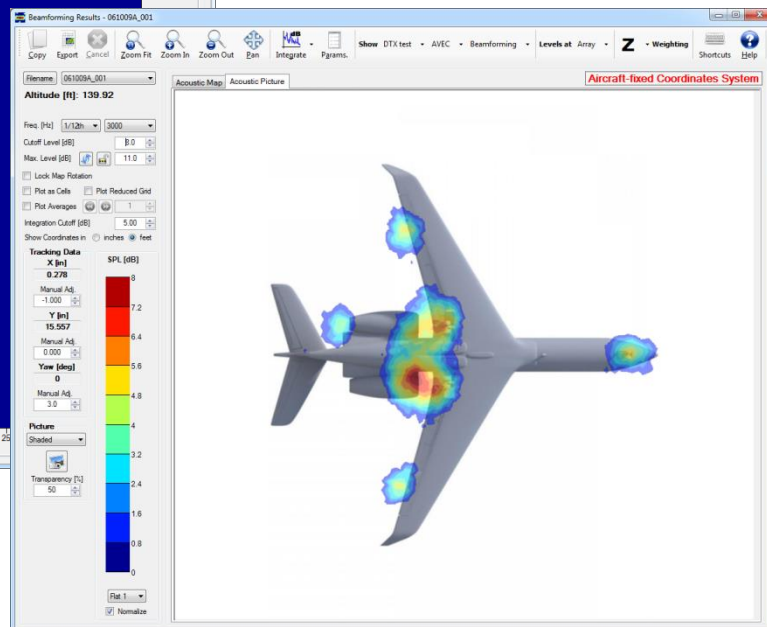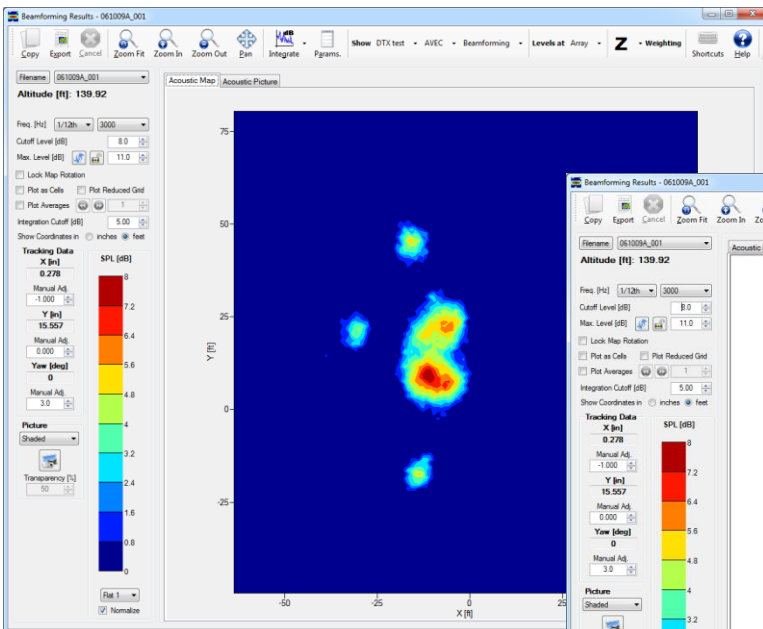- Acoustic maps (for narrowband or different octave bands) can be visualized as conventional contour plots or overlaid with pictures/drawings of the aircraft.

- Multiple pictures (e.g. for different test configurations) can be easily defined and assigned to multiple files.

- Different contour coloring, transparency, and flooding options are available.

- The levels can be obtained at the array, the source, or a certification distance (e.g. 120m). The levels can also be weighted (Z, A, B, C, D).

- The beamforming map for each time-step can be plotted. The interface also indicates the tracking information relative to the array (altitude, position, rotation, emission angle).

- The parameters of the file being analyzed (tracking, processing options, weather, etc.) can be easily accessed from the results window.
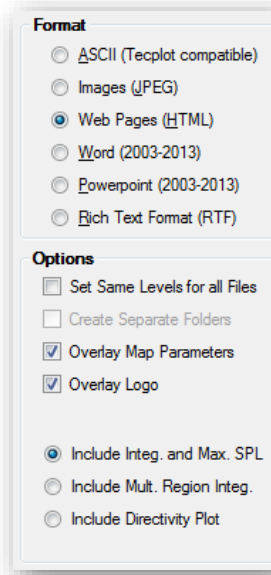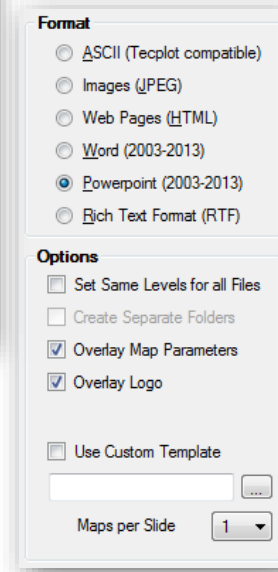
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Exporting Results and Generating Reports

AVEC's software has unique features that can be used to automatically export the beamforming results for multiple files and frequencies. The features in the export module increase user productivity and allows for more time to be spent analyzing data instead of copying, pasting, and cropping figures. Depending on the selected format, tables indicating the tracking and processing parameters are included. The acoustic map parameters and/or customer's logo can be included in every map. The available export formats and some of their unique features include:

➢ **Web Pages (HTML):** a separate web page is generated for each file exported allowing the user to easily visualize and access the acoustic maps and integrated spectra for the beamforming or deconvolution results. An index page is created to easily access the results for each exported file.

➢ **Word®:** this option generates professional looking reports including cross-referenced figure captions, table of contents, and table of figures.

➢ **PowerPoint®:** this format allows the maps to be exported to slides (1, 2, or 4 per slide) on a user-defined template.

➢ **Images (JPEG):** the results for each file can be exported to individual folders. Folders and files are automatically named and created.

➢ **ASCII:** this option can be used to export the maps to a text file in a format compatible with Tecplot®.

➢ **Rich-Text Format (RTF):** this option is useful when Microsoft Office® is not available.

*window detail

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*sample HTML output

Tecplot® is a registered trademark of Tecplot, Inc. Office®, Word®, Excel® and PowerPoint® are registered trademarks of Microsoft Corporation.
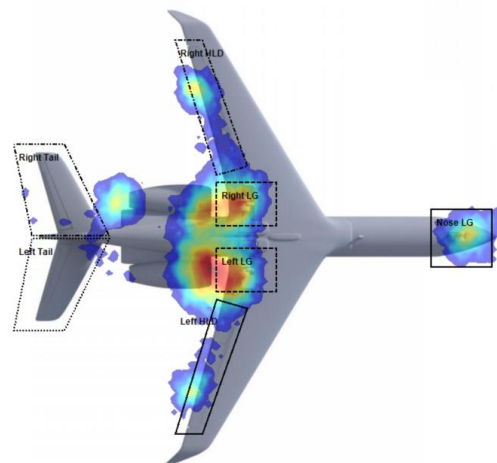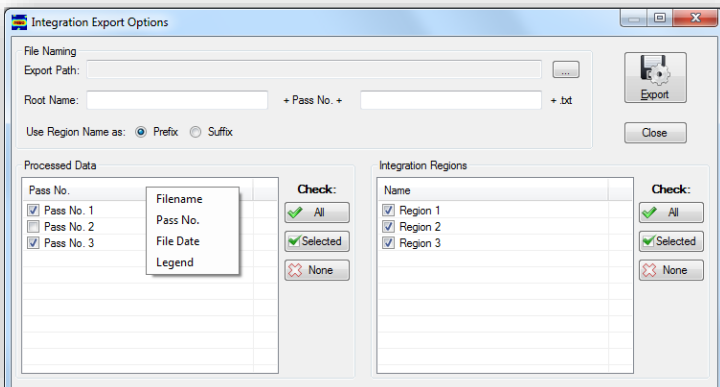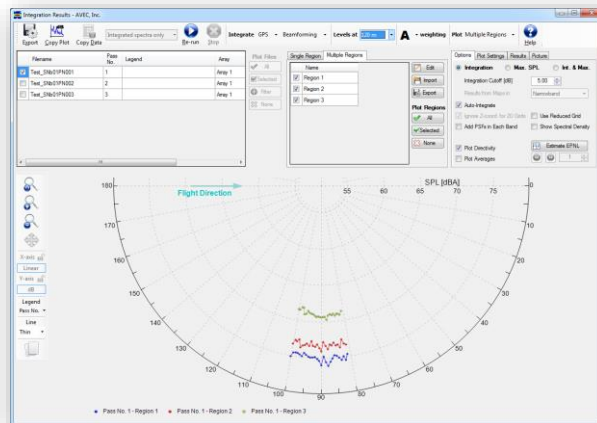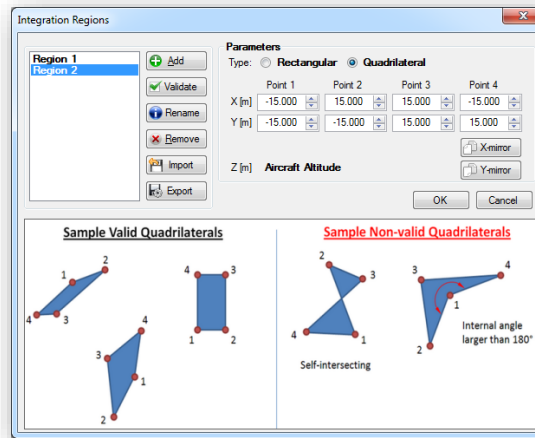
Integration Module

An easy-to-use array integration module has been implemented to quantify the noise from particular regions on the acoustic maps. The features in this module include:

➤ Spectra calculation from normalized integration or maximum SPL "extraction".

➤ The integration can be calculated for single (or multiple) rectangular or quadrilateral regions.

➤ These regions can be defined by "clicking" on the acoustic maps, using the region coordinates, or importing an ASCII file.

➤ Multiple results can be exported to ASCII files, or copied/pasted into a spreadsheet.

➤ The EPNL can be estimated for the entire aircraft or for each component/region. If needed, the available data (frequencies and levels) is automatically extrapolated.

➤ The integration (or max. SPL) for each time-step can be used to estimate and plot the directivity of the entire aircraft or any desired component/region.

➤ The levels can be weighted (Z, A, B, C, or D) and shown as spectral density.

➤ The features in this window allow results for different cases, files, regions, processing codes (AVEC or customer's, if applicable), deconvolution, and maximum SPL vs. integration to be compared.

➤ Automated or customizable colors, lines, and markers based on plot type.

Freq [Hz]	Pass No. 1 - Region 1 – SPL [dB] (re. 20e-6 Pa)	Pass No. 1 - Region 2 – SPL [dB] (re. 20e-6 Pa)	Pass No. 2 - Region 1 – SPL [dB] (re. 20e-6 Pa)	Pass No. 2 - Region 2 – SPL [dB] (re. 20e-6 Pa)
200	65.8	60.6	65.5	56.1
250	71.4	65.1	71.1	61.7
315	72.8	65.2	72.3	62.8
400	72.8	67	72.5	65.2
500	72.5	64.6	72.1	66.1
630	77.9	70.2	77.5	70.1
800	77.6	70.6	77.3	72.6
1000	81.4	70.9	80.9	76.2
1250	77.3	70.4	77.1	74.7
1600	82.4	71.3	82.3	75
2000	83.8	72.6	82.3	77.7
2500	86	78.4	85.8	78.5
3150	78.9	76.7	78.6	75.3
4000	74.5	77	74.4	74.4
5000	73.6	79.9	73.5	76.9

*table borders and coloring were added after pasting the results in a spreadsheet
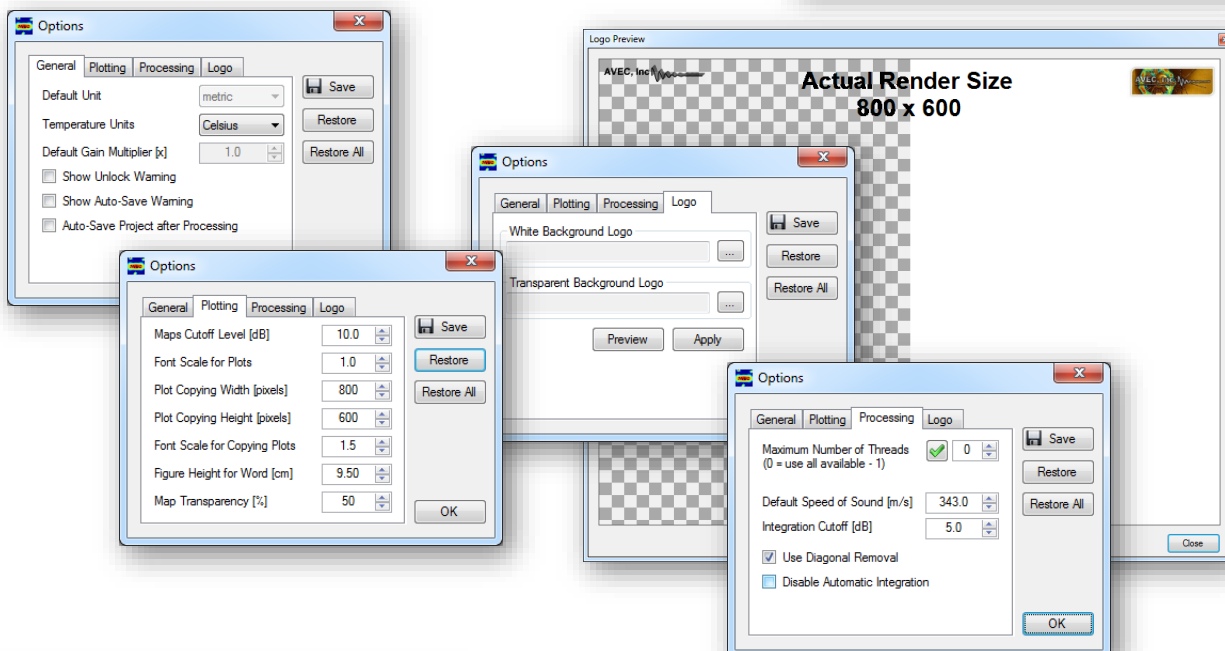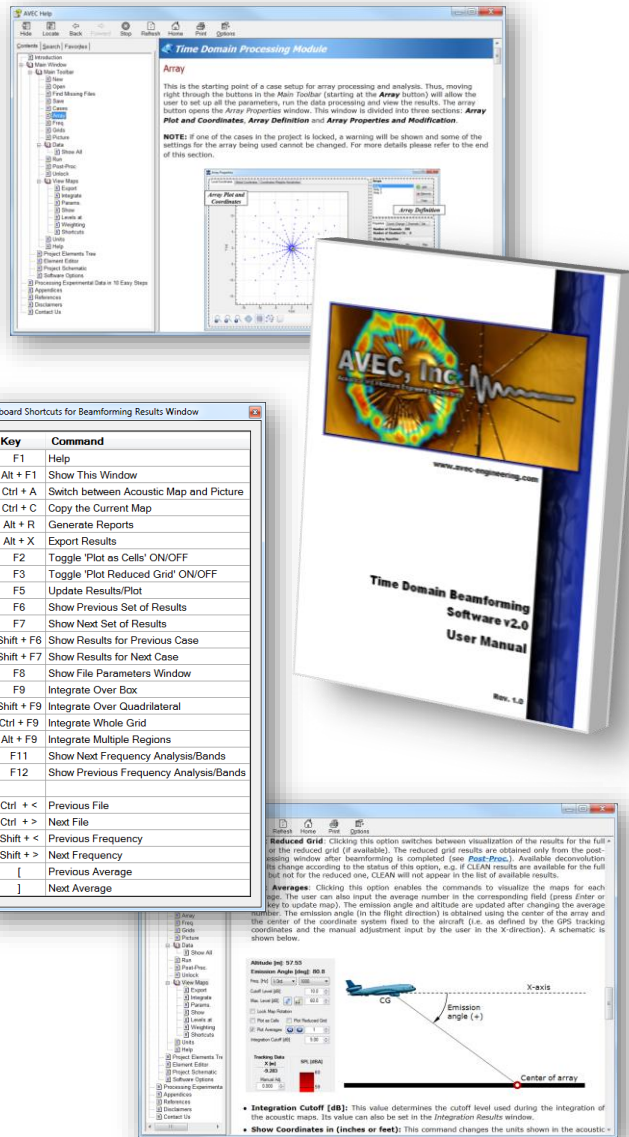
Documentation and Other Features

Other software features include:

➢ Projects and results can be easily moved to other computers for analysis (without needing the raw data files).

➢ Comprehensive user manual, help files, and list of available shortcuts.

➢ Keyboard shortcuts significantly speed-up data navigation (optional custom USB keypad also available).

➢ All the plots in the software and spectral data can be easily copied and pasted into a different application (e.g. spreadsheet or word processor).

➢ A filter tool can be used to quickly select multiple files for processing, integration, or export.

➢ Several software settings and options can be easily changed. This includes options to define and preview custom logos to be used in the exported maps.

➢ Licensing model using encrypted USB key allows the installation of the software on several PCs without requiring complex activation procedures.

Custom Software Solutions

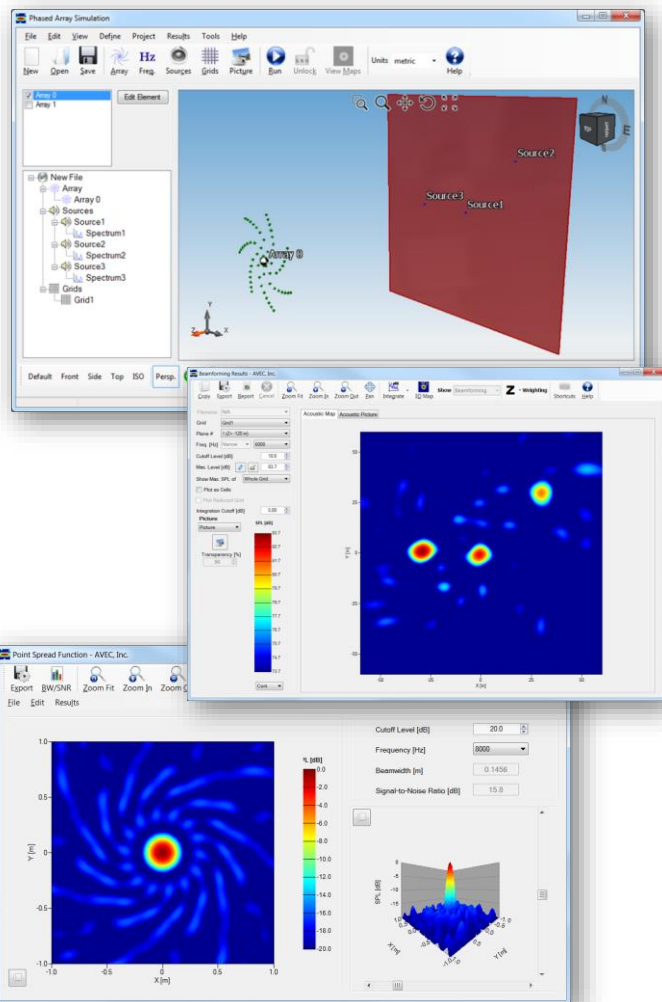In addition to our commercial software, AVEC offers custom solutions to fit the customer's needs, including:

➢ Integration with the customer's data acquisition system.

➢ Custom file formats (raw data, tracking, weather, line camera, etc.).

➢ Integration of the user interface with the client's beamforming/post-processing codes.

➢ Implementation of additional export formats, processing, or visualization techniques.

Please do not hesitate to contact us about any special requirements.

Services and Other Products

Other services and products from AVEC include:

➢ On-site software training.

➢ Test support, data processing, and data analysis services.

➢ Turn-key phased array systems, including: microphones, cabling, signal conditioning, and data acquisition system.

➢ Frequency domain beamforming software (optimized for wind tunnel testing in open jet or hard-wall configurations).

➢ Software for array design and simulation.

AVEC, Inc

Contact Information

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