

DATA PROCESSING KIT FOR MULTI-HOLE PROBES

For use with ID7HP, ID8HP and FD7HP-series probes



WARNING

Read this document before using the software.

This system is not certified for use on aircraft.

Contents

1	INTRODUCTION	1
2	THIRD-PARTY SOFTWARE AND DRIVERS.....	2
3	CALIBRATION ALGORITHM	4
4	CALIBRATION DATA RESTRUCTURING	5
5	MEASUREMENT DATA CONVERSION	8
6	TECHNICAL SUPPORT	11
	Appendix: Reference coordinate systems	12

Version Control

Version	Date	Summary of changes	Software release
1.0	08-2026	New document	2.0

1 INTRODUCTION

Principle of operation

This is a generalized data reduction algorithm which converts the pressures obtained from individual multihole probes with arbitrary configurations and channel numbers into three components of velocity. This software utility was developed for use with the ID7HP-series digital probes, ID8HP-series flight probes and FD7HP-series 'Cobra' probes, but may be used with any multi-hole probe system providing that the data files are formatted and stored appropriately.

System description

Software application and development kit for multihole probes.

System components

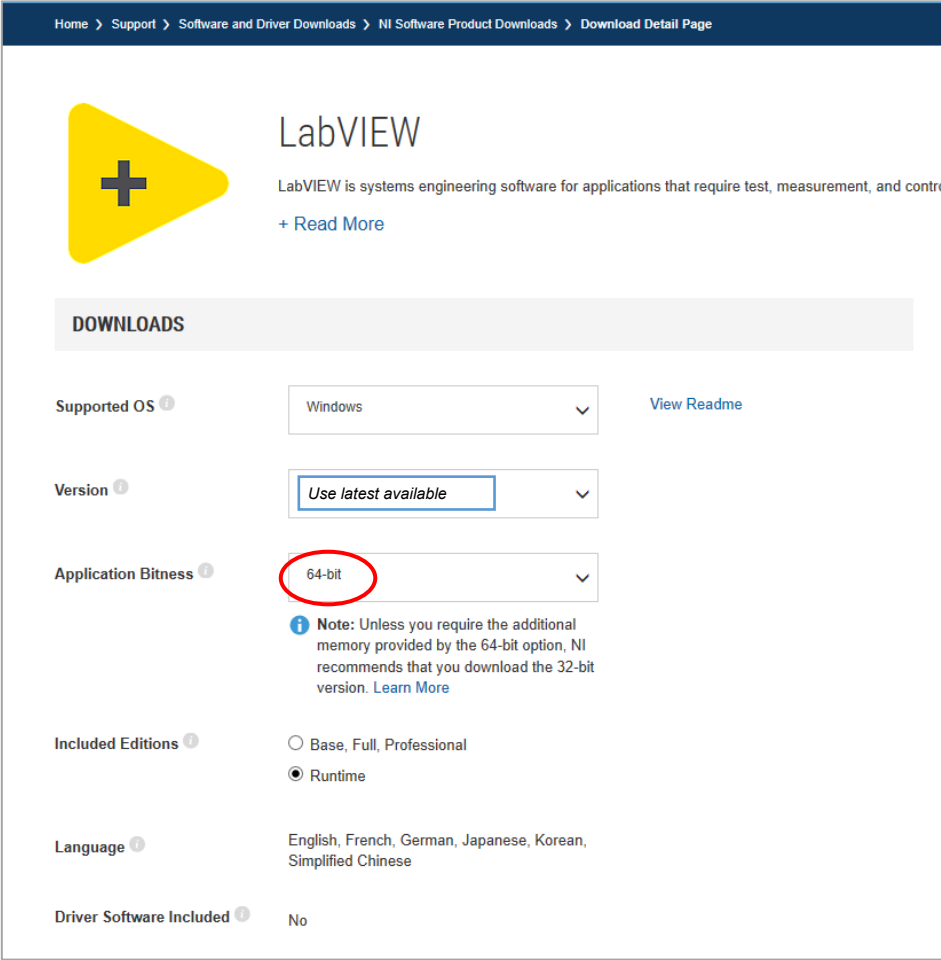
Calibration data resampler	CALIBRATION RATE RESAMPLER.EXE Utility for converting unstructured calibration data files into the structured data formats required for the data reduction process
Data converter	OFFLINE DATA CONVERTER.EXE Utility for converting measured pressures from probes of arbitrary configurations into three components of velocity
Development kit	Software development kit for National Instruments LabVIEW environment
Example dataset	Examples of data file formats needed

2 THIRD-PARTY SOFTWARE AND DRIVERS

There are two external drivers which must be downloaded and installed on the computer in order for the PC to be able to interface with the rake system, in addition to the specific system driver for your rake.

- [National Instruments LabView Run Time Engine \(LVRTE\)](#)
- [National Instruments VISA Run-Time Engine \(NIVISA\)](#)

These drivers are freely available for download from National Instruments. Ensure that the 64-bit version of the NI LabVIEW Run Time Engine is selected (note this is not the default option), and restart the computer following each installation. Correct download settings for each driver are shown in figures 6 and 7 below.



Home > Support > Software and Driver Downloads > NI Software Product Downloads > Download Detail Page

LabVIEW

LabVIEW is systems engineering software for applications that require test, measurement, and control.

[+ Read More](#)

DOWNLOADS

Supported OS [?] Windows [View Readme](#)

Version [?]

Application Bitness [?]

Note: Unless you require the additional memory provided by the 64-bit option, NI recommends that you download the 32-bit version. [Learn More](#)

Included Editions [?] ☐ Base, Full, Professional ☒ Runtime

Language [?] English, French, German, Japanese, Korean, Simplified Chinese

Driver Software Included [?] No

Figure 1: Download settings for NI LabVIEW Runtime Engine

Home > Support > Software and Driver Downloads > NI Driver Downloads > Download Detail Page

NI-VISA

NI-VISA provides support for customers using Ethernet, GPIB, serial, USB, and other types of instrument interfaces.

[+ Read More](#)

Note: Install programming environments such as NI LabVIEW or Microsoft Visual Studio.

DOWNLOADS

Supported OS	Windows	View Readme
Version	Use latest available	
Application Bitness	32-bit & 64-bit	
Included Editions	Full	
Language	English, French, German, Japanese, Korean, Simplified Chinese	

Figure 2: Download settings for NI VISA Runtime Engine

All of the software packages are compatible with 64-bit NI LabVIEW 2022-Q3 or later. For other versions, please contact your Surrey Sensors Ltd. sales representative.

3 CALIBRATION ALGORITHM

The calibration algorithm used is the generalized, sectorless technique based on that of Shaw-Ward *et al*¹, but updated to accommodate unsteady flows if required.

The pressure at each hole i on a probe sting (having any number of holes n) is reduced to a nondimensional coefficient C_i as

$$C_i = \frac{P_i - P_{min}}{P_{max} - P_{min}}$$

where P_i is the differential pressure recorded at hole $i = 0, 1, 2, \dots, n-1$; P_{max} and P_{min} are the maximum and minimum differential pressures recorded over all holes on a particular probe sting, respectively, and n is the number of holes. These coefficients are reasonably independent of velocity magnitude, but calibration should still be carried out near the expected operating speeds or at the centre of the expected range. During calibration, empirical functions $C_i(\alpha, \beta)$ are obtained (where α and β are the pitch and yaw angles) as well as a stagnation differential pressure coefficient C_0 .

During measurement, then, P_i is converted into C_i and an interpolation process is used to return the closest matching flow angles. With the matching flow angles then known, C_0 can be interpolated from the calibration data at those angles, returning the local stagnation pressure; the velocity magnitude can then be obtained from the stagnation pressure.

This generalized data reduction process is independent of the number of holes in the probe head and their arrangement (although three independent measures of pressure are fundamentally required in order to resolve three components of velocity). Typically, the uncertainty in a particular measurement will decrease with increasing hole numbers. Figure 3 shows the ranges of relative mean-square error ε as a function of number of holes k in a hemispherical-tip probe; error bars show variability in uncertainty with hole arrangement.

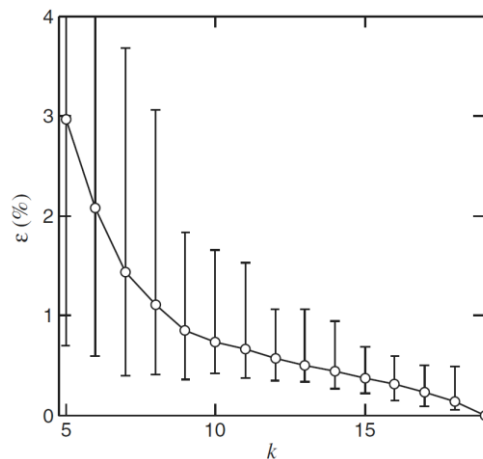


Figure 3: MSE Uncertainty bounds for arbitrarily positioned holes in a hemispherical-tip probe (from Shaw-Ward *et al.*¹)

¹ Shaw-Ward, S., Titchmarsh, A. and Birch, D. M. (2015) "Calibration and use of n -hole velocity probes." AIAA J. 53(2), 336-346.

4 CALIBRATION DATA RESTRUCTURING

Calibration files will normally be supplied as an unstructured list of data points; to be used in the data reduction process, these must first be converted into structured grids.

Calibration data file

The unstructured calibration data file must be in ASCII tab-delimited format with two header rows. An example of this is included in the sample data directory as [`\raw_calibration_files\Calibration_data.txt`]. The file may have any name and any extension, but the extension must be included any time the file name is used.

For a calibration file having n pressure measurements, the columns of the calibration data file must be organized as follows (with units as indicated):

β (deg)	α (deg)	P_0 (Pa)	P_1 (Pa)	...	P_{n-1} (Pa)	U_{REF} (m/s)	ρ (kg/m ³)	P_{ATM} (mBar)	T_{ATM} (°C)	RH (%)	a_x (g)	a_y (g)	a_z (g)
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The variables are defined as follows:

- α and β : these are the prescribed angles of pitch and yaw (respectively) for each calibration point.
- $P_0, P_1, \dots, P_{n-1}$: these are the list of pressures P_i for each calibration point, where $i = 0, 1, \dots, n-1$ and n is the number of pressure sensors. Note that P_0 here is the pressure at hole index [0], and **not** the stagnation pressure.
- U_{REF} : This is the free-stream speed at which the probe was calibrated. At every calibration point, then, $(u^2 + v^2 + w^2)^{1/2} = U_{REF}$ by definition.
- ρ : This is the estimated density of the fluid during calibration. Normally, this is approximated from the ideal gas law as $\rho = P_{ATM}/(\mathcal{R}T_{ATM})$, where $\mathcal{R}$ is the specific gas constant of the fluid ($\mathcal{R} \sim 287.05$ J/kgK for dry air).
- P_{ATM} and T_{ATM} : These are the ambient static pressure and temperature (respectively) during calibration. Note that P_{ATM} only is expressed in mBar (= Pa/100) here, for legacy reasons.
- RH : This is the relative humidity of the air at the time of calibration. The assumption here is that the calibration was carried out in air; if the humidity is unknown, enter zeros in this column.
- a_x, a_y and a_z : The ID7HP, ID8HP and FD7HP-series probes return the acceleration vector at each calibration point, for alignment purposes. These are not used as part of the calibration process; if not available, they may be populated with zeros.

Generating calibration data files

To facilitate (and accelerate) the interpolation process, the calibration data files used by the testing executable need to be in the form of structured grids in (α, β) . These are saved as independent files in user-readable ASCII format, for verification purposes. Appropriately-formatted calibration files may be generated from a single unstructured table of data points using the calibration file generation tool, CALIBRATION DATA RESAMPLER.EXE.

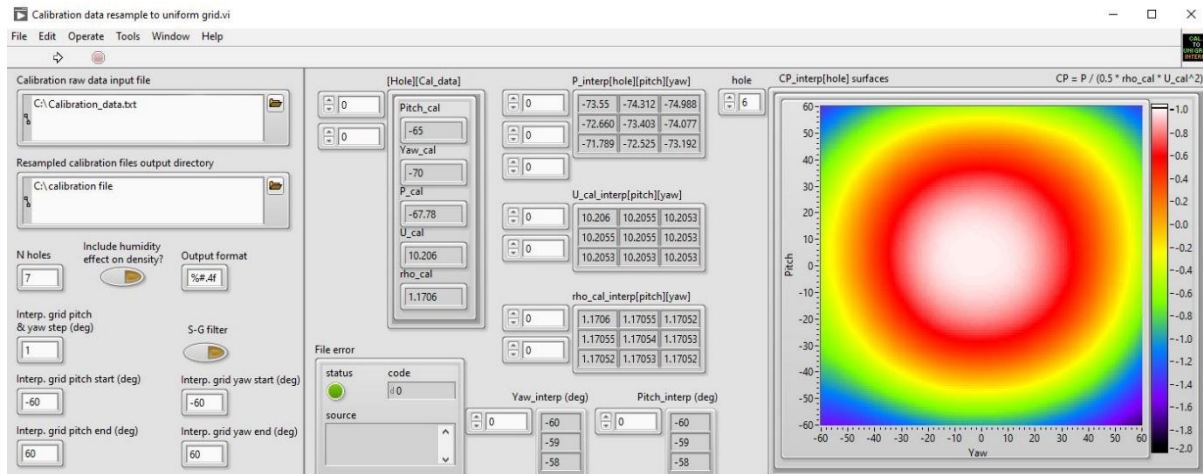


Figure 4: Calibration data resampler user interface

Operating instructions:

Step 1: Identify the unstructured (raw) calibration data file as described above. Once the file is identified, click on the folder icon in the [CALIBRATION RAW DATA INPUT FILE] field and navigate to the file location; select the file and click [OK].

Step 2: Locate directory for output files. The output files must all be in the same directory. Once the directory is identified, click on the folder icon in the [OUTPUT DIRECTORY] field and navigate to the directory location. Click on [CURRENT FOLDER] to select the active directory currently open in the window.

Step 3: Enter desired parameters for resampling. This software will interpolate your data over a regular grid, as required for the data conversion process. The user can tailor how this is done. The editable parameters are as follows:

N holes: Enter here the total number of pressure measurements from the probe. This should correspond to the number n of pressure channels appearing in the data files.

IMPORTANT: The ID8HP-series probes store the absolute static pressure as channel 0, and have an extra external temperature channel. These should not be used in the data reduction process. These columns of data will need to be manually removed from the data traces before conversion if this utility is used.

Include humidity effect on density?: When this button is enabled, the density estimates of the fluid will be adjusted to account for the relative humidity in the calibration data. If relative humidity data is not available, this should be left disabled.

Output format: This allows the user to modify the precision of the output data. Normally, this should be left to four decimal places, or [%#.4f], for calibration files.

Interp grid pitch & yaw step (deg): This allows the user to specify the grid spacing over which the data will be resampled. It is normally recommended that this be set to the raw data grid spacing (or smallest spacing, if a nonuniform measurement grid was used). Data will be resampled to the specified grid spacing using a piecewise nonlinear interpolation.

S-G filter: This option is available to minimize the influence of noise in the data fields, and reduce the uncertainty if the individual data points were not well converged. When enabled, a Savitzky-Golay² filter is used to smooth the fields.

Interp. grid. pitch start (deg): Minimum pitch angle at which calibration data will be required. This should normally be the minimum angle at which calibration data were obtained, although the option is available to use only a subset of the available raw data.

Interp. grid. yaw start (deg): Minimum yaw angle at which calibration data will be required. This should normally be the minimum angle at which calibration data were obtained, although the option is available to use only a subset of the available raw data.

Interp. grid. pitch end (deg): Maximum pitch angle at which calibration data will be required. This should normally be the maximum angle at which calibration data were obtained, although the option is available to use only a subset of the available raw data.

Interp. grid. yaw end (deg): Maximum yaw angle at which calibration data will be required. This should normally be the maximum angle at which calibration data were obtained, although the option is available to use only a subset of the available raw data.

Step 4: Run the executable. This is done by clicking on the arrow icon under the menu bar.

If the executable ran without error, a green indicator will appear under [STATUS] in the [FILE ERROR] field.

Once processing is complete, the executable will also display a contour plot of pressure coefficient as a function of α and β . The results from individual holes can be selected using the [HOLE] selector.

Output files

The calibration data resampler will generate a number of output data files which will later be used for data reduction.

Within the calibration directory, the structured calibration files will appear as follows:

Parameter	Filename
Pitch angles	Pitch_cal.txt
Yaw angles	yaw_cal.txt
Velocity	U_cal.txt
Density	rho_cal.txt
Pressures	P*_cal.txt

There are no header rows in these files: the variables will be stored in the same units as those in the unstructured data files. The structured calibration data file names must not be changed, or the data reduction software will not be able to locate them.

² Schafer, R. W. (2011) "What is a Savitzky-Golay Filter?" IEEE Sig. Proc. 28(4).

5 MEASUREMENT DATA CONVERSION

Data file format

Measurement data files will generally be in the form of time-histories from each of the sensors, measured simultaneously. The data conversion software requires a data file having two header rows, and columns as follows:

t	P_0	P_1	...	P_{n-1}	T_{ATM}	P_{ATM}	T_B	RH	a_x	a_y	a_z	ω_x	ω_y	ω_z
(s)	(Pa)	(Pa)		(Pa)	(°C)	(Pa)	(°C)	(%)	(g)	(g)	(g)	(°/s)	(°/s)	(°/s)

The variables are defined as follows:

- t : this is the time at which each measurement was collected, normally measured from the start of acquisition.
- $P_0, P_1, \dots, P_{n-1}$: these are the list of pressures P_i for each calibration point, where $i = 0, 1, \dots, n-1$, and n is the number of channels. Note that P_0 here is the pressure at hole index [0], and **not** the stagnation pressure.
- T_{ATM} and P_{ATM} : These are the ambient static pressure and temperature during measurement, which are required for data reduction.
- T_B : This is a measure of the system's internal temperature and is used for health monitoring. This is not used for data reduction; if the values are unavailable, enter zeros in this column.
- RH : This is the relative humidity of the air at the time of measurement. The assumption here is that the measurements were carried out in air; if the humidity is unknown or if the fluid was other than air, enter zeros in this column.
- a_x, a_y and a_z : The MD24HP-series rakes return the acceleration vector at each measurement point. These are not used as part of the data reduction process; if not available, these columns may be populated with zeros.
- ω_x, ω_y and ω_z : The MD24HP-series rakes also return the angular velocity vector at each measurement point. These are not used as part of the data reduction process; if not available, these columns may likewise be populated with zeros.

There may be additional columns that follow, if online data conversion had been enabled while the probe was measuring. These are ignored in the offline data reduction process.

Converting measurement data

The data reduction software [OFFLINE DATA CONVERTER.EXE] will read in a measurement time-history file and convert the pressures into three components of velocity.

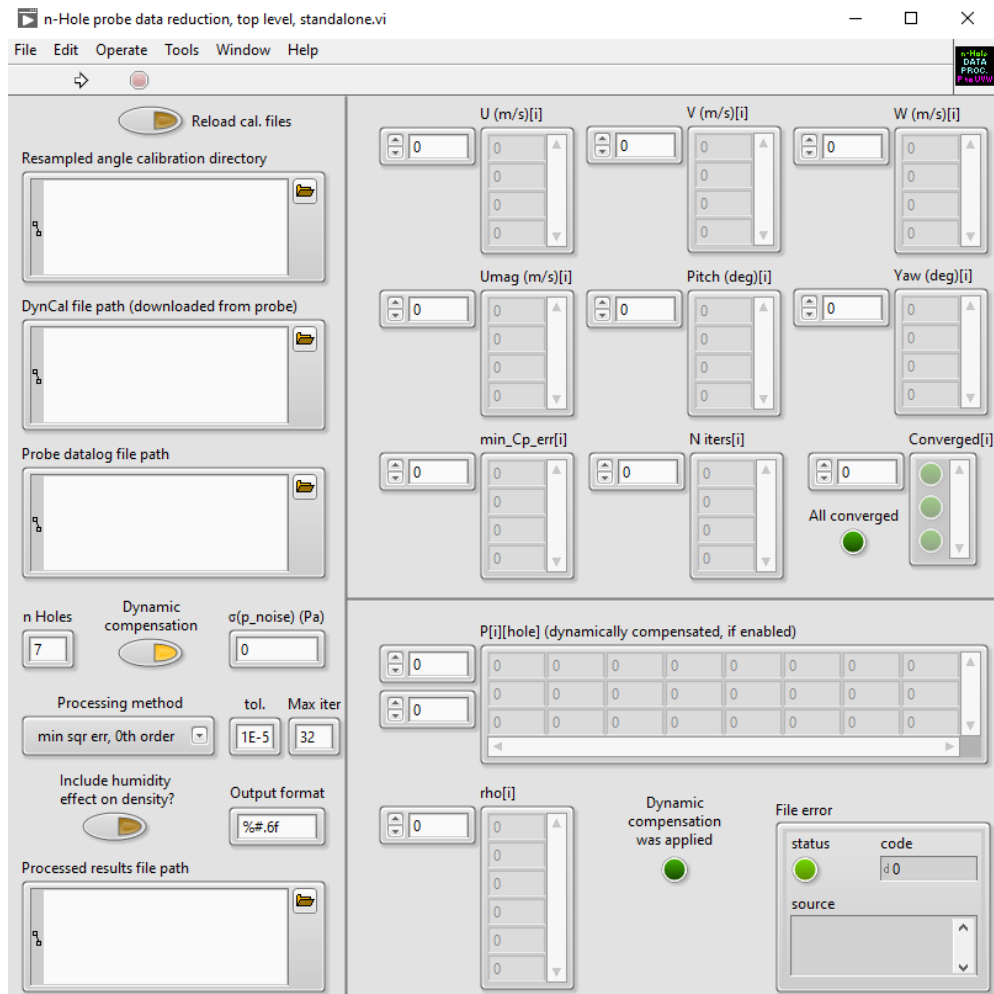


Figure 5: Data converter user interface

Operating instructions:

Step 1: Click on the folder icon in the [RESAMPLED ANGLE CALIBRATION DIRECTORY] field and navigate to the directory containing the calibration data. When these directories are visible in the navigation window, click the [SELECT FOLDER] button to select the currently active directory.

Step 2: If the probe was dynamically calibrated, the dynamic calibration data is stored in the probe's onboard memory. Download the calibration data file to the local disc following the instructions in the probe manual. Once downloaded from the probe, click on the folder icon in the [DYNCAL FILE PATH (DOWNLOADED FROM PROBE)] field and navigate to the file. Select the file and click [OK]. If the probe was not dynamically calibrated, leave this field blank.

Calibration data will be held in memory and reused unless the [RELOAD CAL. FILES] switch is enabled.

Step 3: Locate the measurement data file. Once the file is identified, click on the folder icon in the [PROBE DATALOG FILE PATH] field and navigate to the file. Select the file and click [OK].

Step 4: Select or create a directory for output file. Click on the folder icon in the [PROCESSED RESULTS FILE PATH] field and create the file name. Click on [OK].

Step 5: Enter desired parameters for data conversion. The editable parameters are as follows:

N Holes: Enter here the total number of pressure measurements from the probe. This should correspond to the number n of pressure channels appearing in the calibration data files. Because the indexing starts at [0], the highest channel index will be $n-1$. Again, note that for the ID8HP-series, channel 0 should not be included here.

Dynamic compensation: If the probe was dynamically calibrated and dynamic calibration data are identified in the [DYNCAL FILE PATH] field, the dynamic calibration process will be carried out as part of the post-processing. If the probe was not dynamically calibrated, leave this function disabled.

$\sigma(P_noise)$: If the probe was dynamically calibrated, the probe's background noise can be filtered from the dynamic calibration process. Enter the value here of the background noise measured at the time of the experiments (see the probe's instruction manual for how to obtain this value).

Processing method: This instructs the software which method to use when interpolating from the calibration data grids; different techniques will yield slightly different results, and the quality of the output from each technique may vary depending on the measurements collected. Note that [0TH ORDER] does not interpolate and instead returns the closest point from the calibration.

Tol.: This is the convergence threshold for the interpolation process. A value of 10^{-5} (entered as [1E-5]) is recommended.

Max iter.: This allows the user to specify the maximum number of iterations in the interpolation process, to avoid hang-ups on oscillating solutions. A value of [32] is recommended.

Include humidity effect on density?: When this button is enabled, the density estimates of the fluid will be adjusted to account for the relative humidity in the measurement data. If relative humidity data is not available or not relevant, this should be left disabled.

Output format: This allows the user to modify the precision of the output data. Normally, this should be left to six decimal places, or [%# . 6f].

Step 6: Run the executable. This is done by clicking on the arrow icon under the menu bar.

If the executable ran without error, a green indicator will appear under [STATUS] in the [FILE ERROR] field. The user may then inspect the outputs.

Output files

Within the output data file, there will be one header line containing column labels, followed by data arranged in columns as follows:

t (s)	U (m/s)	V (m/s)	W (m/s)	U_{MAG} (m/s)	α (deg)	β (deg)	ρ (kg/m ³)	ΔC_p	n_{IT}	<i>Converged</i>
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The variables are defined as follows:

- t : this is the time of the data point, reproduced from the original (raw) data file.
- U , V , W : these are the three orthogonal velocity components obtained from the data reduction process. The directions x , y and z are defined by the coordinate system used during calibration.
- U_{MAG} : this is the magnitude of the output velocity, obtained from the velocity components as $U_{MAG} = (U^2 + V^2 + W^2)^{1/2}$.
- α and β : these are the angles of pitch and yaw (respectively) of the output velocity, obtained from the velocity components.
- ρ : this is the density estimate used for data reduction at this point.
- ΔC_p : this is the estimated maximum interpolation error in pressure coefficient at this point.
- n_{IT} : this is the number of iterations required to achieve convergence at this point. Note that this is not relevant if "zeroth order" interpolation was selected under [PROCESSING METHOD].
- *Converged?*: This is a check-bit for convergence. The value will be [0] if the interpolator was unable to converge to a solution at this point, so that the data returned will be invalid. Note that this is not relevant if "zeroth order" interpolation was selected under [PROCESSING METHOD].

6 TECHNICAL SUPPORT

Full technical support is available for the implementation of this software with Surrey Sensors Ltd. products.

If you experience any difficulty in installation or use, or if you need additional support in the operation of the system, please contact your Surrey Sensors Ltd. account manager or technical representative.

Appendix: Reference coordinate systems

The spherical coordinate system commonly used in physics (ISO 80000-2:2019 convention) is adopted here and used throughout. By convention, the pitch angle α increases with rotation toward the z-axis, and the yaw angle β is positive rotating anti-clockwise about the z-axis (see figure 9). Here, u , v and w are the velocity components along x , y and z , respectively.

In some early data reduction algorithms, the cone angle θ and roll angle ϕ were used. These are not relevant here.

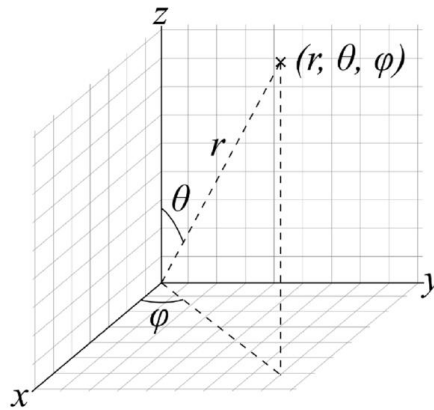


Figure 6: Coordinate conventions

In all cases, by convention, the pitch angle α and yaw angle β are defined as

$$\begin{aligned}\alpha &= 90^\circ - \theta \\ \beta &= \phi\end{aligned}$$

Probe-based coordinate system:

This convention is intended for use on a moving platform, such as an aircraft or vehicle.

$$\begin{aligned}u &= |U| \cos(\beta) \cos(\alpha) \\ v &= |U| \sin(\beta) \cos(\alpha) \\ w &= |U| \sin(\alpha)\end{aligned}$$

Wind tunnel-based coordinate system:

This convention is intended for use in stationary-probe wind tunnel applications with a right-handed coordinate system with the probe pointing in the upstream x direction, such that the z -axis is vertical (environmental flow convention).

$$\begin{aligned}u &= |U| \cos(\beta) \cos(\alpha) \\ v &= -|U| \sin(\beta) \cos(\alpha) \\ w &= |U| \sin(\alpha)\end{aligned}$$

Rotated wind tunnel-based coordinate system:

This convention is intended for use in stationary-probe wind tunnel applications with a right-handed coordinate system with the probe pointing in the upstream x direction, such that the y-axis is vertical (aerospace flow convention).

$$\begin{aligned}u &= |U| \cos(\beta) \cos(\alpha) \\v &= |U| \sin(\alpha) \\w &= |U| \sin(\beta) \cos(\alpha)\end{aligned}$$

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