# Report on Acceleration Comparison SIM.AUV.V-K1

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## ABSTRACT

The first regional key comparison in vibration conducted under the auspices of the Inter-American System of Metrology (SIM) was begun in 1996. The comparison was registered with the International Bureau of Weights and Measures (BIPM) through the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV) under the key comparison designation of SIM.AUV.V-K1. The National Measurement Institutes (NMIs) of five countries participating in SIM performed and reported calibrations of one back-to-back and two single-ended accelerometers for this comparison during the time period of 1997 to 1999. The participants in the comparison were: Argentina (INTI); Brazil (INMETRO); Canada (NRC); Mexico (CENAM); and the United States (NIST). Reference Values (RVs) were established for the SIM.AUV.V-K1 comparison using maximum likelihood consensus estimation applied to the summary values of charge sensitivity with the nominal numbers of repeat measurements reported by the participating NMIs. Degrees of equivalence between the results reported by the NMIs and the RVs as well as pairwise degrees of equivalence between the results reported by the NMIs were computed using the uncertainties associated with the results reported by the NMIs and those of the RVs as appropriate. Transformation values were found in order to link the results of SIM.AUV.V-K1 with those of the first international key comparison in vibration conducted under the auspices of the CCAUV during 1999 to 2001 (CCAUV.V-K1). The degrees of equivalence between the NMIs participating in SIM.AUV.V-K1 and those participating in CCAUV.V-K1 were established using linkage values computed from the transformation values.

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## 1. Introduction

This report presents the results and statistical analysis of the first Regional Metrology Organization (RMO) comparison in vibration by the Inter-American System of Metrology (SIM), SIM.AUV.V-K1. Planning of the comparison began in 1996, in part, as a result of discussions related to the development of regional mutual recognition agreements that took place among regional metrology organizations. The measurement results for the comparison were obtained concurrently with the formal development of the Mutual Recognition Arrangement (CIPM MRA) and the associated *Guidelines for CIPM key comparisons*. Consequently, it was not possible at the outset of the comparison to fully conform to the procedures given in these documents. Nonetheless, the results reported for this comparison by the participating National Measurement Institutes (NMIs), and the statistical analysis of these results, in general, indicate robust agreement among the NMI results as well as among these results and the SIM Reference Values (SIM RVs), given the claimed uncertainties of the NMIs and the uncertainties of the SIM RVs. This report supersedes the Provisional Report dated 09 December 2004 that is duplicated in Appendix I which was submitted to the BIPM in December 2004. The Provisional Report was subjected to review and approval by all of the NMIs that participated in the comparison.

## 2. Participants

The National Measurement Institutes that participated in SIM.AUV.V-K1 were all members of SIM (the Regional Metrology Organization of the Americas) and were representatives of the SIM subregions of NORAMET and SURAMET.

Listed in alphabetical order, the five participants in SIM.AUV.V-K1 were:

Argentina: Instituto Nacional de Technología Industrial (INTI);
Brazil: Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO);
Canada: National Research Council Canada (NRC);
Mexico: Centro Nacional de Metrología (CENAM);
United States: National Institute of Standards and Technology (NIST), Pilot Lab.

The transfer standards were circulated in the following chronological order beginning with NIST. The time periods during which measurements were performed by the NMIs are given next to the names of the institutes.

| | |
|---|---|
| NIST | February – May 1997 |
| NRC | September – October 1997 |
| INMETRO | February – March 1998 |
| CENAM | March – April 1998 |
| INTI | July – September 1998 |
| NIST | December 1998 – January 1999 |

The instruments were hand-carried from institute to institute by laboratory personnel. The results of calibrations performed at NIST in 1997 and 1998-1999 are contained in the Provisional Report and are designated as NIST97 and NIST99, respectively.

The NIST results used to derive the statistical figures of merit contained in this report, the SIM RVs, degrees of equivalence, etc., are based on the mean of NIST97 and NIST99 and are denoted simply as NIST. The transducers are listed in order of decreasing sensitivity beginning with the most sensitive, and the NMIs are listed in the chronological order in which the measured sensitivities were obtained by the participating laboratories, ending with the average of the 1997 and 1998-1999 results obtained by NIST. These ordering conventions are followed throughout the main body of this report.

## 3. Measurement Protocol

Sensitivities were determined for two single-ended (SE) and one back-to-back (BB) piezoelectric accelerometers using sinusoidal excitation over a frequency range of 50 Hz to 5 kHz and a nominal amplitude range of 20 $m/s^2$ to 200 $m/s^2$ peak. A signal conditioning (charge) amplifier was circulated with the accelerometers and used in determining the sensitivities of the transducers. The actual instrumentation used in the comparison is summarized in Table 1.

Table 1. Transfer Standards and Charge Amplifier[a].

| Instrument | Manufacturer | Model | Serial Number |
|---|---|---|---|
| SE Accelerometer | Endevco | 2270M8 | 10472 |
| BB Accelerometer | Brüel & Kjær | 8305 | 1687773 |
| SE Accelerometer | Kistler | 8002K | 100443 |
| Charge Amplifier | Brüel & Kjær | 2626 | 1662291 |

[a] Identification of the equipment listed does not imply recommendation or endorsement by NIST, nor does it imply that the equipment identified is necessarily the best available for the purpose.

INMETRO, CENAM, INTI, and NIST measured and reported the gain of the charge amplifier in voltage per unit charge (see the Provisional Report in Appendix I) as well as the sensitivities of the accelerometers in charge per unit acceleration. NRC did not calibrate the gain of the charge amplifier and reported the sensitivity of the accelerometers in combination with the charge amplifier in voltage per unit acceleration.

Standardized primary methods defined in ISO 5347-1:1993 (subsequently revised by ISO 16063-11:1999) were to be used to calibrate the sensitivity of the accelerometers. Standardized secondary methods defined in ISO 5347-3:1993 (subsequently revised by ISO 16063-21:2003) were also acceptable [1-5]. The four methods used to calibrate the sensitivities of the accelerometers for SIM.AUV.V-K1 were: fringe counting (FC); minimum point (MP); fringe disappearance (FD); and comparison (C). Fringe counting, minimum point and fringe disappearance are primary methodologies, and comparison is a secondary methodology. When calibrations were performed by comparison, the primary standard was a back-to-back accelerometer (either one independently owned by the NMI or the one used in the regional comparison) that had been calibrated using one of the primary methods listed above. The results reported by the NMIs were typically derived from measurements made using one method, with some exceptions depending on the NMI, frequency, and the type of transducer. The methods used by the NMIs in performing calibrations for SIM.AUV.V-K1 are listed in Table 2 as a function and frequency and transducer.

Table 2. Calibration Methodologies[a].

| Frequency (Hz) | SE Transducer Endevco 2270M8 s/n 10472 | | | | |
|---|---|---|---|---|---|
| | NRC | INMETRO | CENAM | INTI | NIST |
| 50 | C | FC | FC | FC | FC |
| 80 | C | FC & C | FC | FC | FC |
| 100 | C | C | FC | FC | FC |
| 159.2 | C | FC & C | FC | FC | FC |
| 250 | C | FC & C | FC | FC | FC |
| 500 | C | FC & C | FC | FC | FC |
| 800 | C | FC & C | MP & FC | FC | FC |
| 1000 | C | FC & C | MP | FC | FC |
| 3500 | C | MP & C | MP | | FD |
| 5000 | C | C | MP | | FD |
| | BB Transducer Brüel & Kjær 8305 s/n 1687773[b] | | | | |
| 50 | FC | FC | FC | FC | FC |
| 80 | FC | FC | FC | FC | FC |
| 100 | FC | FC | FC | FC | FC |
| 159.2 | FC | FC | FC | FC | FC |
| 250 | FC | FC | FC | FC | FC |
| 500 | FC | FC | FC | FC | FC |
| 800 | MP | FC | MP & FC | FC | FC |
| 1000 | MP | FC | MP | MP & FC | FC |
| 3500 | MP | MP | MP | MP | FD |
| 5000 | MP | MP | MP | MP | FD |
| | SE Transducer Kistler 8002K s/n 100443 | | | | |
| 50 | C | FC & C | FC | FC | FC |
| 80 | C | FC & C | FC | FC | FC |
| 100 | C | FC & C | FC | FC | FC |
| 159.2 | C | FC & C | FC | FC | FC |
| 250 | C | FC & C | FC | FC | FC |
| 500 | C | FC & C | FC | FC | FC |
| 800 | C | FC & C | MP & FC | FC | FC |
| 1000 | C | FC & C | MP | FC | FC |
| 3500 | C | MP & C | MP | | FD |
| 5000 | C | C | MP | | FD |

[a]Methodologies: Fringe Counting (FC); Minimum Point (MP); Fringe Disappearance (FD); Comparison (C).

[b]Nominal mass loading of the back-to-back transducer during calibration: NRC 4 g; INMETRO 2 g; CENAM 20 g; INTI 5 g; and NIST <1 g.

## 4. Results

Measured sensitivities were reported as a function of frequency and transducer by the five NMIs as single values ($x_i$, i = 1-5) with, in some cases, the measurement results of repeat trials also included. The voltage sensitivities reported by NRC (see Table II-1 in Appendix II) were converted to charge sensitivities, upon the recommendation and with the approval of the NRC, by taking the ratio of the sensitivities reported by NRC to the mean of the gains of the charge amplifier reported by CENAM, INMETRO, INTI, and NIST (see Appendix I). The voltage sensitivities and their associated relative combined uncertainties reported by NRC as well as the charge sensitivities and their associated relative combined uncertainties computed for NRC are contained in Appendix II. The SIM Comparison Reference Values (SIM RVs) and degrees of equivalence ($D_i$, $U_i$ and $D_{ij}$, $U_{ij}$) contained in this report are based on charge sensitivity as reported by, or computed for, the participating NMIs.

The SIM Comparison Reference Values ($x_{RV}$) as well as their associated uncertainties were computed from the mean values of sensitivity with associated standard uncertainties and the nominal numbers of repeat measurements reported by the NMIs using Maximum Likelihood Estimation (MLE) [6]. The SIM RV's reported here are based on measurements from five NMIs except for the single-ended accelerometers at 3.5 kHz and 5 kHz for which only four NMIs submitted results. The combined uncertainties ($u_i$, i = 1-5) of the five NMIs were computed by normalizing each expanded uncertainty by the coverage factor ($k$) [7] reported by the participating laboratories as a function of frequency and transducer. In the case of NRC, the mean of the uncertainties (for $k = 1$) reported by the other four NMIs (INMETRO, CENAM, INTI, and NIST) in determining gain of the charge amplifier were combined in root-sum-square with the combined uncertainties reported by NRC for their respective voltage sensitivities. The uncertainties ($u_{RV}$) of the SIM RVs were computed using an approximation to maximum likelihood [6]. The summary results reported by the NMIs and their relative uncertainties, as well as the SIM RVs and their relative uncertainties, are contained in Tables 3a through 3c as a function of frequency and transducer for a coverage factor of $k = 1$. The summary results of charge sensitivity and associated uncertainties are expressed to the number of significant figures reported by the participating NMIs. These values are those that were used to compute the SIM RVs, the degrees of equivalence, and their related uncertainties. The number of nominal repeat measurements used to compute the SIM RVs are contained in Table 4 as a function of NMI, frequency, and transducer.

It is often the case that consensus estimates are based on data from more than one source, one method, or both. This is especially true when no single source or method can provide the necessary level of accuracy, or when there is no single method whose sources of uncertainty are well understood and quantified. Measurements from different sources, different instruments, and different methods can exhibit significant between-source and between-method variability, as well as distinct within-source and within-method variability. The objective in computing a SIM RV is to compute a best consensus value, and to attach a meaningful consensus uncertainty to that value.

One approach to computing consensus estimates is to obtain an explicit estimate of the inter-method (between-laboratory) variance and to combine that with a pooled estimate of the within-method (within-laboratory) variances—using the combination to weight the contributions from the different methods and laboratories to compute a consensus mean. An estimation equation approach to the determination of variance of the between-method component, between-laboratory component, or both components has long been employed at NIST. Vangel-Rukhin [6] showed that an appropriately modified version of this approach yields arbitrarily good approximations to the maximum likelihood estimate of the consensus mean. The MLE estimate of the interlaboratory variance is determined, and added in quadrature to the standard pooled estimate of within-laboratory variance. This method has the virtue of explicitly quantifying the “within” component and “between” component of variance, and the advantage of being rooted in the broadly applicable general method of maximum likelihood.

Table 3a. Single-Ended Accelerometer: Endevco 2270M8 s/n 10472.
Summary results reported by National Measurement Institutes ($x_i$) and the associated SIM Reference Value ($x_{RV}$) with relative uncertainties ($u_i$ & $u_{RV}$) for a coverage factor of *k* = 1.

| Source | Quantity | Unit | Frequency (Hz) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 50 | 80 | 100 | 159.2 | 250 |
| NRC | $x_1$ | pC/(m/s$^2$) | 0.2022 | 0.2031 | 0.2026 | 0.2022 | 0.2024 |
| | $u_1$ | % | 0.460 | 0.461 | 0.460 | 0.461 | 0.471 |
| INMETRO | $x_2$ | pC/(m/s$^2$) | 0.20305 | 0.20309 | 0.20298 | 0.20300 | 0.20284 |
| | $u_2$ | % | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| CENAM | $x_3$ | pC/(m/s$^2$) | 0.2029 | 0.2027 | 0.2027 | 0.2025 | 0.2025 |
| | $u_3$ | % | 0.253 | 0.253 | 0.253 | 0.253 | 0.404 |
| INTI | $x_4$ | pC/(m/s$^2$) | 0.20377 | 0.20348 | 0.20285 | 0.20276 | 0.20281 |
| | $u_4$ | % | 0.55 | 0.55 | 0.55 | 0.55 | 0.65 |
| NIST | $x_5$ | pC/(m/s$^2$) | 0.20335 | 0.20271 | 0.20254 | 0.20287 | 0.20248 |
| | $u_5$ | % | 0.15 | 0.15 | 0.14 | 0.15 | 0.15 |
| SIM RV | $x_{RV}$ | pC/(m/s$^2$) | 0.20317 | 0.20283 | 0.20267 | 0.20279 | 0.20256 |
| | $u_{RV}$ | % | 0.061 | 0.044 | 0.049 | 0.041 | 0.039 |

| Source | Quantity | Unit | Frequency (Hz) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 500 | 800 | 1000 | 3500 | 5000 |
| NRC | $x_1$ | pC/(m/s$^2$) | 0.2022 | 0.2024 | 0.2021 | 0.2012 | 0.2010 |
| | $u_1$ | % | 0.539 | 0.926 | 0.925 | 0.928 | 0.948 |
| INMETRO | $x_2$ | pC/(m/s$^2$) | 0.20273 | 0.20286 | 0.20289 | 0.20344 | 0.20450 |
| | $u_2$ | % | 0.25 | 0.25 | 0.25 | 0.50 | 0.50 |
| CENAM | $x_3$ | pC/(m/s$^2$) | 0.2022 | 0.2022 | 0.2027 | 0.2029 | 0.2024 |
| | $u_3$ | % | 0.404 | 0.404 | 0.408 | 0.714 | 0.765 |
| INTI | $x_4$ | pC/(m/s$^2$) | 0.20423 | 0.20409 | 0.20455 | | |
| | $u_4$ | % | 0.65 | 0.65 | 0.65 | | |
| NIST | $x_5$ | pC/(m/s$^2$) | 0.20247 | 0.20279 | 0.20207 | 0.20397 | 0.20479 |
| | $u_5$ | % | 0.17 | 0.43 | 0.23 | 0.63 | 0.60 |
| SIM RV | $x_{RV}$ | pC/(m/s$^2$) | 0.20255 | 0.20279 | 0.20257 | 0.20322 | 0.20396 |
| | $u_{RV}$ | % | 0.045 | 0.073 | 0.127 | 0.161 | 0.241 |

Table 3b. Back-to-Back Accelerometer: Brüel & Kjær 8305 s/n 1687773.
Summary results reported by National Measurement Institutes ($x_i$) and the associated SIM Reference Value ($x_{RV}$) with relative uncertainties ($u_i$ & $u_{RV}$) for a coverage factor of $k$ = 1.

| Source | Quantity | Unit | Frequency (Hz) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 50 | 80 | 100 | 159.2 | 250 |
| NRC | $x_1$ | pC/(m/s$^2$) | 0.1249 | 0.1254 | 0.1250 | 0.1251 | 0.1251 |
| | $u_1$ | % | 0.145 | 0.138 | 0.145 | 0.154 | 0.167 |
| INMETRO | $x_2$ | pC/(m/s$^2$) | 0.12515 | 0.12513 | 0.12511 | 0.12512 | 0.12524 |
| | $u_2$ | % | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| CENAM | $x_3$ | pC/(m/s$^2$) | 0.1251 | 0.1252 | 0.1252 | 0.1252 | 0.1250 |
| | $u_3$ | % | 0.253 | 0.253 | 0.253 | 0.253 | 0.253 |
| INTI | $x_4$ | pC/(m/s$^2$) | 0.12441 | 0.12444 | 0.12454 | 0.12466 | 0.12485 |
| | $u_4$ | % | 0.55 | 0.55 | 0.55 | 0.55 | 0.65 |
| NIST | $x_5$ | pC/(m/s$^2$) | 0.12519 | 0.12503 | 0.12499 | 0.12507 | 0.12502 |
| | $u_5$ | % | 0.15 | 0.15 | 0.14 | 0.15 | 0.15 |
| SIM RV | $x_{RV}$ | pC/(m/s$^2$) | 0.12505 | 0.12519 | 0.12502 | 0.12509 | 0.12507 |
| | $u_{RV}$ | % | 0.062 | 0.080 | 0.023 | 0.016 | 0.027 |

| Source | Quantity | Unit | Frequency (Hz) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 500 | 800 | 1000 | 3500 | 5000 |
| NRC | $x_1$ | pC/(m/s$^2$) | 0.1250 | 0.1258 | 0.1266 | 0.1256 | 0.1263 |
| | $u_1$ | % | 0.314 | 0.391 | 0.398 | 0.393 | 0.440 |
| INMETRO | $x_2$ | pC/(m/s$^2$) | 0.12522 | 0.12531 | 0.12538 | 0.12631 | 0.12761 |
| | $u_2$ | % | 0.25 | 0.25 | 0.25 | 0.50 | 0.50 |
| CENAM | $x_3$ | pC/(m/s$^2$) | 0.1252 | 0.1252 | 0.1252 | 0.1253 | 0.1260 |
| | $u_3$ | % | 0.253 | 0.253 | 0.255 | 0.253 | 0.253 |
| INTI | $x_4$ | pC/(m/s$^2$) | 0.12522 | 0.12489 | 0.12491 | 0.12538 | 0.12642 |
| | $u_4$ | % | 0.65 | 0.65 | 0.65 | 0.75 | 0.75 |
| NIST | $x_5$ | pC/(m/s$^2$) | 0.12511 | 0.12490 | 0.12503 | 0.12691 | 0.12744 |
| | $u_5$ | % | 0.17 | 0.43 | 0.23 | 0.63 | 0.60 |
| SIM RV | $x_{RV}$ | pC/(m/s$^2$) | 0.12514 | 0.12527 | 0.12530 | 0.12561 | 0.12655 |
| | $u_{RV}$ | % | 0.023 | 0.073 | 0.114 | 0.163 | 0.238 |

Table 3c. Single-Ended Accelerometer: Kistler 8002K s/n 100443.
Summary results reported by National Measurement Institutes ($x_i$) and the associated SIM Reference Value ($x_{RV}$) with relative uncertainties ($u_i$ & $u_{RV}$) for a coverage factor of $k$ = 1.

| Source | Quantity | Unit | Frequency (Hz) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 50 | 80 | 100 | 159.2 | 250 |
| NRC | $x_1$ | pC/(m/s$^2$) | 0.1065 | 0.1069 | 0.1066 | 0.1065 | 0.1066 |
| | $u_1$ | % | 0.460 | 0.459 | 0.459 | 0.460 | 0.471 |
| INMETRO | $x_2$ | pC/(m/s$^2$) | 0.10650 | 0.10646 | 0.10646 | 0.10653 | 0.10656 |
| | $u_2$ | % | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| CENAM | $x_3$ | pC/(m/s$^2$) | 0.1069 | 0.1064 | 0.1065 | 0.1062 | 0.1061 |
| | $u_3$ | % | 0.255 | 0.255 | 0.255 | 0.255 | 0.408 |
| INTI | $x_4$ | pC/(m/s$^2$) | 0.10579 | 0.10593 | 0.10601 | 0.10617 | 0.10618 |
| | $u_4$ | % | 0.55 | 0.55 | 0.55 | 0.55 | 0.65 |
| NIST | $x_5$ | pC/(m/s$^2$) | 0.10665 | 0.10637 | 0.10647 | 0.10669 | 0.10660 |
| | $u_5$ | % | 0.15 | 0.15 | 0.14 | 0.15 | 0.15 |
| SIM RV | $x_{RV}$ | pC/(m/s$^2$) | 0.10663 | 0.10640 | 0.10646 | 0.10654 | 0.10654 |
| | $u_{RV}$ | % | 0.055 | 0.035 | 0.018 | 0.095 | 0.048 |
| Source | Quantity | Unit | Frequency (Hz) | | | | |
| | | | 500 | 800 | 1000 | 3500 | 5000 |
| NRC | $x_1$ | pC/(m/s$^2$) | 0.1066 | 0.1061 | 0.1065 | 0.1068 | 0.1072 |
| | $u_1$ | % | 0.539 | 0.926 | 0.926 | 0.928 | 0.947 |
| INMETRO | $x_2$ | pC/(m/s$^2$) | 0.10655 | 0.10663 | 0.10670 | 0.10755 | 0.10849 |
| | $u_2$ | % | 0.25 | 0.25 | 0.25 | 0.50 | 0.50 |
| CENAM | $x_3$ | pC/(m/s$^2$) | 0.1060 | 0.1060 | 0.1064 | 0.1065 | 0.1066 |
| | $u_3$ | % | 0.408 | 0.408 | 0.408 | 0.765 | 0.612 |
| INTI | $x_4$ | pC/(m/s$^2$) | 0.10661 | 0.10718 | 0.10725 | | |
| | $u_4$ | % | 0.65 | 0.65 | 0.65 | | |
| NIST | $x_5$ | pC/(m/s$^2$) | 0.10652 | 0.10683 | 0.10637 | 0.10790 | 0.10842 |
| | $u_5$ | % | 0.17 | 0.43 | 0.23 | 0.63 | 0.60 |
| SIM RV | $x_{RV}$ | pC/(m/s$^2$) | 0.10649 | 0.10657 | 0.10654 | 0.10736 | 0.10779 |
| | $u_{RV}$ | % | 0.046 | 0.120 | 0.096 | 0.218 | 0.399 |

Table 4. Number of Repeat Measurements Used for Computing the SIM RVs

| Frequency (Hz) | NRC | | | INMETRO | | | CENAM | | | INTI | | | NIST | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SE[a] | BB[b] | SE[c] | SE[a] | BB[b] | SE[c] | SE[a] | BB[b] | SE[c] | SE[a] | BB[b] | SE[c] | SE[a] | BB[b] | SE[c] |
| 50 | 22 | 20 | 22 | 10 | 20 | 12 | 90 | 78 | 102 | 6 | 6 | 6 | 6 | 8 | 7 |
| 80 | 22 | 20 | 22 | 12 | 20 | 12 | 90 | 78 | 102 | 6 | 6 | 6 | 6 | 8 | 7 |
| 100 | 22 | 20 | 22 | 2 | 20 | 12 | 90 | 78 | 102 | 6 | 6 | 6 | 8 | 8 | 7 |
| 159.2 | 22 | 20 | 22 | 12 | 20 | 12 | 90 | 78 | 102 | 6 | 6 | 6 | 8 | 8 | 7 |
| 250 | 22 | 20 | 22 | 12 | 20 | 12 | 90 | 78 | 102 | 6 | 6 | 6 | 8 | 8 | 7 |
| 500 | 22 | 20 | 22 | 12 | 20 | 12 | 90 | 78 | 102 | 6 | 6 | 6 | 8 | 8 | 7 |
| 800 | 22 | 20 | 22 | 12 | 20 | 12 | 90 | 78 | 102 | 6 | 6 | 6 | 8 | 8 | 7 |
| 1000 | 22 | 20 | 22 | 12 | 20 | 12 | 228 | 124 | 314 | 6 | 6 | 6 | 8 | 8 | 7 |
| 3500 | 22 | 20 | 22 | 12 | 20 | 12 | 212 | 82 | 150 | | 4 | | 9 | 14 | 16 |
| 5000 | 22 | 20 | 22 | 2 | 20 | 2 | 268 | 86 | 146 | | 3 | | 9 | 14 | 15 |

[a]Endevco 2270M8 s/n 10472
[b]Brüel & Kjær 8305 s/n 1687773
[c]Kistler 8002K s/n 100443

Plots shown in Figure 1 summarize trends of the SIM RVs with expanded uncertainty for the three standard accelerometers as a function of frequency (x-axis). As expected, the transducers exhibit increasing sensitivity with increasing frequency and have relatively uniform sensitivity at frequencies less than 1 kHz.

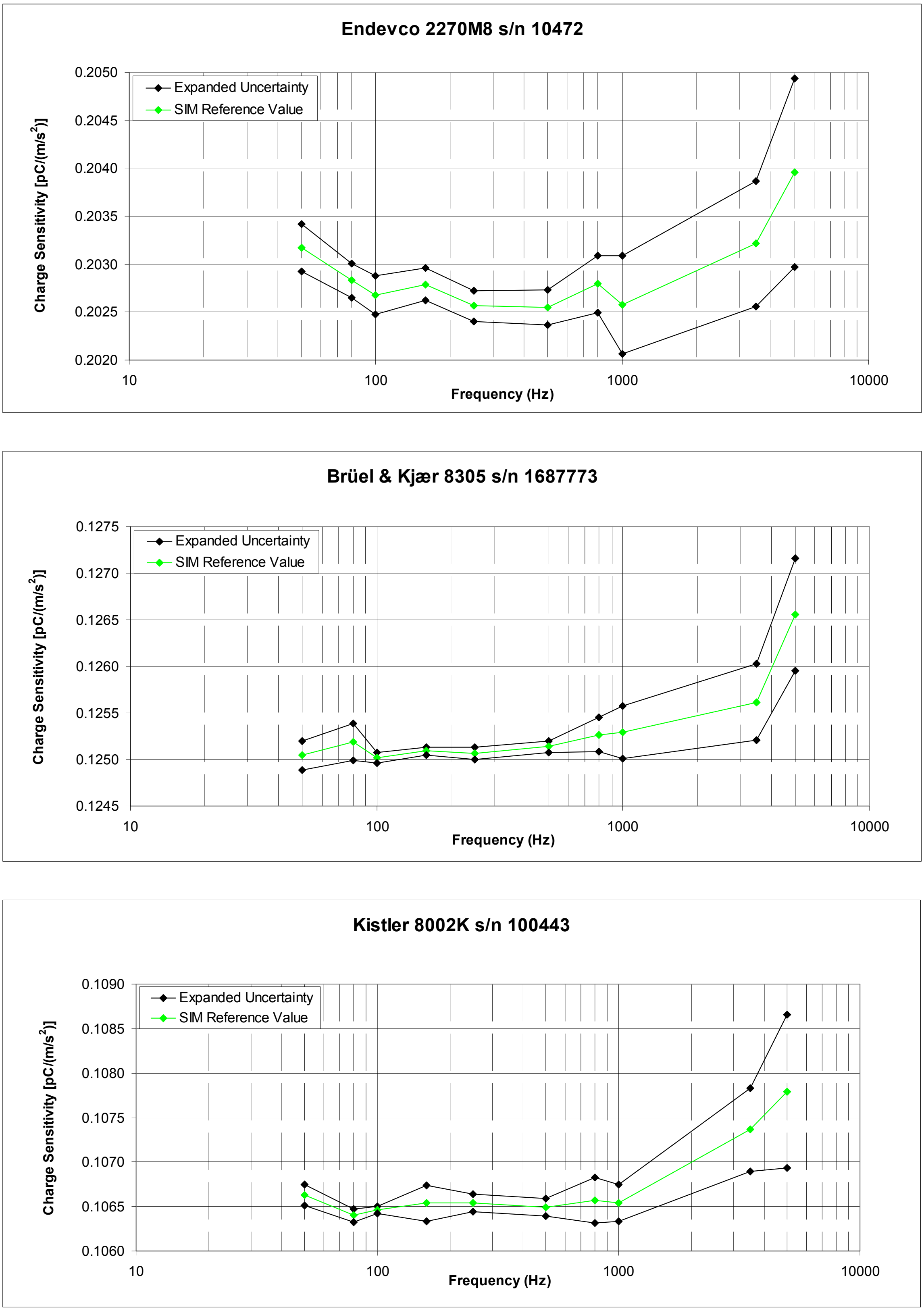



Figure 1. SIM RV with expanded uncertainty for a coverage factor *k* = 2.

## 5. Degrees of Equivalence

The degrees of equivalence of laboratory results with respect to the SIM RVs and between pairs of laboratories are given in tables below as a function of frequency and transducer. The degree of equivalence with respect to a SIM RV is the difference ($D_i$) between the summary value reported by a laboratory and the SIM RV estimator with an associated uncertainty of this difference expanded by a coverage factor of $k = 2$ ($U_i$). The pairwise degree of equivalence between laboratories is the difference between summary values reported by two laboratories ($D_{ij}$) and the uncertainty associated with this difference expanded by a coverage factor of $k = 2$ ($U_{ij}$). These differences and associated uncertainties are accompanied by a plot showing the relative measurement performance of each laboratory given a specific frequency and accelerometer. The reported summary values are drawn as dark blue diamonds with the whiskers representing associated expanded uncertainties for a coverage factor of $k = 2$. The plots also show the SIM RV (bright green diamond) and associated expanded uncertainty for a coverage factor of $k = 2$. Formulae from which the degrees of equivalence, that is the differences and their uncertainties, were calculated are at the bottom of each of the tables.

In the case of the expression for the uncertainty $U(D)_i$ of differences between the summary values reported by the participating laboratories and the SIM reference values, the computation employed the summation in quadrature of the uncertainties associated with the means ($x_i$) reported by the laboratories and the uncertainty associated with the corresponding consensus value ($x_{\mathrm{RV}}$). This ignores the potential contribution(s) of the covariance($x_i$,$x_{\mathrm{RV}}$) term. Given the way in which $x_{\mathrm{RV}}$ is computed using the MLE method, it can be shown that incorporating such contributions would deflate (decrease the magnitude of) the estimates of uncertainty. In the interest of simplicity and a more conservative estimate of uncertainty, a more direct approach of quadrature summation was used. While in principle this increase in uncertainty might lead to a greater probability of a given laboratory's uncertainty bounds overlapping the uncertainty bounds of the reference values of the SIM regional comparison, in fact this was not the case for the SIM.AUV.V-K1 regional comparison as demonstrated in the figures on pages 15 through 44. Further, the reference values computed for the SIM regional comparison were not used in any way in establishing the degrees of equivalence between the results of the SIM comparison and the international key comparison nor in computing the differences between results obtained by the laboratories that participated in the SIM.AUV.V-K1 regional comparison.

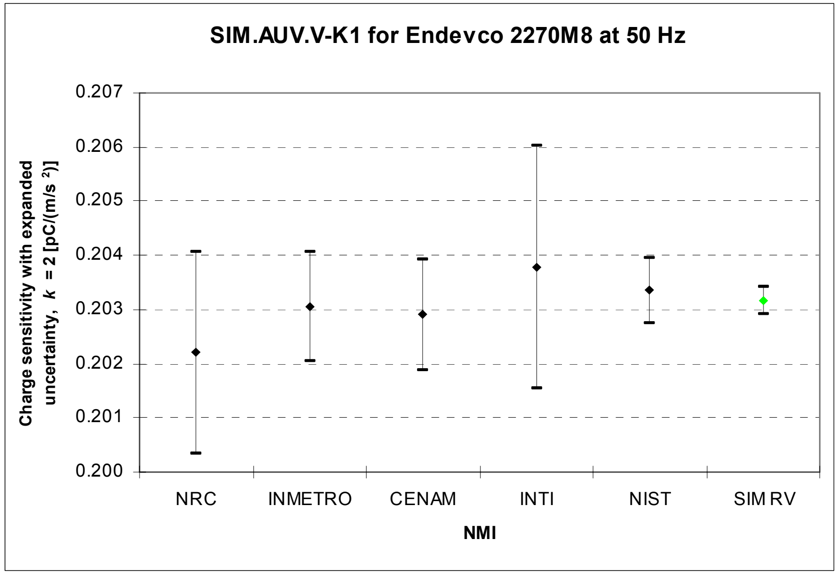
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Endevco 2270M8 s/n 10472 Frequency: 50 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00085 | 0.00212 | -0.00070 | 0.00212 | -0.00157 | 0.00291 | -0.00115 | 0.00196 |
| **INMETRO** | 0.00085 | 0.00212 | | | 0.00015 | 0.00144 | -0.00072 | 0.00246 | -0.00030 | 0.00118 |
| **CENAM** | 0.00070 | 0.00212 | -0.00015 | 0.00144 | | | -0.00087 | 0.00247 | -0.00045 | 0.00119 |
| **INTI** | 0.00157 | 0.00291 | 0.00072 | 0.00246 | 0.00087 | 0.00247 | | | 0.00042 | 0.00232 |
| **NIST** | 0.00115 | 0.00196 | 0.00030 | 0.00118 | 0.00045 | 0.00119 | -0.00042 | 0.00232 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_{ij}$ | $U_{ij}$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.2022 | 0.00093 | -0.00097 | 0.00188 |
| **INMETRO** | 0.20305 | 0.00051 | -0.00012 | 0.00104 |
| **CENAM** | 0.2029 | 0.00051 | -0.00027 | 0.00106 |
| **INTI** | 0.20377 | 0.00112 | 0.00060 | 0.00225 |
| **NIST** | 0.20335 | 0.00031 | 0.00018 | 0.00066 |
| **SIM RV** | 0.20317 | 0.00012 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

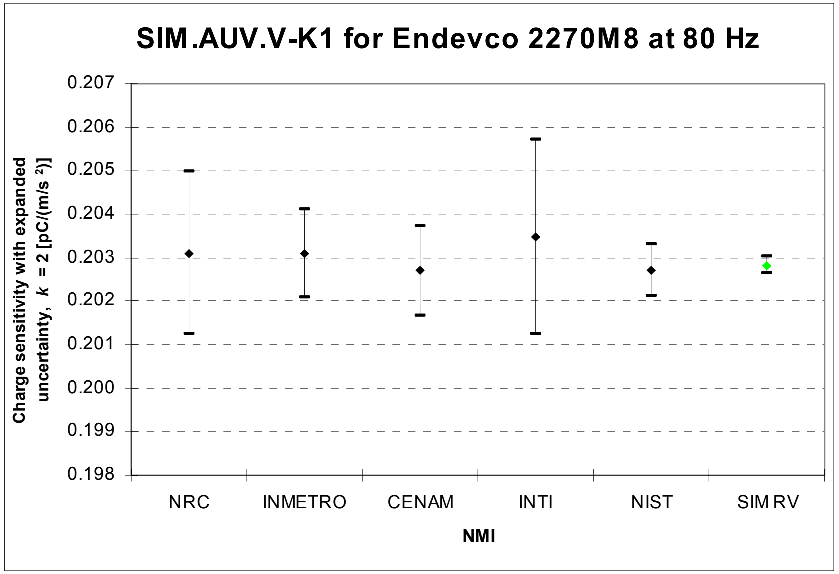
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Endevco 2270M8 s/n 10472 Frequency: 80 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | 0.00001 | 0.00213 | 0.00040 | 0.00214 | -0.00038 | 0.00292 | 0.00039 | 0.00197 |
| **INMETRO** | -0.00001 | 0.00213 | | | 0.00039 | 0.00144 | -0.00039 | 0.00246 | 0.00038 | 0.00118 |
| **CENAM** | -0.00040 | 0.00214 | -0.00039 | 0.00144 | | | -0.00078 | 0.00246 | -0.00001 | 0.00119 |
| **INTI** | 0.00038 | 0.00292 | 0.00039 | 0.00246 | 0.00078 | 0.00246 | | | 0.00077 | 0.00232 |
| **NIST** | -0.00039 | 0.00197 | -0.00038 | 0.00118 | 0.00001 | 0.00119 | -0.00077 | 0.00232 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.2031 | 0.00094 | 0.00027 | 0.00188 |
| **INMETRO** | 0.20309 | 0.00051 | 0.00026 | 0.00103 |
| **CENAM** | 0.2027 | 0.00051 | -0.00013 | 0.00104 |
| **INTI** | 0.20348 | 0.00112 | 0.00065 | 0.00225 |
| **NIST** | 0.20271 | 0.00030 | -0.00012 | 0.00063 |
| **SIM RV** | 0.20283 | 0.00009 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

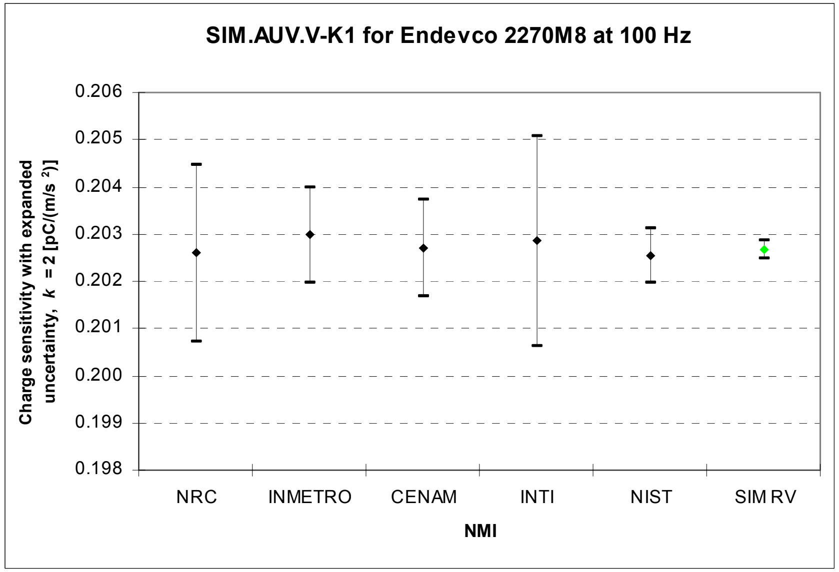
**Regional Comparison: SIM.AUV.V-K1**
**Single-Ended Accelerometer: Endevco 2270M8 s/n 10472 Frequency: 100 Hz**

**Degrees of Interlaboratory Equivalence**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00038 | 0.00212 | -0.00010 | 0.00213 | -0.00025 | 0.00291 | 0.00006 | 0.00195 |
| **INMETRO** | 0.00038 | 0.00212 | | | 0.00028 | 0.00144 | 0.00013 | 0.00245 | 0.00044 | 0.00116 |
| **CENAM** | 0.00010 | 0.00213 | -0.00028 | 0.00144 | | | -0.00015 | 0.00246 | 0.00016 | 0.00117 |
| **INTI** | 0.00025 | 0.00291 | -0.00013 | 0.00245 | 0.00015 | 0.00246 | | | 0.00031 | 0.00230 |
| **NIST** | -0.00006 | 0.00195 | -0.00044 | 0.00116 | -0.00016 | 0.00117 | -0.00031 | 0.00230 | | |

**Degrees of Laboratory to Reference Value Equivalence**

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.2026 | 0.00093 | -0.00007 | 0.00187 |
| **INMETRO** | 0.20298 | 0.00051 | 0.00031 | 0.00103 |
| **CENAM** | 0.2027 | 0.00051 | 0.00003 | 0.00104 |
| **INTI** | 0.20285 | 0.00112 | 0.00018 | 0.00224 |
| **NIST** | 0.20254 | 0.00028 | -0.00013 | 0.00060 |
| **SIM RV** | 0.20267 | 0.00010 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

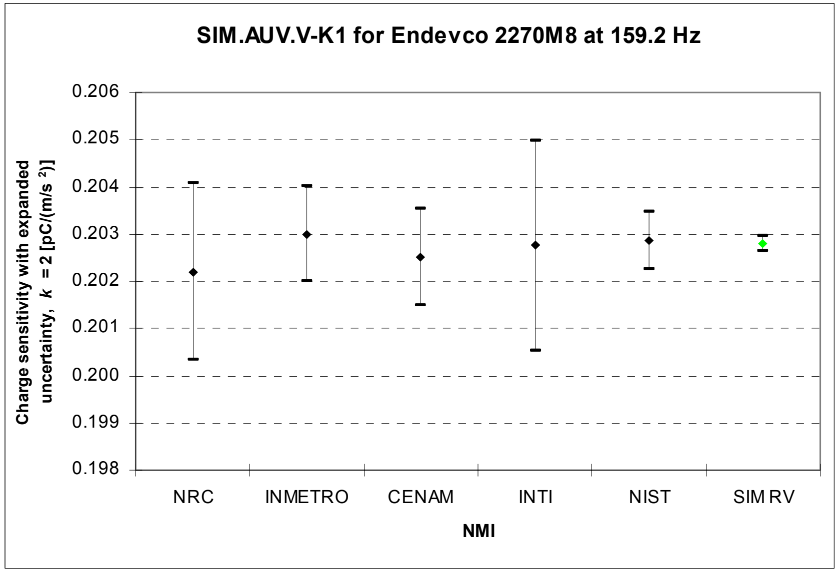
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Endevco 2270M8 s/n 10472 Frequency: 159.2 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **NRC** | | | -0.00080 | 0.00212 | -0.00030 | 0.00213 | -0.00056 | 0.00291 | -0.00067 | 0.00196 |
| **INMETRO** | 0.00080 | 0.00212 | | | 0.00050 | 0.00144 | 0.00024 | 0.00245 | 0.00013 | 0.00118 |
| **CENAM** | 0.00030 | 0.00213 | -0.00050 | 0.00144 | | | -0.00026 | 0.00245 | -0.00037 | 0.00119 |
| **INTI** | 0.00056 | 0.00291 | -0.00024 | 0.00245 | 0.00026 | 0.00245 | | | -0.00011 | 0.00231 |
| **NIST** | 0.00067 | 0.00196 | -0.00013 | 0.00118 | 0.00037 | 0.00119 | 0.00011 | 0.00231 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s²) | | pC/(m/s²) | |
| **NRC** | 0.2022 | 0.00093 | -0.00059 | 0.00187 |
| **INMETRO** | 0.20300 | 0.00051 | 0.00021 | 0.00103 |
| **CENAM** | 0.2025 | 0.00051 | -0.00029 | 0.00104 |
| **INTI** | 0.20276 | 0.00112 | -0.00003 | 0.00224 |
| **NIST** | 0.20287 | 0.00030 | 0.00008 | 0.00063 |
| **SIM RV** | 0.20279 | 0.00008 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

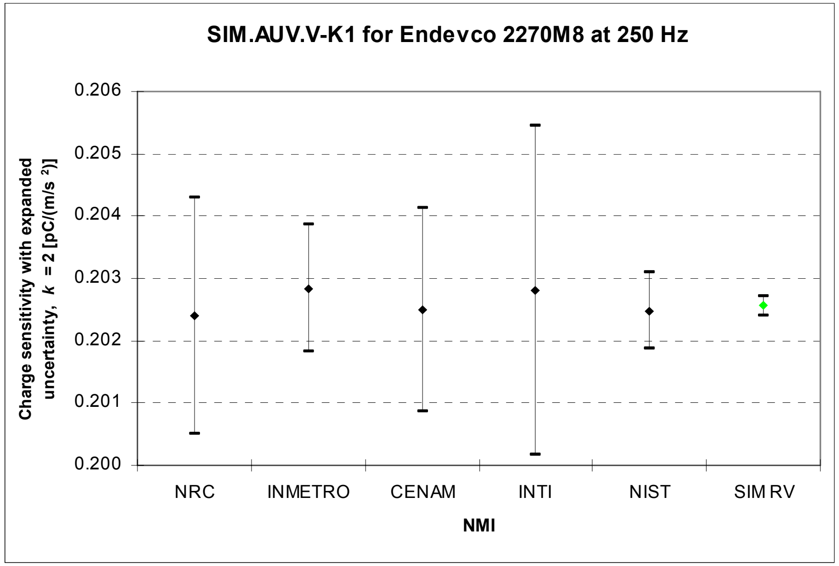
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Endevco 2270M8 s/n 10472 Frequency: 250 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00044 | 0.00216 | -0.00010 | 0.00251 | -0.00041 | 0.00325 | -0.00008 | 0.00200 |
| **INMETRO** | 0.00044 | 0.00216 | | | 0.00034 | 0.00193 | 0.00003 | 0.00282 | 0.00036 | 0.00118 |
| **CENAM** | 0.00010 | 0.00251 | -0.00034 | 0.00193 | | | -0.00031 | 0.00310 | 0.00002 | 0.00175 |
| **INTI** | 0.00041 | 0.00325 | -0.00003 | 0.00282 | 0.00031 | 0.00310 | | | 0.00033 | 0.00271 |
| **NIST** | 0.00008 | 0.00200 | -0.00036 | 0.00118 | -0.00002 | 0.00175 | -0.00033 | 0.00271 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.2024 | 0.00095 | -0.00016 | 0.00191 |
| **INMETRO** | 0.20284 | 0.00051 | 0.00028 | 0.00103 |
| **CENAM** | 0.2025 | 0.00082 | -0.00006 | 0.00164 |
| **INTI** | 0.20281 | 0.00132 | 0.00025 | 0.00264 |
| **NIST** | 0.20248 | 0.00030 | -0.00008 | 0.00063 |
| **SIM RV** | 0.20256 | 0.00008 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

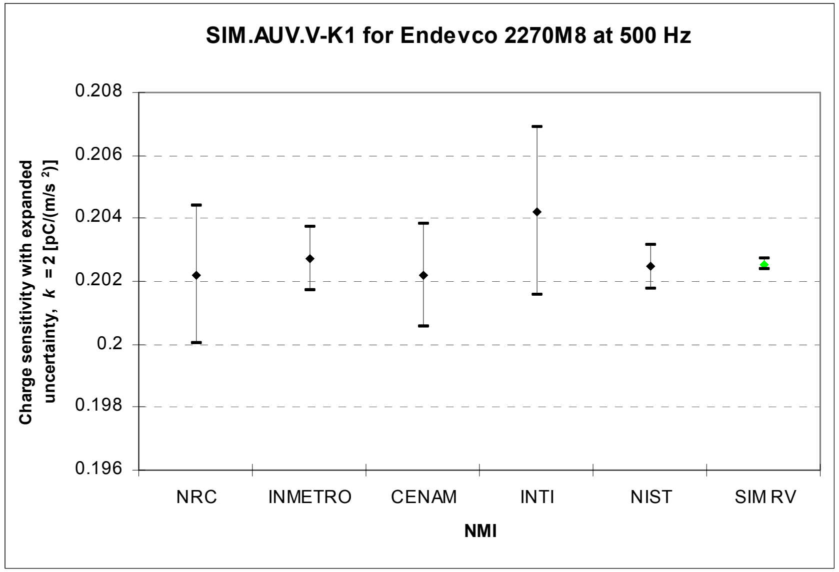
**Regional Comparison: SIM.AUV.V-K1**
**Single-Ended Accelerometer: Endevco 2270M8 s/n 10472 Frequency: 500 Hz**

**Degrees of Interlaboratory Equivalence**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00053 | 0.00240 | 0.00000 | 0.00272 | -0.00203 | 0.00344 | -0.00027 | 0.00229 |
| **INMETRO** | 0.00053 | 0.00240 | | | 0.00053 | 0.00192 | -0.00150 | 0.00284 | 0.00026 | 0.00123 |
| **CENAM** | 0.00000 | 0.00272 | -0.00053 | 0.00192 | | | -0.00203 | 0.00312 | -0.00027 | 0.00177 |
| **INTI** | 0.00203 | 0.00344 | 0.00150 | 0.00284 | 0.00203 | 0.00312 | | | 0.00176 | 0.00274 |
| **NIST** | 0.00027 | 0.00229 | -0.00026 | 0.00123 | 0.00027 | 0.00177 | -0.00176 | 0.00274 | | |

**Degrees of Laboratory to Reference Value Equivalence**

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.2022 | 0.00109 | -0.00035 | 0.00219 |
| **INMETRO** | 0.20273 | 0.00051 | 0.00018 | 0.00103 |
| **CENAM** | 0.2022 | 0.00082 | -0.00035 | 0.00164 |
| **INTI** | 0.20423 | 0.00133 | 0.00168 | 0.00266 |
| **NIST** | 0.20247 | 0.00034 | -0.00008 | 0.00071 |
| **SIM RV** | 0.20255 | 0.00009 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

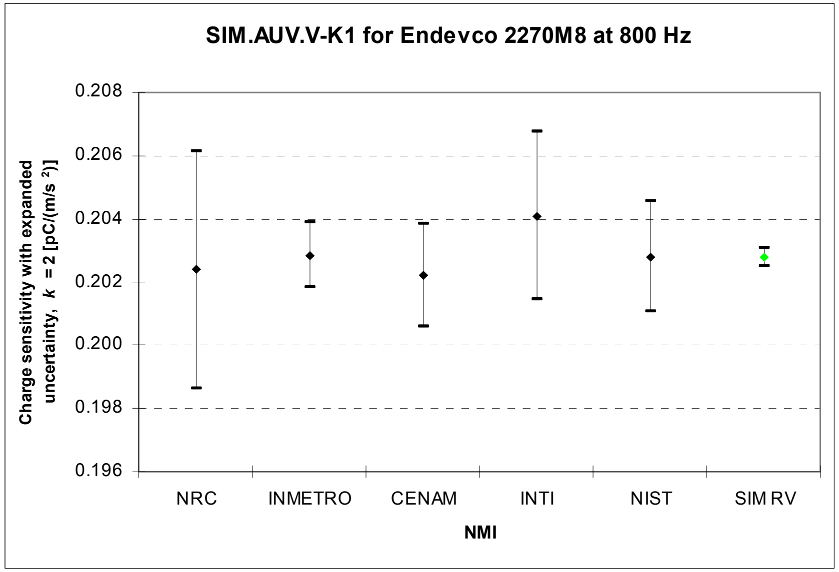
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Endevco 2270M8 s/n 10472 Frequency: 800 Hz

**Degrees of Interlaboratory Equivalence**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00046 | 0.00388 | 0.00020 | 0.00409 | -0.00169 | 0.00459 | -0.00039 | 0.00413 |
| **INMETRO** | 0.00046 | 0.00388 | | | 0.00066 | 0.00192 | -0.00123 | 0.00284 | 0.00007 | 0.00202 |
| **CENAM** | -0.00020 | 0.00409 | -0.00066 | 0.00192 | | | -0.00189 | 0.00312 | -0.00059 | 0.00239 |
| **INTI** | 0.00169 | 0.00459 | 0.00123 | 0.00284 | 0.00189 | 0.00312 | | | 0.00130 | 0.00318 |
| **NIST** | 0.00039 | 0.00413 | -0.00007 | 0.00202 | 0.00059 | 0.00239 | -0.00130 | 0.00318 | | |

**Degrees of Laboratory to Reference Value Equivalence**

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.2024 | 0.00187 | -0.00039 | 0.00376 |
| **INMETRO** | 0.20286 | 0.00051 | 0.00007 | 0.00106 |
| **CENAM** | 0.2022 | 0.00082 | -0.00059 | 0.00166 |
| **INTI** | 0.20409 | 0.00133 | 0.00130 | 0.00267 |
| **NIST** | 0.20279 | 0.00087 | 0.00000 | 0.00177 |
| **SIM RV** | 0.20279 | 0.00015 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $$D_i = x_i - x_{RV}$$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $$U_i = 2\sqrt{u_i^2 + u_{RV}^2}$$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $$D_{ij} = x_i - x_j$$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $$U_{ij} = 2\sqrt{u_i^2 + u_j^2}$$

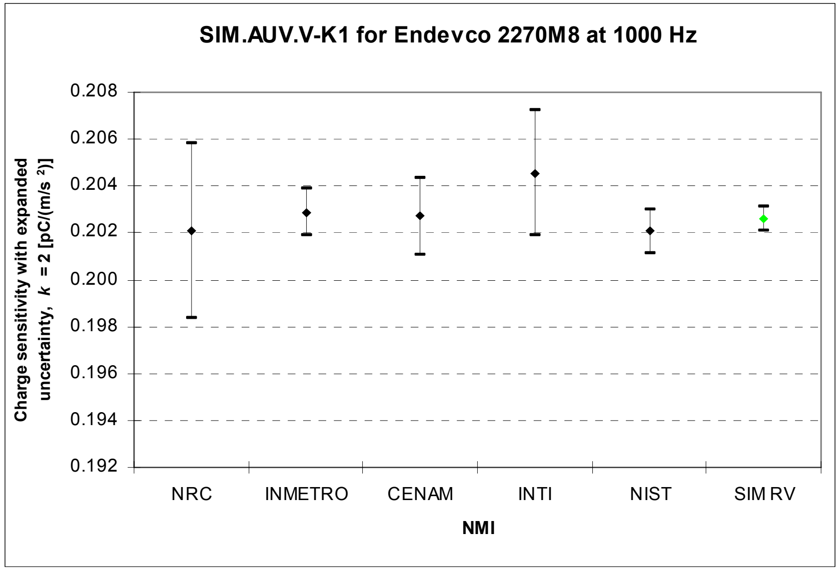
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Endevco 2270M8 s/n 10472 Frequency: 1000 Hz

**Degrees of Interlaboratory Equivalence**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00079 | 0.00387 | -0.00060 | 0.00409 | -0.00245 | 0.00459 | 0.00003 | 0.00385 |
| **INMETRO** | 0.00079 | 0.00387 | | | 0.00019 | 0.00194 | -0.00166 | 0.00285 | 0.00082 | 0.00138 |
| **CENAM** | 0.00060 | 0.00409 | -0.00019 | 0.00194 | | | -0.00185 | 0.00313 | 0.00063 | 0.00190 |
| **INTI** | 0.00245 | 0.00459 | 0.00166 | 0.00285 | 0.00185 | 0.00313 | | | 0.00248 | 0.00282 |
| **NIST** | -0.00003 | 0.00385 | -0.00082 | 0.00138 | -0.00063 | 0.00190 | -0.00248 | 0.00282 | | |

**Degrees of Laboratory to Reference Value Equivalence**

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.2021 | 0.00187 | -0.00047 | 0.00377 |
| **INMETRO** | 0.20289 | 0.00051 | 0.00032 | 0.00114 |
| **CENAM** | 0.2027 | 0.00083 | 0.00013 | 0.00173 |
| **INTI** | 0.20455 | 0.00133 | 0.00198 | 0.00271 |
| **NIST** | 0.20207 | 0.00046 | -0.00050 | 0.00106 |
| **SIM RV** | 0.20257 | 0.00026 | | |




T The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

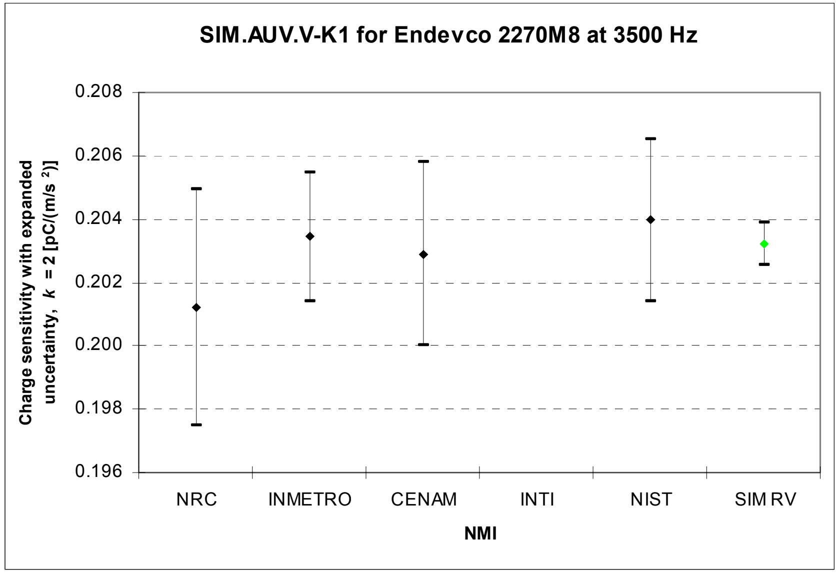
**Regional Comparison: SIM.AUV.V-K1**
**Single-Ended Accelerometer: Endevco 2270M8 s/n 10472 Frequency: 3500 Hz**

**Degrees of Interlaboratory Equivalence**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00224 | 0.00425 | -0.00170 | 0.00473 | | | -0.00277 | 0.00453 |
| **INMETRO** | 0.00224 | 0.00425 | | | 0.00054 | 0.00354 | | | -0.00053 | 0.00328 |
| **CENAM** | 0.00170 | 0.00473 | -0.00054 | 0.00354 | | | | | -0.00107 | 0.00387 |
| **INTI** | | | | | | | | | | |
| **NIST** | 0.00277 | 0.00453 | 0.00053 | 0.00328 | 0.00107 | 0.00387 | | | | |

**Degrees of Laboratory to Reference Value Equivalence**

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.2012 | 0.00187 | -0.00202 | 0.00379 |
| **INMETRO** | 0.20344 | 0.00102 | 0.00022 | 0.00214 |
| **CENAM** | 0.2029 | 0.00145 | -0.00032 | 0.00297 |
| **INTI** | | | | |
| **NIST** | 0.20397 | 0.00129 | 0.00075 | 0.00265 |
| **SIM RV** | 0.20322 | 0.00033 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by:

$$D_i = x_i - x_{RV}$$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by:

$$U_i = 2\sqrt{u_i^2 + u_{RV}^2}$$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by:

$$D_{ij} = x_i - x_j$$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by:

$$U_{ij} = 2\sqrt{u_i^2 + u_j^2}$$

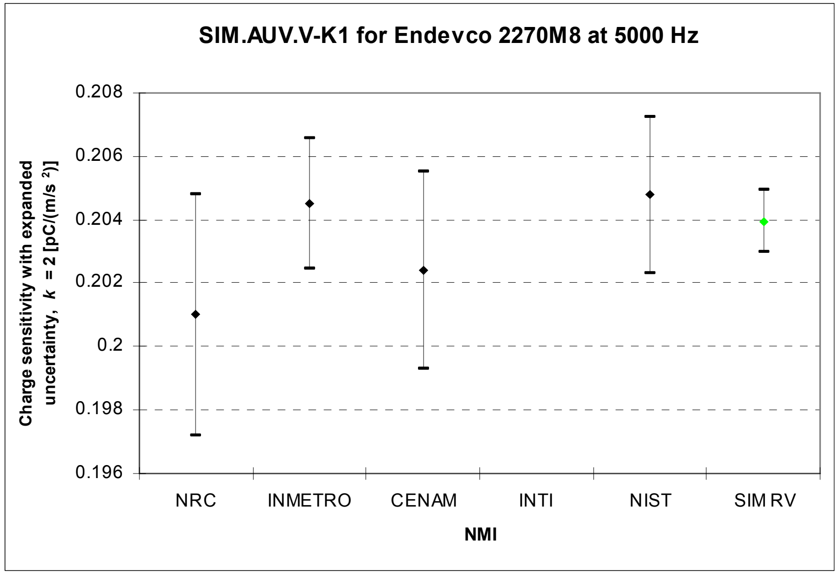
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Endevco 2270M8 s/n 10472 Frequency: 5000 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00350 | 0.00433 | -0.00140 | 0.00491 | | | -0.00379 | 0.00453 |
| **INMETRO** | 0.00350 | 0.00433 | | | 0.00210 | 0.00371 | | | -0.00029 | 0.00320 |
| **CENAM** | 0.00140 | 0.00491 | -0.00210 | 0.00371 | | | | | -0.00239 | 0.00395 |
| **INTI** | | | | | | | | | | |
| **NIST** | 0.00379 | 0.00453 | 0.00029 | 0.00320 | 0.00239 | 0.00395 | | | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.2010 | 0.00191 | -0.00296 | 0.00394 |
| **INMETRO** | 0.20450 | 0.00102 | 0.00054 | 0.00227 |
| **CENAM** | 0.2024 | 0.00155 | -0.00156 | 0.00325 |
| **INTI** | | | | |
| **NIST** | 0.20479 | 0.00123 | 0.00083 | 0.00265 |
| **SIM RV** | 0.20396 | 0.00049 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

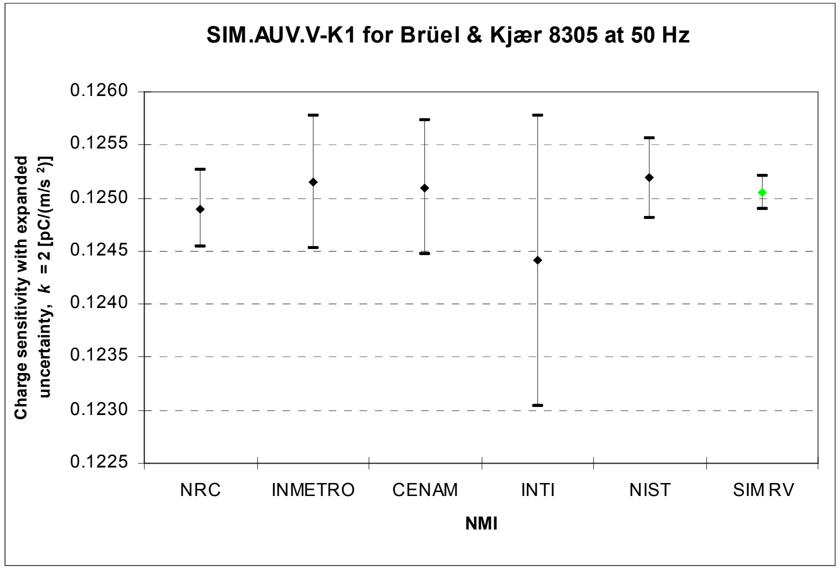
## Back-to-Back Accelerometer: Brüel & Kjær 8305 s/n 1687773 Frequency: 50 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00025 | 0.00072 | -0.00020 | 0.00073 | 0.00049 | 0.00142 | -0.00029 | 0.00052 |
| **INMETRO** | 0.00025 | 0.00072 | | | 0.00005 | 0.00089 | 0.00074 | 0.00150 | -0.00004 | 0.00073 |
| **CENAM** | 0.00020 | 0.00073 | -0.00005 | 0.00089 | | | 0.00069 | 0.00151 | -0.00009 | 0.00074 |
| **INTI** | -0.00049 | 0.00142 | -0.00074 | 0.00150 | -0.00069 | 0.00151 | | | -0.00078 | 0.00142 |
| **NIST** | 0.00029 | 0.00052 | 0.00004 | 0.00073 | 0.00009 | 0.00074 | 0.00078 | 0.00142 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1249 | 0.00018 | -0.00015 | 0.00039 |
| **INMETRO** | 0.12515 | 0.00031 | 0.00010 | 0.00064 |
| **CENAM** | 0.1251 | 0.00032 | 0.00005 | 0.00065 |
| **INTI** | 0.12441 | 0.00068 | -0.00064 | 0.00138 |
| **NIST** | 0.12519 | 0.00019 | 0.00014 | 0.00041 |
| **SIM RV** | 0.12505 | 0.00008 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

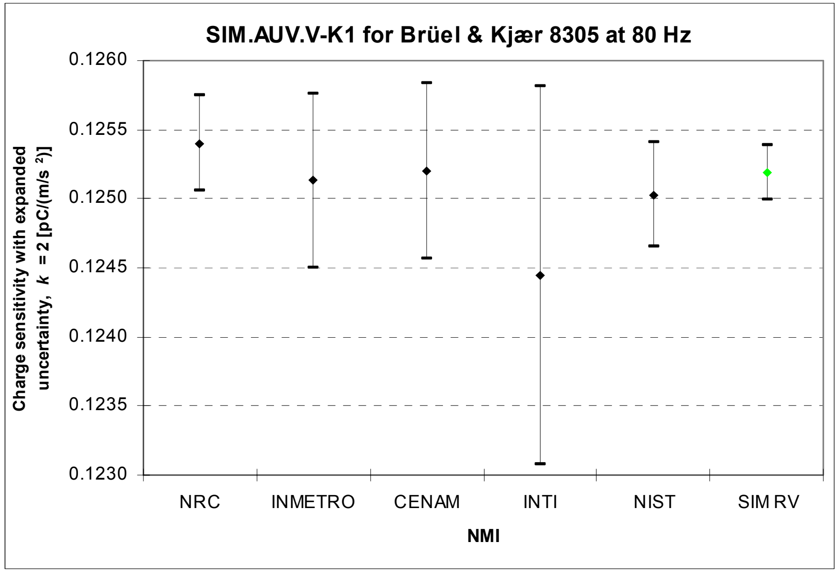
## Back-to-Back Accelerometer: Brüel & Kjær 8305 s/n 1687773 Frequency: 80 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | 0.00027 | 0.00072 | 0.00020 | 0.00072 | 0.00096 | 0.00141 | 0.00037 | 0.00051 |
| **INMETRO** | -0.00027 | 0.00072 | | | -0.00007 | 0.00089 | 0.00069 | 0.00150 | 0.00010 | 0.00073 |
| **CENAM** | -0.00020 | 0.00072 | 0.00007 | 0.00089 | | | 0.00076 | 0.00151 | 0.00017 | 0.00074 |
| **INTI** | -0.00096 | 0.00141 | -0.00069 | 0.00150 | -0.00076 | 0.00151 | | | -0.00059 | 0.00142 |
| **NIST** | -0.00037 | 0.00051 | -0.00010 | 0.00073 | -0.00017 | 0.00074 | 0.00059 | 0.00142 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1254 | 0.00017 | 0.00021 | 0.00040 |
| **INMETRO** | 0.12513 | 0.00031 | -0.00006 | 0.00066 |
| **CENAM** | 0.1252 | 0.00032 | 0.00001 | 0.00066 |
| **INTI** | 0.12444 | 0.00068 | -0.00075 | 0.00138 |
| **NIST** | 0.12503 | 0.00019 | -0.00016 | 0.00042 |
| **SIM RV** | 0.12519 | 0.00010 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by:

$$D_i = x_i - x_{RV}$$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by:

$$U_i = 2\sqrt{u_i^2 + u_{RV}^2}$$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by:

$$D_{ij} = x_i - x_j$$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by:

$$U_{ij} = 2\sqrt{u_i^2 + u_j^2}$$

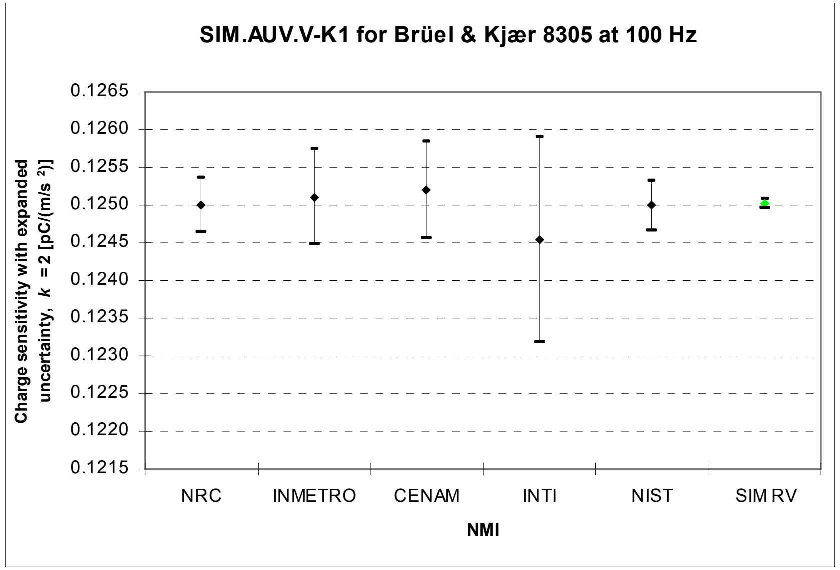
## Back-to-Back Accelerometer: Brüel & Kjær 8305 s/n 1687773 Frequency: 100 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00011 | 0.00072 | -0.00020 | 0.00073 | 0.00046 | 0.00141 | 0.00001 | 0.00050 |
| **INMETRO** | 0.00011 | 0.00072 | | | -0.00009 | 0.00089 | 0.00057 | 0.00150 | 0.00012 | 0.00071 |
| **CENAM** | 0.00020 | 0.00073 | 0.00009 | 0.00089 | | | 0.00066 | 0.00150 | 0.00021 | 0.00072 |
| **INTI** | -0.00046 | 0.00141 | -0.00057 | 0.00150 | -0.00066 | 0.00150 | | | -0.00045 | 0.00140 |
| **NIST** | -0.00001 | 0.00050 | -0.00012 | 0.00071 | -0.00021 | 0.00072 | 0.00045 | 0.00140 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1250 | 0.00018 | -0.00002 | 0.00037 |
| **INMETRO** | 0.12511 | 0.00031 | 0.00009 | 0.00063 |
| **CENAM** | 0.1252 | 0.00032 | 0.00018 | 0.00064 |
| **INTI** | 0.12454 | 0.00068 | -0.00048 | 0.00136 |
| **NIST** | 0.12499 | 0.00017 | -0.00003 | 0.00034 |
| **SIM RV** | 0.12502 | 0.00003 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

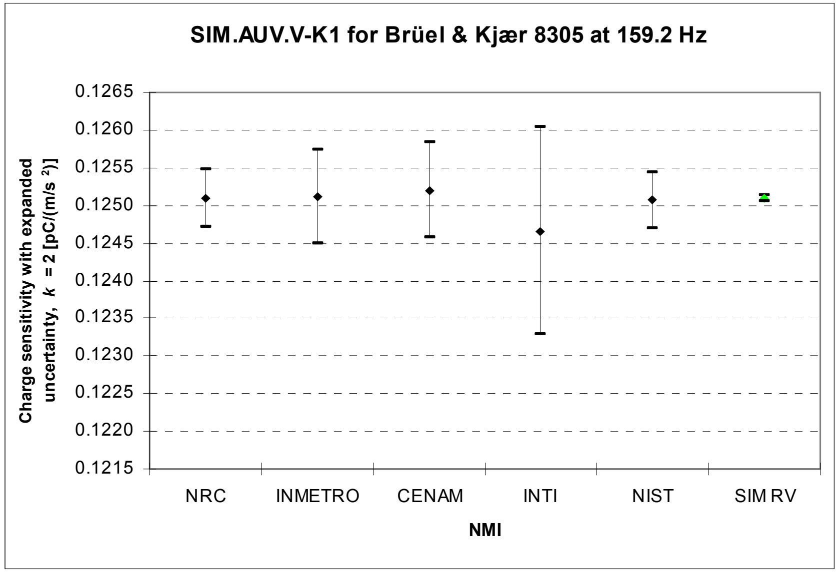
## Back-to-Back Accelerometer: Brüel & Kjær 8305 s/n 1687773 Frequency: 159.2 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00002 | 0.00073 | -0.00010 | 0.00074 | 0.00044 | 0.00142 | 0.00003 | 0.00054 |
| **INMETRO** | 0.00002 | 0.00073 | | | -0.00008 | 0.00089 | 0.00046 | 0.00151 | 0.00005 | 0.00073 |
| **CENAM** | 0.00010 | 0.00074 | 0.00008 | 0.00089 | | | 0.00054 | 0.00151 | 0.00013 | 0.00074 |
| **INTI** | -0.00044 | 0.00142 | -0.00046 | 0.00151 | -0.00054 | 0.00151 | | | -0.00041 | 0.00142 |
| **NIST** | -0.00003 | 0.00054 | -0.00005 | 0.00073 | -0.00013 | 0.00074 | 0.00041 | 0.00142 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1251 | 0.00019 | 0.00001 | 0.00039 |
| **INMETRO** | 0.12512 | 0.00031 | 0.00003 | 0.00063 |
| **CENAM** | 0.1252 | 0.00032 | 0.00011 | 0.00063 |
| **INTI** | 0.12466 | 0.00069 | -0.00043 | 0.00137 |
| **NIST** | 0.12507 | 0.00019 | -0.00002 | 0.00038 |
| **SIM RV** | 0.12509 | 0.00002 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

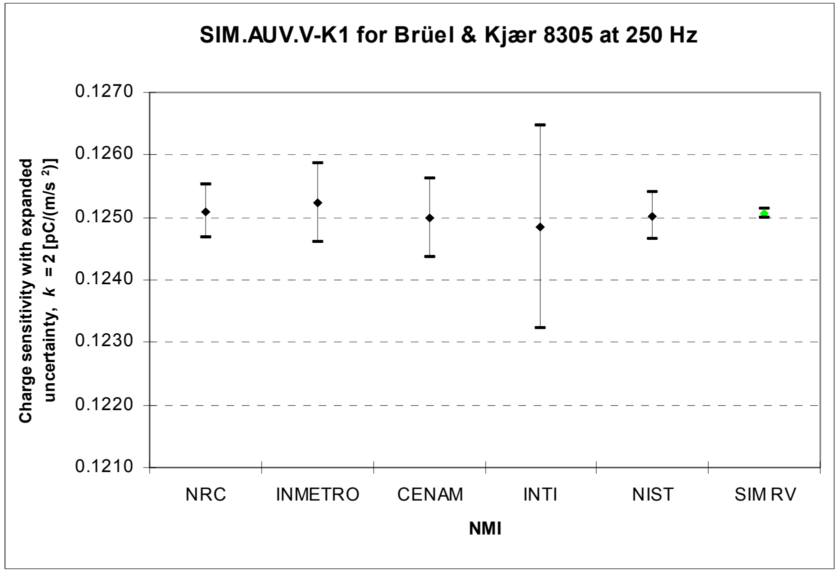
## Back-to-Back Accelerometer:  Brüel & Kjær 8305 s/n 1687773     Frequency:  250 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00014 | 0.00075 | 0.00010 | 0.00076 | 0.00025 | 0.00168 | 0.00008 | 0.00056 |
| **INMETRO** | 0.00014 | 0.00075 | | | 0.00024 | 0.00089 | 0.00039 | 0.00174 | 0.00022 | 0.00073 |
| **CENAM** | -0.00010 | 0.00076 | -0.00024 | 0.00089 | | | 0.00015 | 0.00174 | -0.00002 | 0.00074 |
| **INTI** | -0.00025 | 0.00168 | -0.00039 | 0.00174 | -0.00015 | 0.00174 | | | -0.00017 | 0.00167 |
| **NIST** | -0.00008 | 0.00056 | -0.00022 | 0.00073 | 0.00002 | 0.00074 | 0.00017 | 0.00167 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1251 | 0.00021 | 0.00003 | 0.00042 |
| **INMETRO** | 0.12524 | 0.00031 | 0.00017 | 0.00063 |
| **CENAM** | 0.1250 | 0.00032 | -0.00007 | 0.00064 |
| **INTI** | 0.12485 | 0.00081 | -0.00022 | 0.00162 |
| **NIST** | 0.12502 | 0.00019 | -0.00005 | 0.00038 |
| **SIM RV** | 0.12507 | 0.00003 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $$D_i = x_i - x_{RV}$$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $$U_i = 2\sqrt{u_i^2 + u_{RV}^2}$$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $$D_{ij} = x_i - x_j$$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $$U_{ij} = 2\sqrt{u_i^2 + u_j^2}$$

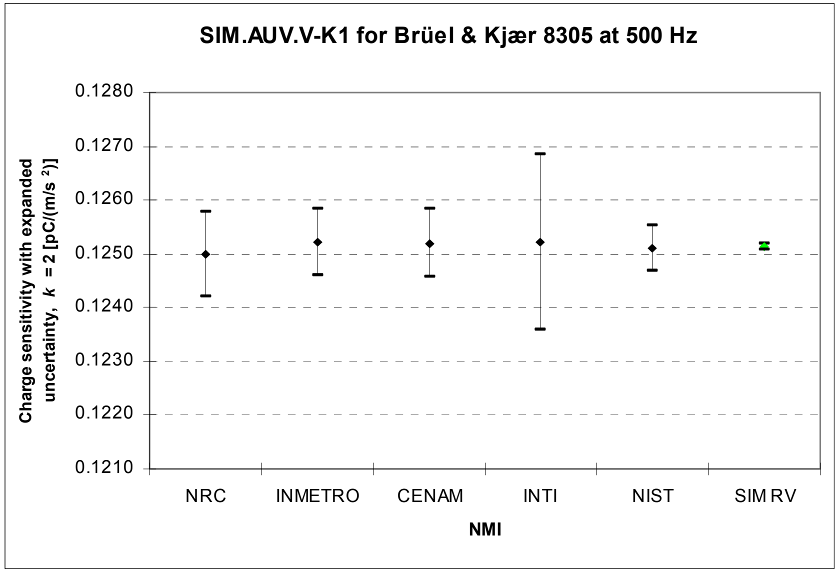
# Regional Comparison: SIM.AUV.V-K1
## Back-to-Back Accelerometer: Brüel & Kjær 8305 s/n 1687773 Frequency: 500 Hz

**Degrees of Interlaboratory Equivalence**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00022 | 0.00100 | -0.00020 | 0.00101 | -0.00022 | 0.00181 | -0.00011 | 0.00089 |
| **INMETRO** | 0.00022 | 0.00100 | | | 0.00002 | 0.00089 | 0.00000 | 0.00174 | 0.00011 | 0.00076 |
| **CENAM** | 0.00020 | 0.00101 | -0.00002 | 0.00089 | | | -0.00002 | 0.00175 | 0.00009 | 0.00076 |
| **INTI** | 0.00022 | 0.00181 | 0.00000 | 0.00174 | 0.00002 | 0.00175 | | | 0.00011 | 0.00168 |
| **NIST** | 0.00011 | 0.00089 | -0.00011 | 0.00076 | -0.00009 | 0.00076 | -0.00011 | 0.00168 | | |

**Degrees of Laboratory to Reference Value Equivalence**

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1250 | 0.00039 | -0.00014 | 0.00079 |
| **INMETRO** | 0.12522 | 0.00031 | 0.00008 | 0.00063 |
| **CENAM** | 0.1252 | 0.00032 | 0.00006 | 0.00064 |
| **INTI** | 0.12522 | 0.00081 | 0.00008 | 0.00163 |
| **NIST** | 0.12511 | 0.00021 | -0.00003 | 0.00043 |
| **SIM RV** | 0.12514 | 0.00003 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $$D_i = x_i - x_{RV}$$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $$U_i = 2\sqrt{u_i^2 + u_{RV}^2}$$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $$D_{ij} = x_i - x_j$$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $$U_{ij} = 2\sqrt{u_i^2 + u_j^2}$$

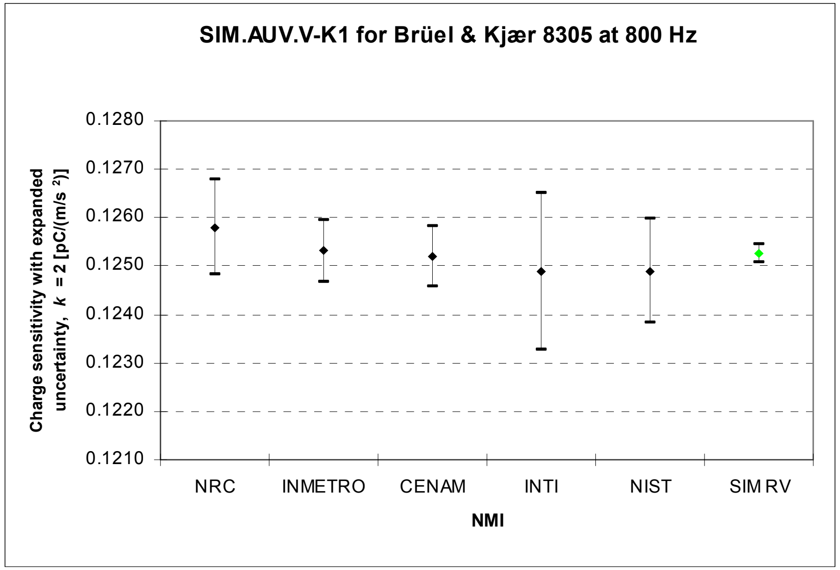
## Regional Comparison: SIM.AUV.V-K1
## Back-to-Back Accelerometer: Brüel & Kjær 8305 s/n 1687773 Frequency: 800 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | 0.00049 | 0.00117 | 0.00060 | 0.00117 | 0.00091 | 0.00190 | 0.00090 | 0.00146 |
| **INMETRO** | -0.00049 | 0.00117 | | | 0.00011 | 0.00089 | 0.00042 | 0.00174 | 0.00041 | 0.00124 |
| **CENAM** | -0.00060 | 0.00117 | -0.00011 | 0.00089 | | | 0.00031 | 0.00174 | 0.00030 | 0.00125 |
| **INTI** | -0.00091 | 0.00190 | -0.00042 | 0.00174 | -0.00031 | 0.00174 | | | -0.00001 | 0.00195 |
| **NIST** | -0.00090 | 0.00146 | -0.00041 | 0.00124 | -0.00030 | 0.00125 | 0.00001 | 0.00195 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1258 | 0.00049 | 0.00053 | 0.00100 |
| **INMETRO** | 0.12531 | 0.00031 | 0.00004 | 0.00065 |
| **CENAM** | 0.1252 | 0.00032 | -0.00007 | 0.00066 |
| **INTI** | 0.12489 | 0.00081 | -0.00038 | 0.00163 |
| **NIST** | 0.12490 | 0.00054 | -0.00037 | 0.00109 |
| **SIM RV** | 0.12527 | 0.00009 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

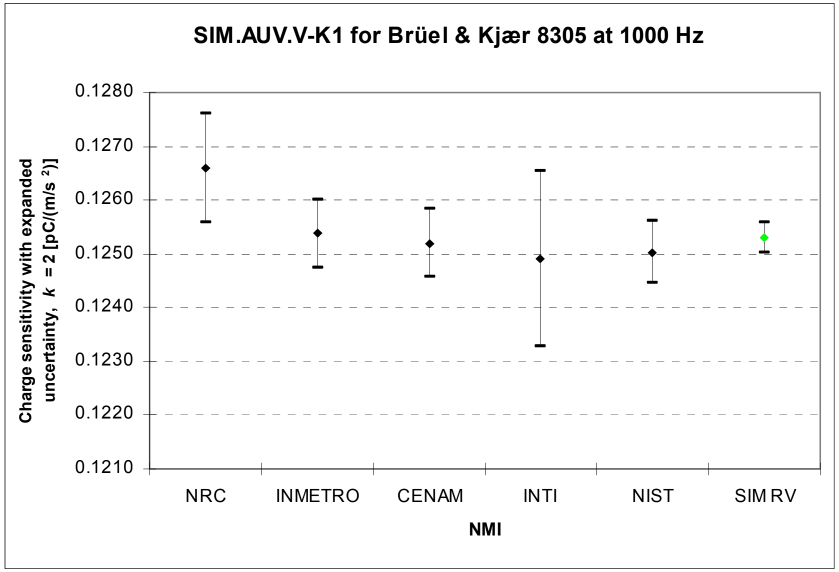
## Regional Comparison: SIM.AUV.V-K1
## Back-to-Back Accelerometer: Brüel & Kjær 8305 s/n 1687773 Frequency: 1000 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | 0.00122 | 0.00119 | 0.00140 | 0.00119 | 0.00169 | 0.00191 | 0.00157 | 0.00116 |
| **INMETRO** | -0.00122 | 0.00119 | | | 0.00018 | 0.00089 | 0.00047 | 0.00174 | 0.00035 | 0.00085 |
| **CENAM** | -0.00140 | 0.00119 | -0.00018 | 0.00089 | | | 0.00029 | 0.00174 | 0.00017 | 0.00085 |
| **INTI** | -0.00169 | 0.00191 | -0.00047 | 0.00174 | -0.00029 | 0.00174 | | | -0.00012 | 0.00172 |
| **NIST** | -0.00157 | 0.00116 | -0.00035 | 0.00085 | -0.00017 | 0.00085 | 0.00012 | 0.00172 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1266 | 0.00050 | 0.00130 | 0.00105 |
| **INMETRO** | 0.12538 | 0.00031 | 0.00008 | 0.00069 |
| **CENAM** | 0.1252 | 0.00031 | -0.00010 | 0.00069 |
| **INTI** | 0.12491 | 0.00081 | -0.00039 | 0.00165 |
| **NIST** | 0.12503 | 0.00029 | -0.00027 | 0.00064 |
| **SIM RV** | 0.12530 | 0.00014 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

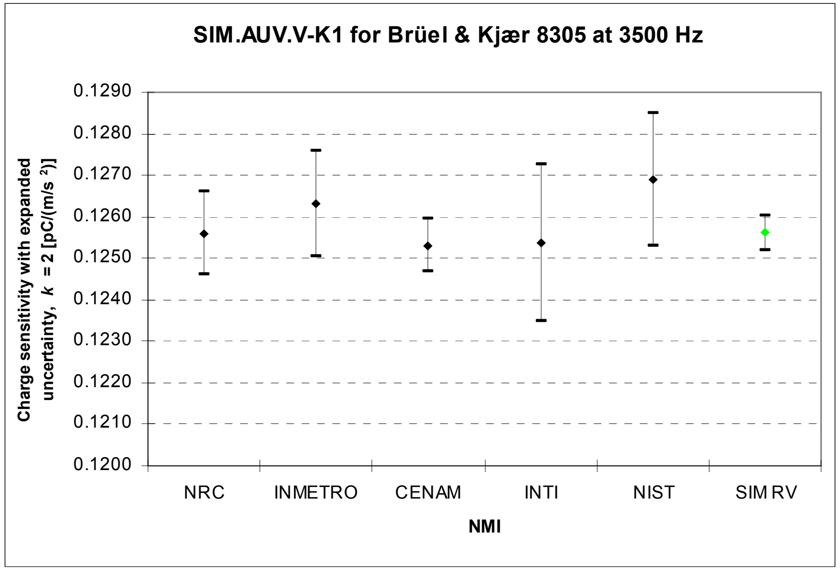
**Regional Comparison: SIM.AUV.V-K1**
**Back-to-Back Accelerometer: Brüel & Kjær 8305 s/n 1687773 Frequency: 3500 Hz**

**Degrees of Interlaboratory Equivalence**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00071 | 0.00160 | 0.00030 | 0.00117 | 0.00022 | 0.00212 | -0.00131 | 0.00188 |
| **INMETRO** | 0.00071 | 0.00160 | | | 0.00101 | 0.00141 | 0.00093 | 0.00227 | -0.00060 | 0.00204 |
| **CENAM** | -0.00030 | 0.00117 | -0.00101 | 0.00141 | | | -0.00008 | 0.00198 | -0.00161 | 0.00172 |
| **INTI** | -0.00022 | 0.00212 | -0.00093 | 0.00227 | 0.00008 | 0.00198 | | | -0.00153 | 0.00247 |
| **NIST** | 0.00131 | 0.00188 | 0.00060 | 0.00204 | 0.00161 | 0.00172 | 0.00153 | 0.00247 | | |

**Degrees of Laboratory to Reference Value Equivalence**

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1256 | 0.00049 | -0.00001 | 0.00107 |
| **INMETRO** | 0.12631 | 0.00063 | 0.00070 | 0.00133 |
| **CENAM** | 0.1253 | 0.00032 | -0.00031 | 0.00075 |
| **INTI** | 0.12538 | 0.00094 | -0.00023 | 0.00192 |
| **NIST** | 0.12691 | 0.00080 | 0.00130 | 0.00165 |
| **SIM RV** | 0.12561 | 0.00020 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by:

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by:

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by:

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by:

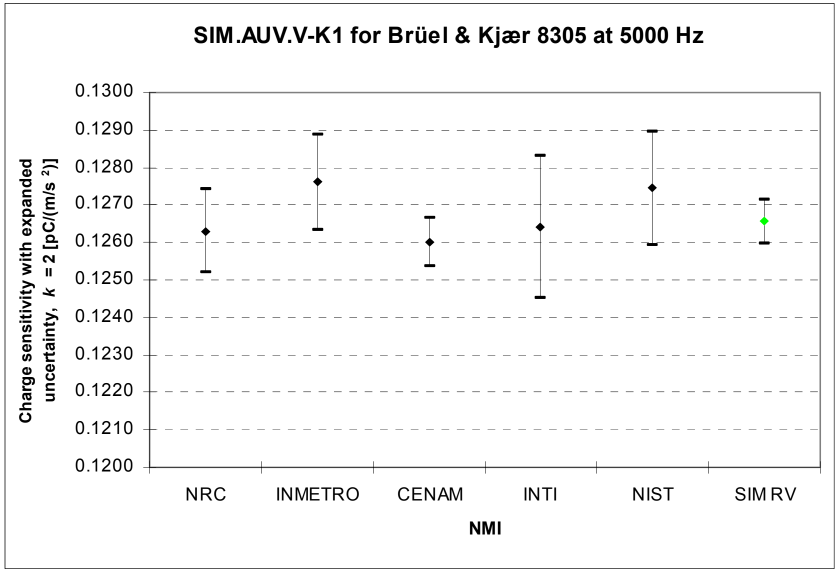
## Regional Comparison: SIM.AUV.V-K1
## Back-to-Back Accelerometer: Brüel & Kjær 8305 s/n 1687773 Frequency: 5000 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00131 | 0.00169 | 0.00030 | 0.00128 | -0.00012 | 0.00220 | -0.00114 | 0.00189 |
| **INMETRO** | 0.00131 | 0.00169 | | | 0.00161 | 0.00143 | 0.00119 | 0.00229 | 0.00017 | 0.00199 |
| **CENAM** | -0.00030 | 0.00128 | -0.00161 | 0.00143 | | | -0.00042 | 0.00200 | -0.00144 | 0.00166 |
| **INTI** | 0.00012 | 0.00220 | -0.00119 | 0.00229 | 0.00042 | 0.00200 | | | -0.00102 | 0.00244 |
| **NIST** | 0.00114 | 0.00189 | -0.00017 | 0.00199 | 0.00144 | 0.00166 | 0.00102 | 0.00244 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | *x* | *u* | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1263 | 0.00056 | -0.00025 | 0.00126 |
| **INMETRO** | 0.12761 | 0.00064 | 0.00106 | 0.00141 |
| **CENAM** | 0.1260 | 0.00032 | -0.00055 | 0.00088 |
| **INTI** | 0.12642 | 0.00095 | -0.00013 | 0.00199 |
| **NIST** | 0.12744 | 0.00076 | 0.00089 | 0.00164 |
| **SIM RV** | 0.12655 | 0.00030 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories *i* and *j* is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

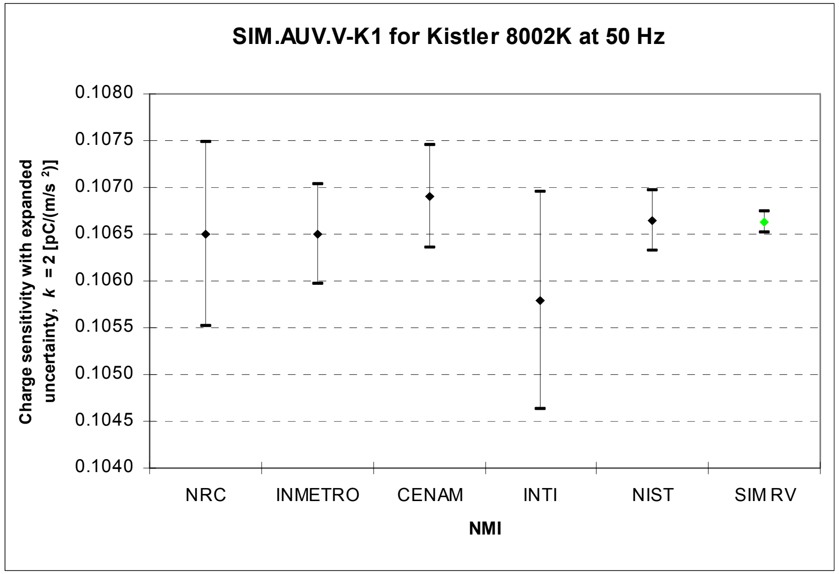
**Regional Comparison: SIM.AUV.V-K1**
**Single-Ended Accelerometer: Kistler 8002K s/n 100443 Frequency: 50 Hz**

**Degrees of Interlaboratory Equivalence**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | 0.00000 | 0.00112 | -0.00040 | 0.00112 | 0.00071 | 0.00152 | -0.00015 | 0.00103 |
| **INMETRO** | 0.00000 | 0.00112 | | | -0.00040 | 0.00076 | 0.00071 | 0.00128 | -0.00015 | 0.00062 |
| **CENAM** | 0.00040 | 0.00112 | 0.00040 | 0.00076 | | | 0.00111 | 0.00128 | 0.00025 | 0.00063 |
| **INTI** | -0.00071 | 0.00152 | -0.00071 | 0.00128 | -0.00111 | 0.00128 | | | -0.00086 | 0.00121 |
| **NIST** | 0.00015 | 0.00103 | 0.00015 | 0.00062 | -0.00025 | 0.00063 | 0.00086 | 0.00121 | | |

**Degrees of Laboratory to Reference Value Equivalence**

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1065 | 0.00049 | -0.00013 | 0.00099 |
| **INMETRO** | 0.10650 | 0.00027 | -0.00013 | 0.00055 |
| **CENAM** | 0.1069 | 0.00027 | 0.00027 | 0.00056 |
| **INTI** | 0.10579 | 0.00058 | -0.00084 | 0.00117 |
| **NIST** | 0.10665 | 0.00016 | 0.00002 | 0.00034 |
| **SIM RV** | 0.10663 | 0.00006 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $$D_i = x_i - x_{RV}$$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $$U_i = 2\sqrt{u_i^2 + u_{RV}^2}$$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $$D_{ij} = x_i - x_j$$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $$U_{ij} = 2\sqrt{u_i^2 + u_j^2}$$

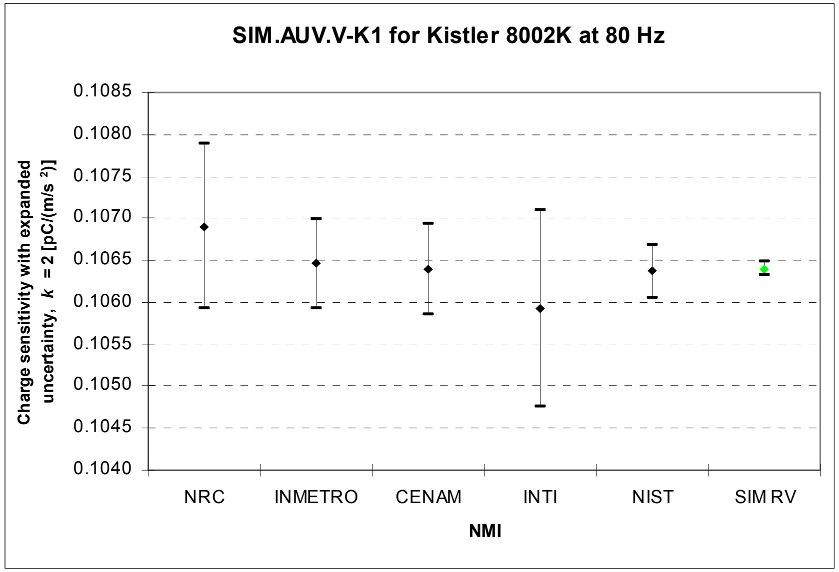
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Kistler 8002K s/n 100443 Frequency: 80 Hz

**Degrees of Interlaboratory Equivalence**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | 0.00044 | 0.00112 | 0.00050 | 0.00112 | 0.00097 | 0.00152 | 0.00053 | 0.00103 |
| **INMETRO** | -0.00044 | 0.00112 | | | 0.00006 | 0.00076 | 0.00053 | 0.00128 | 0.00009 | 0.00062 |
| **CENAM** | -0.00050 | 0.00112 | -0.00006 | 0.00076 | | | 0.00047 | 0.00129 | 0.00003 | 0.00063 |
| **INTI** | -0.00097 | 0.00152 | -0.00053 | 0.00128 | -0.00047 | 0.00129 | | | -0.00044 | 0.00121 |
| **NIST** | -0.00053 | 0.00103 | -0.00009 | 0.00062 | -0.00003 | 0.00063 | 0.00044 | 0.00121 | | |

**Degrees of Laboratory to Reference Value Equivalence**

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1069 | 0.00049 | 0.00050 | 0.00098 |
| **INMETRO** | 0.10646 | 0.00027 | 0.00006 | 0.00054 |
| **CENAM** | 0.1064 | 0.00027 | 0.00000 | 0.00055 |
| **INTI** | 0.10593 | 0.00058 | -0.00047 | 0.00117 |
| **NIST** | 0.10637 | 0.00016 | -0.00003 | 0.00033 |
| **SIM RV** | 0.10640 | 0.00004 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

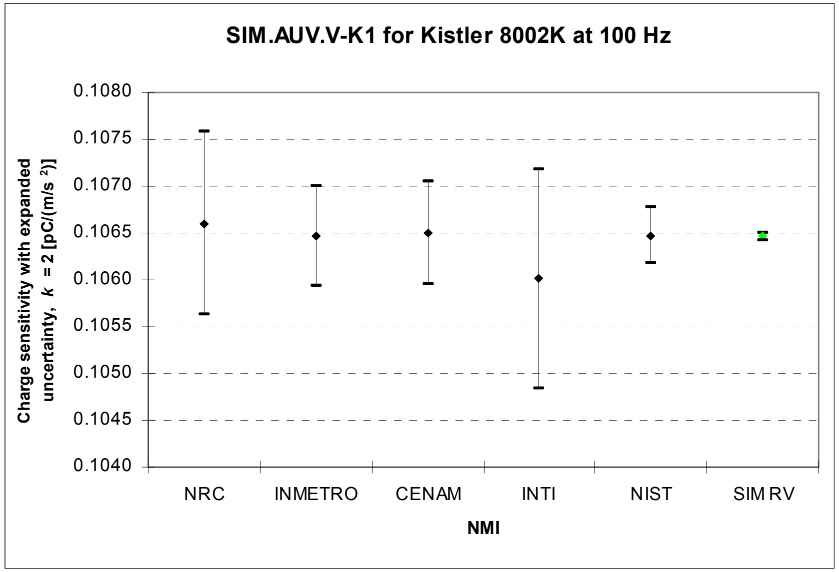
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Kistler 8002K s/n 100443 Frequency: 100 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | 0.00014 | 0.00111 | 0.00010 | 0.00112 | 0.00059 | 0.00152 | 0.00013 | 0.00102 |
| **INMETRO** | -0.00014 | 0.00111 | | | -0.00004 | 0.00076 | 0.00045 | 0.00128 | -0.00001 | 0.00061 |
| **CENAM** | -0.00010 | 0.00112 | 0.00004 | 0.00076 | | | 0.00049 | 0.00129 | 0.00003 | 0.00062 |
| **INTI** | -0.00059 | 0.00152 | -0.00045 | 0.00128 | -0.00049 | 0.00129 | | | -0.00046 | 0.00120 |
| **NIST** | -0.00013 | 0.00102 | 0.00001 | 0.00061 | -0.00003 | 0.00062 | 0.00046 | 0.00120 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1066 | 0.00049 | 0.00014 | 0.00098 |
| **INMETRO** | 0.10646 | 0.00027 | 0.00000 | 0.00053 |
| **CENAM** | 0.1065 | 0.00027 | 0.00004 | 0.00054 |
| **INTI** | 0.10601 | 0.00058 | -0.00045 | 0.00117 |
| **NIST** | 0.10647 | 0.00015 | 0.00001 | 0.00030 |
| **SIM RV** | 0.10646 | 0.00002 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $$D_i = x_i - x_{RV}$$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $$U_i = 2\sqrt{u_i^2 + u_{RV}^2}$$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $$D_{ij} = x_i - x_j$$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $$U_{ij} = 2\sqrt{u_i^2 + u_j^2}$$

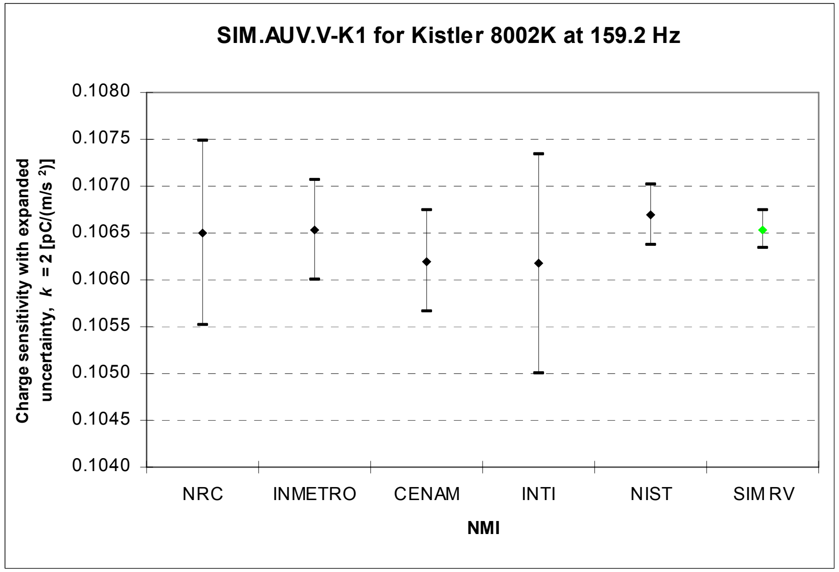
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Kistler 8002K s/n 100443 Frequency: 159.2 Hz

**Degrees of Interlaboratory Equivalence**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00003 | 0.00112 | 0.00030 | 0.00112 | 0.00033 | 0.00152 | -0.00019 | 0.00103 |
| **INMETRO** | 0.00003 | 0.00112 | | | 0.00033 | 0.00076 | 0.00036 | 0.00128 | -0.00016 | 0.00062 |
| **CENAM** | -0.00030 | 0.00112 | -0.00033 | 0.00076 | | | 0.00003 | 0.00129 | -0.00049 | 0.00063 |
| **INTI** | -0.00033 | 0.00152 | -0.00036 | 0.00128 | -0.00003 | 0.00129 | | | -0.00052 | 0.00121 |
| **NIST** | 0.00019 | 0.00103 | 0.00016 | 0.00062 | 0.00049 | 0.00063 | 0.00052 | 0.00121 | | |

**Degrees of Laboratory to Reference Value Equivalence**

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1065 | 0.00049 | -0.00004 | 0.00100 |
| **INMETRO** | 0.10653 | 0.00027 | -0.00001 | 0.00057 |
| **CENAM** | 0.1062 | 0.00027 | -0.00034 | 0.00058 |
| **INTI** | 0.10617 | 0.00058 | -0.00037 | 0.00119 |
| **NIST** | 0.10669 | 0.00016 | 0.00015 | 0.00038 |
| **SIM RV** | 0.10654 | 0.00010 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

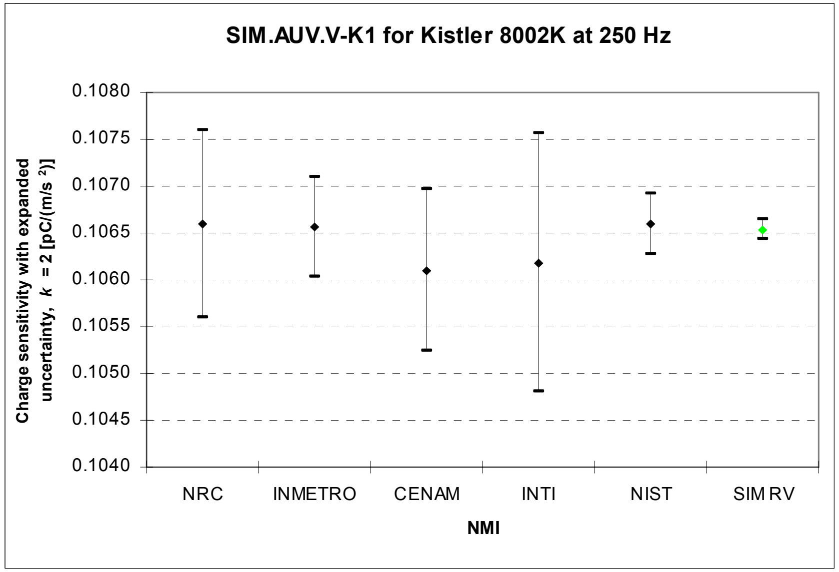
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Kistler 8002K s/n 100443 Frequency: 250 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | 0.00004 | 0.00114 | 0.00050 | 0.00133 | 0.00042 | 0.00171 | 0.00000 | 0.00105 |
| **INMETRO** | -0.00004 | 0.00114 | | | 0.00046 | 0.00102 | 0.00038 | 0.00148 | -0.00004 | 0.00062 |
| **CENAM** | -0.00050 | 0.00133 | -0.00046 | 0.00102 | | | -0.00008 | 0.00163 | -0.00050 | 0.00092 |
| **INTI** | -0.00042 | 0.00171 | -0.00038 | 0.00148 | 0.00008 | 0.00163 | | | -0.00042 | 0.00142 |
| **NIST** | 0.00000 | 0.00105 | 0.00004 | 0.00062 | 0.00050 | 0.00092 | 0.00042 | 0.00142 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1066 | 0.00050 | 0.00006 | 0.00101 |
| **INMETRO** | 0.10656 | 0.00027 | 0.00002 | 0.00054 |
| **CENAM** | 0.1061 | 0.00043 | -0.00044 | 0.00087 |
| **INTI** | 0.10618 | 0.00069 | -0.00036 | 0.00138 |
| **NIST** | 0.10660 | 0.00016 | 0.00006 | 0.00034 |
| **SIM RV** | 0.10654 | 0.00005 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

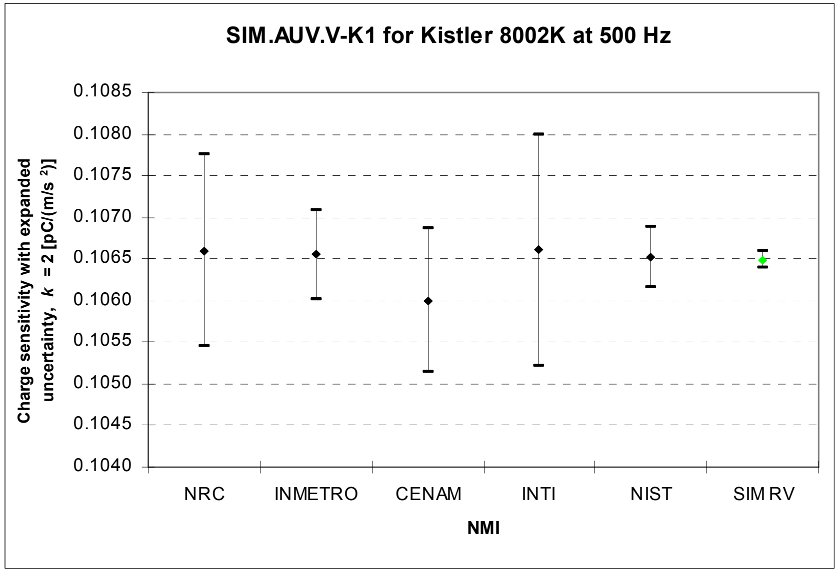
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Kistler 8002K s/n 100443 Frequency: 500 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | 0.00005 | 0.00127 | 0.00060 | 0.00144 | -0.00001 | 0.00180 | 0.00008 | 0.00120 |
| **INMETRO** | -0.00005 | 0.00127 | | | 0.00055 | 0.00102 | -0.00006 | 0.00148 | 0.00003 | 0.00064 |
| **CENAM** | -0.00060 | 0.00144 | -0.00055 | 0.00102 | | | -0.00061 | 0.00163 | -0.00052 | 0.00094 |
| **INTI** | 0.00001 | 0.00180 | 0.00006 | 0.00148 | 0.00061 | 0.00163 | | | 0.00009 | 0.00143 |
| **NIST** | -0.00008 | 0.00120 | -0.00003 | 0.00064 | 0.00052 | 0.00094 | -0.00009 | 0.00143 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1066 | 0.00057 | 0.00011 | 0.00115 |
| **INMETRO** | 0.10655 | 0.00027 | 0.00006 | 0.00054 |
| **CENAM** | 0.1060 | 0.00043 | -0.00049 | 0.00087 |
| **INTI** | 0.10661 | 0.00069 | 0.00012 | 0.00139 |
| **NIST** | 0.10652 | 0.00018 | 0.00003 | 0.00038 |
| **SIM RV** | 0.10649 | 0.00005 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

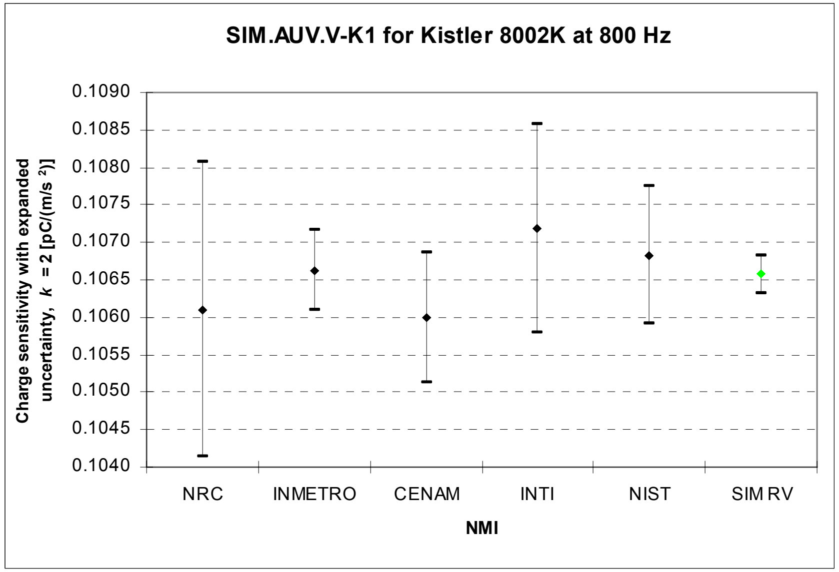
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Kistler 8002K s/n 100443 Frequency: 800 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00053 | 0.00204 | 0.00010 | 0.00215 | -0.00108 | 0.00241 | -0.00073 | 0.00217 |
| **INMETRO** | 0.00053 | 0.00204 | | | 0.00063 | 0.00102 | -0.00055 | 0.00149 | -0.00020 | 0.00106 |
| **CENAM** | -0.00010 | 0.00215 | -0.00063 | 0.00102 | | | -0.00118 | 0.00164 | -0.00083 | 0.00126 |
| **INTI** | 0.00108 | 0.00241 | 0.00055 | 0.00149 | 0.00118 | 0.00164 | | | 0.00035 | 0.00167 |
| **NIST** | 0.00073 | 0.00217 | 0.00020 | 0.00106 | 0.00083 | 0.00126 | -0.00035 | 0.00167 | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1061 | 0.00098 | -0.00047 | 0.00198 |
| **INMETRO** | 0.10663 | 0.00027 | 0.00006 | 0.00059 |
| **CENAM** | 0.1060 | 0.00043 | -0.00057 | 0.00090 |
| **INTI** | 0.10718 | 0.00070 | 0.00061 | 0.00142 |
| **NIST** | 0.10683 | 0.00046 | 0.00026 | 0.00095 |
| **SIM RV** | 0.10657 | 0.00013 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

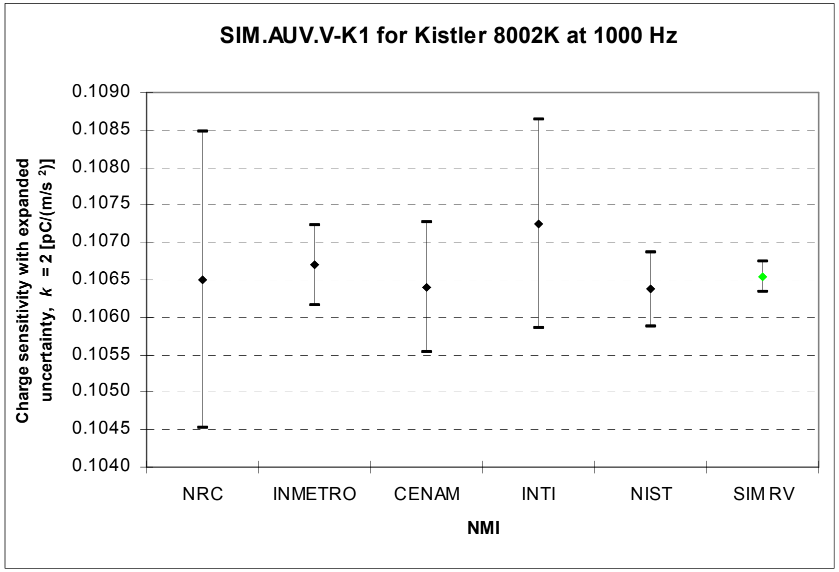
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Kistler 8002K s/n 100443 Frequency: 1000 Hz

**Degrees of Interlaboratory Equivalence**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00020 | 0.00204 | 0.00010 | 0.00216 | -0.00075 | 0.00242 | 0.00013 | 0.00203 |
| **INMETRO** | 0.00020 | 0.00204 | | | 0.00030 | 0.00102 | -0.00055 | 0.00149 | 0.00033 | 0.00072 |
| **CENAM** | -0.00010 | 0.00216 | -0.00030 | 0.00102 | | | -0.00085 | 0.00164 | 0.00003 | 0.00100 |
| **INTI** | 0.00075 | 0.00242 | 0.00055 | 0.00149 | 0.00085 | 0.00164 | | | 0.00088 | 0.00148 |
| **NIST** | -0.00013 | 0.00203 | -0.00033 | 0.00072 | -0.00003 | 0.00100 | -0.00088 | 0.00148 | | |

**Degrees of Laboratory to Reference Value Equivalence**

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1065 | 0.00099 | -0.00004 | 0.00198 |
| **INMETRO** | 0.10670 | 0.00027 | 0.00016 | 0.00057 |
| **CENAM** | 0.1064 | 0.00043 | -0.00014 | 0.00089 |
| **INTI** | 0.10725 | 0.00070 | 0.00071 | 0.00141 |
| **NIST** | 0.10637 | 0.00024 | -0.00017 | 0.00053 |
| **SIM RV** | 0.10654 | 0.00010 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

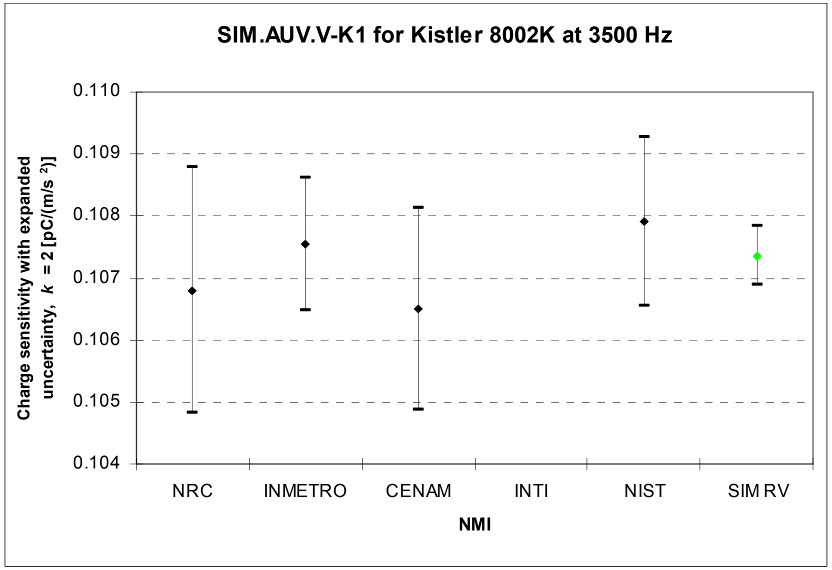
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Kistler 8002K s/n 100443 Frequency: 3500 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00075 | 0.00226 | 0.00030 | 0.00257 | | | -0.00110 | 0.00240 |
| **INMETRO** | 0.00075 | 0.00226 | | | 0.00105 | 0.00195 | | | -0.00035 | 0.00173 |
| **CENAM** | -0.00030 | 0.00257 | -0.00105 | 0.00195 | | | | | -0.00140 | 0.00212 |
| **INTI** | | | | | | | | | | |
| **NIST** | 0.00110 | 0.00240 | 0.00035 | 0.00173 | 0.00140 | 0.00212 | | | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1068 | 0.00099 | -0.00056 | 0.00204 |
| **INMETRO** | 0.10755 | 0.00054 | 0.00019 | 0.00117 |
| **CENAM** | 0.1065 | 0.00081 | -0.00086 | 0.00170 |
| **INTI** | | | | |
| **NIST** | 0.10790 | 0.00068 | 0.00054 | 0.00144 |
| **SIM RV** | 0.10736 | 0.00023 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

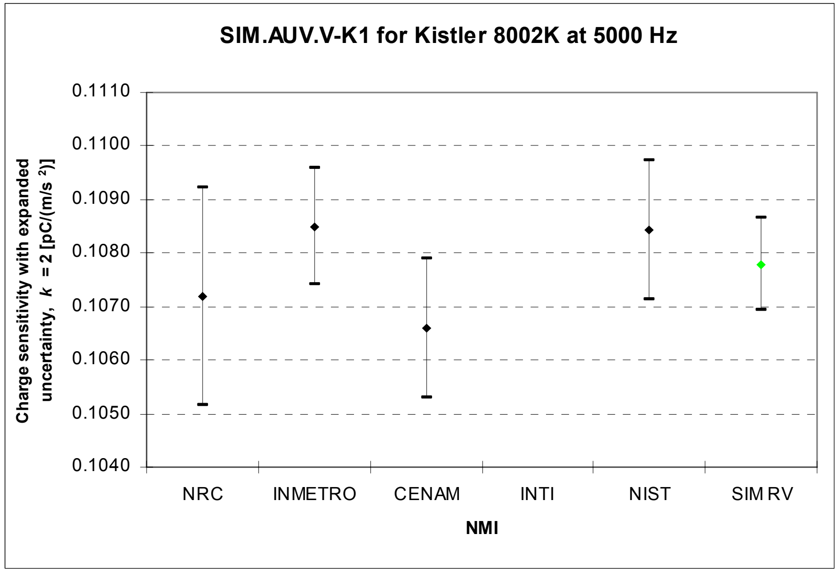
## Regional Comparison: SIM.AUV.V-K1
## Single-Ended Accelerometer: Kistler 8002K s/n 100443 Frequency: 5000 Hz

### Degrees of Interlaboratory Equivalence

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ | $D_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | | | -0.00129 | 0.00230 | 0.00060 | 0.00241 | | | -0.00122 | 0.00241 |
| **INMETRO** | 0.00129 | 0.00230 | | | 0.00189 | 0.00170 | | | 0.00007 | 0.00169 |
| **CENAM** | -0.00060 | 0.00241 | -0.00189 | 0.00170 | | | | | -0.00182 | 0.00184 |
| **INTI** | | | | | | | | | | |
| **NIST** | 0.00122 | 0.00241 | -0.00007 | 0.00169 | 0.00182 | 0.00184 | | | | |

### Degrees of Laboratory to Reference Value Equivalence

| | $x$ | $u$ | $D_i$ | $U(D)_i$ |
|---|---|---|---|---|
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **NRC** | 0.1072 | 0.00102 | -0.00059 | 0.00220 |
| **INMETRO** | 0.10849 | 0.00054 | 0.00070 | 0.00138 |
| **CENAM** | 0.1066 | 0.00065 | -0.00119 | 0.00156 |
| **INTI** | | | | |
| **NIST** | 0.10842 | 0.00065 | 0.00063 | 0.00156 |
| **SIM RV** | 0.10779 | 0.00043 | | |




The difference ($D_i$) of each laboratory with respect to the reference value is given by: $D_i = x_i - x_{RV}$

The expanded uncertainty [$U(D)_i$] for $k$ = 2 of the value of the difference $D_i$ is given by: $U_i = 2\sqrt{u_i^2 + u_{RV}^2}$

The difference ($D_{ij}$) between laboratories $i$ and $j$ is given by: $D_{ij} = x_i - x_j$

The expanded uncertainty ($U_{ij}$) for $k$ = 2 of the value of the difference $D_{ij}$ is given by: $U_{ij} = 2\sqrt{u_i^2 + u_j^2}$

## 6. Conclusions

Five NMIs of the Inter-American Metrology System (SIM) measured the sensitivity of two single-ended and one back-to-back accelerometers at ten frequencies over the range of 50 Hz to 5 kHz. Reference Values (RVs) were computed from the measurement results and the nominal numbers of repeat trials reported by the NMIs that participated in the comparison. Degrees of equivalence between the measurement results reported by the NMIs and the SIM RVs as well as pairwise degrees of equivalence between each of the participating NMIs were evaluated for each accelerometer at all frequencies. The absolute reported sensitivities and the SIM RVs are plotted for each accelerometer at all frequencies with upper and lower expanded uncertainty limits shown for a coverage factor of $k = 2$ . These plots typically indicate robust overlap among the expanded uncertainties of the measurement results reported by the NMIs and the SIM RVs. The results of the SIM.AUV.V-K1 regional comparison are linked to those of the CCAUV.V-K1 in Appendix III. The results of the SIM.AUV.V-K1 comparison represent the calibration capabilities of the NMIs during the time period of the comparison (1997 to 1999) when the measurements were made.

## 7. References


[1] ISO 5347-1:1993, *Methods for the calibration of vibration and shock pick-ups — Part 1: Primary vibration calibration by interferometry.*

[2] ISO 5347-3:1993, *Methods for the calibration of vibration and shock pick-ups — Part 3: Secondary vibration calibration.*

[3] ISO 16063-1:1998, *Methods for the calibration of vibration and shock transducers — Part 1: Basic concepts.*

[4] ISO 16063-11:1999, *Methods for the calibration of vibration and shock transducers — Part 11: Primary vibration calibration by laser interferometry.*

[5] ISO 16063-21:2003, *Methods for the calibration of vibration and shock transducers — Part 21: Vibration calibration by comparison to a reference transducer.*

[6] A. L. Rukhin and M. G. *Vangel, Estimation of a Common Mean and Weighted Means Statistics,* Journal of the American Statistical Association, Vol. 93, No 441, March 1998.

[7] ISO *Guide to the Expression of Uncertainty in Measurement*, International Organization for Standardization, ISBN 92-67-10188-9, Geneva, Switzerland, 1995.

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The authors gratefully acknowledge the many contributions made by others in the preparation of this report. In particular, contributions made by: Beverly F. Payne with NIST (retired), Guillermo Silva Pineda with CENAM, Gustavo Palmeira Ripper with INMETRO, George S. K. Wong and Lixue Wu with NRC, Lucia N. Taibo and Lucía Barceló with INTI in the development of the Provisional Report and for providing details on calibrations performed for SIM.AUV.V-K1.

# Appendix I

# Acceleration comparison SIM.AUV.V-K1
# Provisional Report

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**Lucia N. Taibo and Lucía Barceló**
INTI, Centro de Investigación en Acústica
Av. Gral. Paz e/Albarellos y Av. de los Constituyentes. C.C. 157–(1650) San Martín, Buenos Aires, República Argentina

## Abstract

This report presents the results obtained from an international comparison of the calibration of acceleration standards by participating laboratories of the Interamerican Metrology System (SIM). Participating laboratories were the National Metrology Institutes (NMI) of five american countries, i.e., National Institute of Standards and Technology (NIST - U.S.A.), National Research Council (NRC - Canada), Centro Nacional de Metrología (CENAM - Mexico), Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO - Brazil) and Instituto Nacional de Tecnología Industrial (INTI - Argentina). Interferometric calibrations of three standard accelerometers and charge calibration of a signal conditioner were performed. A meeting was held at CENAM from 14 June 1999 to 18 June 1999 with representatives from NIST, INMETRO and CENAM present. A draft of this report was discussed during a SIM Acoustics and Vibration Metrology Working Group (MWG 9) meeting at INMETRO from 30 October 2000 to 31 October 2000. Conclusions presented in this report were reached at the aforementioned meeting held at INMETRO, where representatives of the five participating NMIs discussed the draft report. The Final Report was accepted by representatives of these NMIs, rechecked and circulated by the pilot laboratory in September 2001, and released the week of 30 September 2001.

## 1. Introduction

This comparison was officially carried out under the framework of SIM, joining two subregions: NORAMET (Canada, Mexico, USA) and SURAMET (Argentina, Brazil). It was conducted in a circular way (see Figure 1), that is, the measurements started and finished at the same laboratory, NIST - USA, called the pilot laboratory. The responsibility for the administrative organization was taken by CENAM - Mexico.

The process started in 1996, the measurements being carried out during 1997 to 1999. Each laboratory had 2 months for the measurements, and the measurement standards were hand carried to the next laboratory to assure the integrity of the items during transportation.

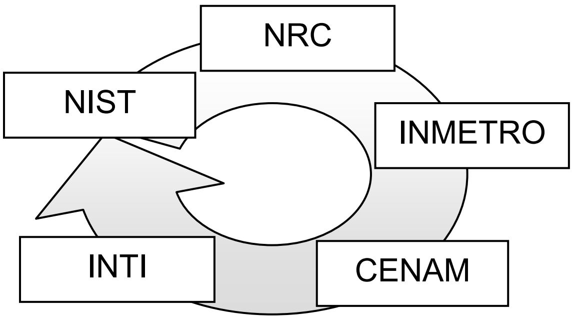



Figure 1. Circulation

The assurance of each instrument's stability during the period of the comparison was achieved by two calibration results reported by NIST: one (designated NIST97) obtained at the start of the comparison, and one (designated NIST99) obtained at the end of the comparison. The average of these two NIST results (designated NIST) is used as the NIST data in all calculations for this report.

The instruments measured during the comparison were one charge amplifier and three different standard accelerometers. Two transducers of the single-ended type and one of the double-ended type (Table 1) were circulated.

| Equipment | Manufacturer | Model | Characteristics |
|---|---|---|---|
| Accelerometer | Brüel & Kjær | 8305 | Double-ended type |
| Accelerometer | Kistler | 8002K | Single-ended type |
| Accelerometer | Endevco | 2270M8 | Single-ended type |
| Charge amplifier | Brüel & Kjær | 2626 | |

Table 1. Instrumentation

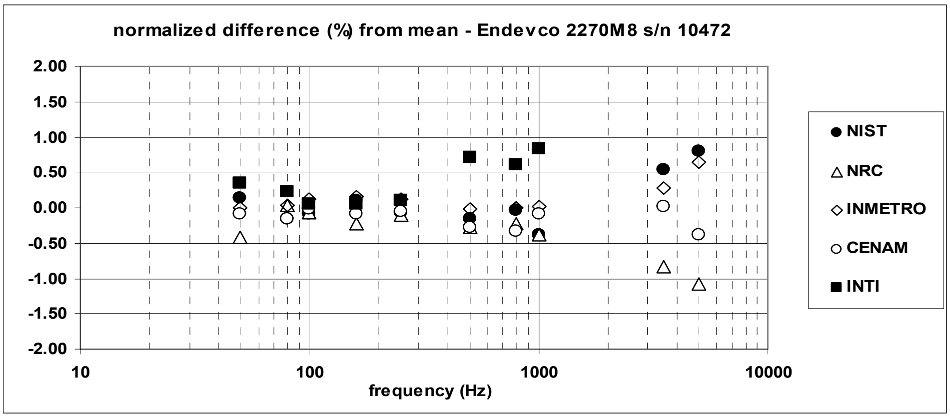
The recommended procedure for calibrating the accelerometers was to use absolute methods according to standard ISO 5347 [1,2] . The accelerometer calibration conditions are listed in Table 2. The charge amplifier was to be calibrated at the same frequencies. There were no restrictions imposed upon the data capture or analysis procedure. Either computer automated systems or manual methods were acceptable.

| Frequency (Hz) | Acceleration ($m/s^2$ peak) | Calibration Method |
|---|---|---|
| 50 | 20 | Laser interferometer |
| 80 | 30 | Laser interferometer |
| 100 | 30 | Laser interferometer |
| 159.2 | 50 | Laser interferometer |
| 250 | 50 | Laser interferometer |
| 500 | 80 | Laser interferometer |
| 800 | 100 | Laser interferometer |
| 1000 | 100 | Laser interferometer |
| 3500 | 60 / 93 | Laser interferometer |
| 5000 | 122 / 190 | Laser interferometer |

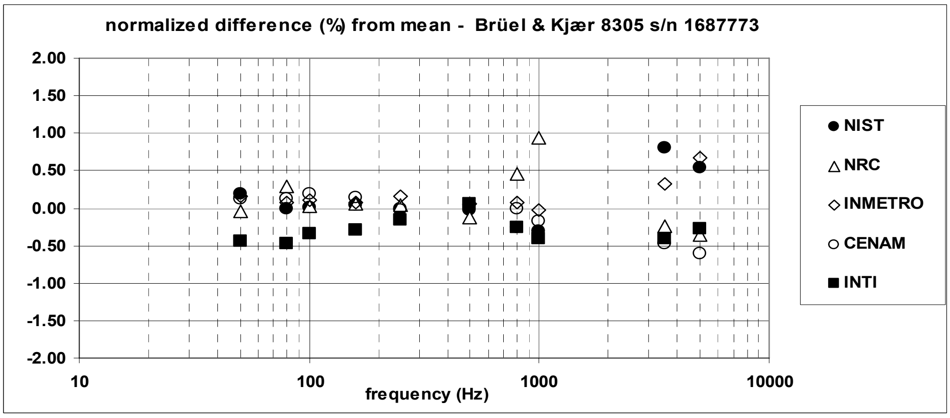
Table 2. Accelerometer calibration conditions

## 2. Results

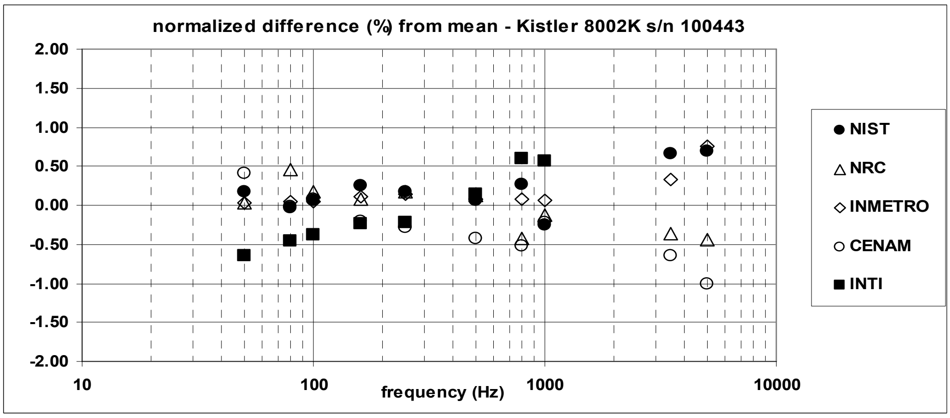
For each laboratory, Figure 2 presents the normalized difference, in percent, of the charge sensitivity from the mean calculated for all five participating laboratories at every measured frequency (see ${}_{l}d_{i}(f)$ in Appendix A).




(a) ${}_{l}d_{1}(f)$




(b) ${}_{l}d_{2}(f)$




(c) ${}_{l}d_{3}(f)$

Figure 2. For each laboratory, ${}_{l}d_{i}(f)$ (%), normalized difference from the mean.

For a given accelerometer, the mean was computed as the average of the results obtained by all participating NMIs (see $X_{mi}(f)$ in Appendix A). Figure 2 shows the normalized difference from the mean for each participating NMI.

The results show that most normalized differences from the mean lie within ± 0.5 % for frequencies up to 1 kHz and ± 1.0 % for 3.5 kHz and 5 kHz. For the reference frequency (159.2 Hz), the absolute values of the normalized differences are no greater than 0.3 %. All these normalized differences are within the applicable limits of uncertainty contained in the Scope of ISO 5347-1:1993 [2], i.e., ± 0.5 % at the reference frequency, ± 1 % up to and including 1000 Hz and ± 2 % for frequencies above 1000 Hz.

For the single-ended accelerometers, all participating laboratories achieved normalized differences from the mean within ± 0.85 % for the frequency range from 50 Hz to 1 kHz, and four laboratories (NIST, NRC, INMETRO and CENAM) achieved normalized differences from the mean within ± 0.55 %. For 3.5 kHz and 5 kHz, these four laboratories achieved normalized differences from the mean within ± 1.1 %, and for NIST, CENAM and INMETRO, the absolute values of the normalized differences from the mean did not exceed 1%.

For the double-ended accelerometer, all participating laboratories achieved normalized differences from the mean within ± 1% for the entire frequency range of calibration, and within ± 0.5 % for frequencies lower than 1 kHz.

Both the normalized differences from the mean and the spread for different accelerometers were the smallest at frequencies near the reference frequency, see Figure 3. Obviously, all laboratories have more experience and knowledge of their systems in this region, so this result was expected.

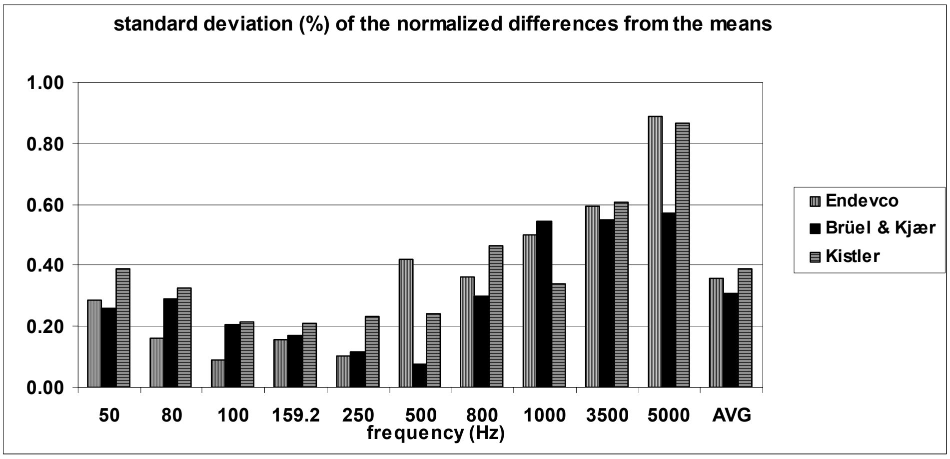



Figure 3. For each accelerometer, $s_{di}(f)$, the standard deviation (%) of the normalized differences.

For each accelerometer type, Figure 3 presents the standard deviation, in percent, of the absolute normalized difference from the mean for all participating laboratories. It should be noted that Kistler and Endevco accelerometers are single-ended types and the Brüel & Kjær accelerometer is a double-ended type.

Figure 4 shows the root mean square (RMS) of the normalized difference from the mean of all accelerometers, by each participating laboratory at every frequency within the calibration range.

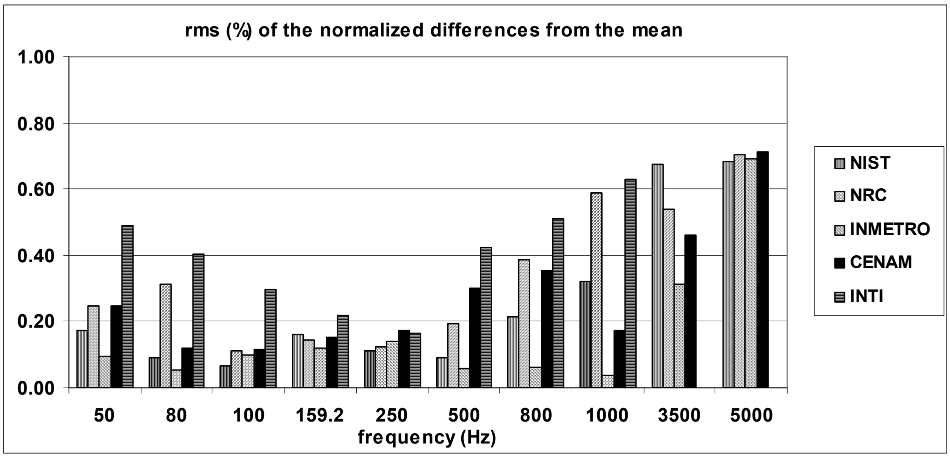



Figure 4. For each laboratory *l*, $_{l}RMS_{d}(f)$, the root mean square of the normalized differences from the mean for the 3 accelerometers.

The results obtained for the gain of the Brüel & Kjær 2626 charge amplifier are presented in Figure 5. Three values from NIST are presented, corresponding to one measurement (NIST97) at the start of the intercomparison, one (NIST99) at the end of the intercomparison, and the average (NIST) of both.

It should be noted that NRC did not report any data regarding the gain of the amplifier, reporting only the voltage sensitivity of the accelerometers plus the amplifier. For comparison against the accelerometer charge sensitivity data from the other laboratories, the accelerometer charge sensitivities for NRC were calculated from NRC voltage sensitivity data using the mean value of the amplifier calibrations from all other laboratories (see $G_m(f)$, Table B-1)

From Table B-2, the measurements of charge amplifier gain show agreement within +0.46/-0.29 % during the two year period of the comparison. Data from NIST, CENAM and INMETRO showed agreement within ± 0.29 %.

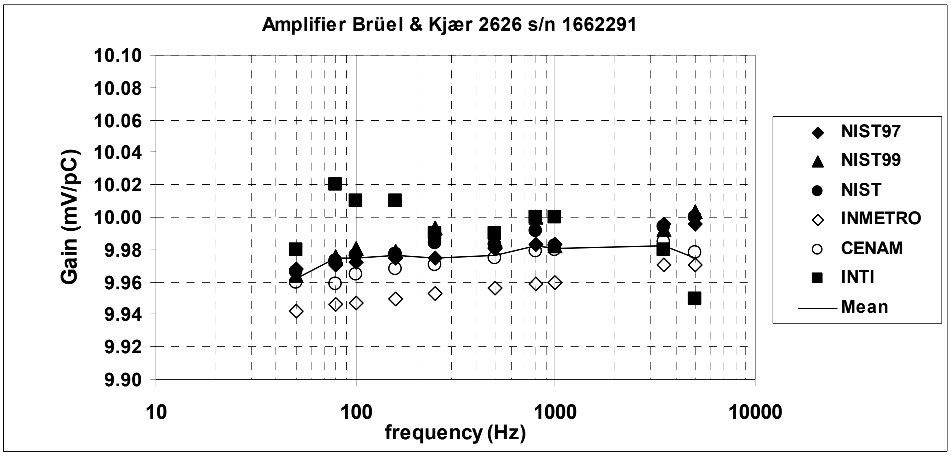



Figure 5. Reported gains of the Brüel & Kjær 2626 charge amplifier.

## 3 Conclusions

The overall results obtained were highly satisfactory. This comparison can be considered the first interamerican comparison on the calibration of vibration standards. This project has undoubtedly increased the technical exchange among the participating laboratories of the Interamerican Metrology System, and will provide them a deeper knowledge of their calibration systems and guide them to future improvements.

These results may lead to achieving a future agreement and mutual recognition among the participating NMIs in their absolute calibration procedures of standard accelerometers.

The results from NIST, CENAM and INMETRO for the frequency range 50 Hz to 5 kHz showed that the absolute values of the normalized differences from the mean did not exceed 1 % for both single-ended and double-ended accelerometers.

For the double-ended accelerometer all the participating laboratories obtained results within ± 1% for the whole frequency range of analysis. For the single-ended types results from all participating laboratories were within the applicable limits of uncertainty given in ISO 5347-1:1993 [2].

Further cooperation and technical interaction will be necessary for agreement in a wider frequency range. It is recommended that the participating laboratories organize a future comparison in accelerometer calibration covering the frequency range 10 Hz to 10 kHz in accordance with new standards [3,4].

[1] ISO 5347-0:1987 Methods for the calibration of vibration and shock pick-ups – Part 0: Basic concepts. This Standard includes: ISO 5347-0/COR1:1990 Technical Corrigendum 1, and ISO 5347-0/COR2:1993 Technical Corrigendum 2.
[2] ISO 5347-1:1993, Methods for the calibration of vibration and shock pick-ups – Part 1: Primary vibration calibration by laser interferometry.
[3] ISO 16063-1:1998 Methods for the calibration of vibration and shock transducers – Part 1: Basic concepts.
[4] ISO 16063-11:1999 Methods for the calibration of vibration and shock transducers – Part 11: Primary vibration calibration by laser interferometry.

# APPENDIX A - Accelerometers

It is important to establish a nomenclature for identifying the results reported by the laboratories and to eliminate misinterpretation of the graphics:

${}_{l}X_{i}(f)$ - result reported by laboratory *l* for accelerometer *i* at frequency *f*

$X_{mi}(f)$ - mean for all laboratories, obtained as the average of all laboratory results for accelerometer *i* at frequency *f*

where *l* = 1 to 5 for NIST, NRC, CENAM, INMETRO, INTI respectively,
*i* = 1 to 3 for Endevco, Brüel & Kjær, Kistler accelerometers respectively

In the following equations, *n* is the number of laboratories reporting data. Depending on frequency or accelerometer type, *n*=4 or *n*=5. In calculations based on these equations, the data for NIST is the average of NIST measurements from 1997 to 1999.

$$X_{mi}(f) = \frac{1}{n}\sum_{l=1}^{n} {}_{l}X_{i}(f)$$

Tabulated in Table A-2 and plotted in Figure A-2, the normalized difference, in percent, of the reported results by each laboratory *l* from the mean value of the charge sensitivity of accelerometer *i* at frequency *f* is given by:

$${}_{l}d_{i}(f) = \left(\frac{{}_{l}X_{i}(f) - X_{mi}(f)}{X_{mi}(f)}\right)\times 100$$

**Accelerometer Endevco 2270M8 – Charge Sensitivity (pC/ms$^{-2}$)**

| Freq. (Hz) | NIST97 | NRC $_2X_1(f)$ | CENAM $_3X_1(f)$ | INMETRO $_4X_1(f)$ | INTI $_5X_1(f)$ | NIST99 | NIST $_1X_1(f)$ | MEAN $X_{m1}(f)$ |
|---|---|---|---|---|---|---|---|---|
| 50 | 0.20307 | 0.20220 | 0.20290 | 0.20305 | 0.20377 | 0.20364 | 0.20336 | 0.20306 |
| 80 | 0.20269 | 0.20310 | 0.20270 | 0.20309 | 0.20348 | 0.20273 | 0.20271 | 0.20302 |
| 100 | 0.20236 | 0.20260 | 0.20270 | 0.20298 | 0.20285 | 0.20272 | 0.20254 | 0.20273 |
| 159.2 | 0.20264 | 0.20220 | 0.20250 | 0.20300 | 0.20276 | 0.20309 | 0.20287 | 0.20267 |
| 250 | 0.20240 | 0.20240 | 0.20250 | 0.20284 | 0.20281 | 0.20256 | 0.20248 | 0.20261 |
| 500 | 0.20232 | 0.20220 | 0.20220 | 0.20273 | 0.20423 | 0.20262 | 0.20247 | 0.20277 |
| 800 | 0.20269 | 0.20240 | 0.20220 | 0.20286 | 0.20409 | 0.20288 | 0.20279 | 0.20287 |
| 1000 | 0.20183 | 0.20210 | 0.20270 | 0.20289 | 0.20455 | 0.20231 | 0.20207 | 0.20286 |
| 3500 | 0.20369 | 0.20120 | 0.20290 | 0.20344 | | 0.20425 | 0.20397 | 0.20288 |
| 5000 | 0.20517 | 0.20100 | 0.20240 | 0.20450 | | 0.20442 | 0.20480 | 0.20318 |

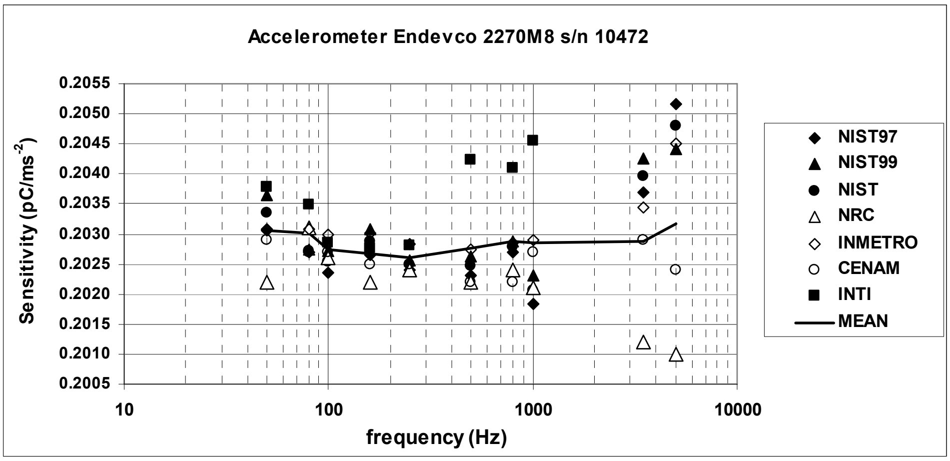
**Accelerometer Brüel & Kjær 8305 – Charge Sensitivity (pC/ms$^{-2}$)**

| Freq. (Hz) | NIST97 | NRC $_2X_2(f)$ | CENAM $_3X_2(f)$ | INMETRO $_4X_2(f)$ | INTI $_5X_2(f)$ | NIST99 | NIST $_1X_2(f)$ | MEAN $X_{m2}(f)$ |
|---|---|---|---|---|---|---|---|---|
| 50 | 0.12499 | 0.12490 | 0.12510 | 0.12515 | 0.12441 | 0.12539 | 0.12519 | 0.12495 |
| 80 | 0.12520 | 0.12540 | 0.12520 | 0.12513 | 0.12444 | 0.12486 | 0.12503 | 0.12504 |
| 100 | 0.12509 | 0.12500 | 0.12520 | 0.12511 | 0.12454 | 0.12489 | 0.12499 | 0.12497 |
| 159.2 | 0.12507 | 0.12510 | 0.12520 | 0.12512 | 0.12466 | 0.12508 | 0.12508 | 0.12503 |
| 250 | 0.12507 | 0.12510 | 0.12500 | 0.12524 | 0.12485 | 0.12497 | 0.12502 | 0.12504 |
| 500 | 0.12507 | 0.12500 | 0.12520 | 0.12522 | 0.12522 | 0.12516 | 0.12512 | 0.12515 |
| 800 | 0.12497 | 0.12580 | 0.12520 | 0.12531 | 0.12489 | 0.12482 | 0.12490 | 0.12522 |
| 1000 | 0.12504 | 0.12660 | 0.12520 | 0.12538 | 0.12491 | 0.12502 | 0.12503 | 0.12542 |
| 3500 | 0.12660 | 0.12560 | 0.12530 | 0.12631 | 0.12538 | 0.12721 | 0.12691 | 0.12590 |
| 5000 | 0.12749 | 0.12630 | 0.12600 | 0.12761 | 0.12642 | 0.1274 | 0.12745 | 0.12676 |

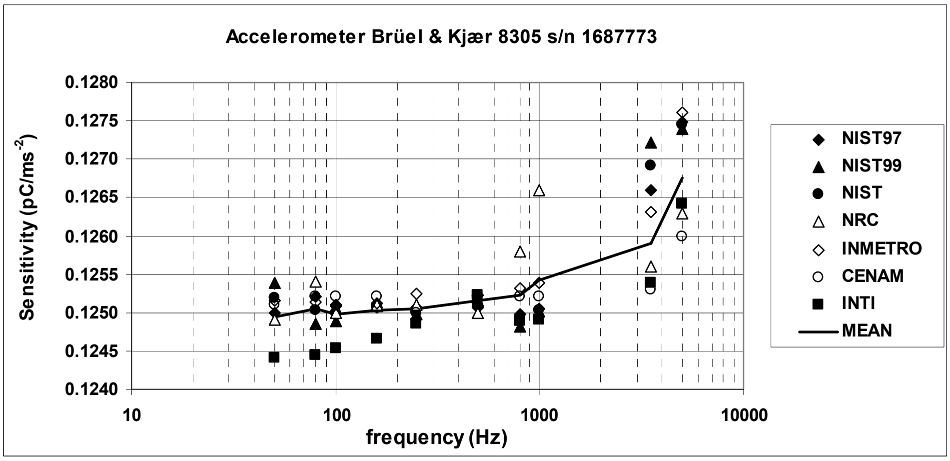
**Accelerometer Kistler 8002K – Charge Sensitivity (pC/ms$^{-2}$)**

| Freq. (Hz) | NIST97 | NRC $_2X_3(f)$ | CENAM $_3X_3(f)$ | INMETRO $_4X_3(f)$ | INTI $_5X_3(f)$ | NIST99 | NIST $_1X_3(f)$ | MEAN $X_{m3}(f)$ |
|---|---|---|---|---|---|---|---|---|
| 50 | 0.10662 | 0.10650 | 0.10690 | 0.10650 | 0.10579 | 0.10669 | 0.10666 | 0.10647 |
| 80 | 0.10648 | 0.10690 | 0.10640 | 0.10646 | 0.10593 | 0.10625 | 0.10637 | 0.10641 |
| 100 | 0.10643 | 0.10660 | 0.10650 | 0.10646 | 0.10601 | 0.10651 | 0.10647 | 0.10641 |
| 159.2 | 0.10664 | 0.10650 | 0.10620 | 0.10653 | 0.10617 | 0.10674 | 0.10669 | 0.10642 |
| 250 | 0.10664 | 0.10660 | 0.10610 | 0.10656 | 0.10618 | 0.10655 | 0.10660 | 0.10641 |
| 500 | 0.10648 | 0.10660 | 0.10600 | 0.10655 | 0.10661 | 0.10656 | 0.10652 | 0.10646 |
| 800 | 0.10665 | 0.10610 | 0.10600 | 0.10663 | 0.10718 | 0.10701 | 0.10683 | 0.10655 |
| 1000 | 0.10626 | 0.10650 | 0.10640 | 0.10670 | 0.10725 | 0.10648 | 0.10637 | 0.10664 |
| 3500 | 0.10776 | 0.10680 | 0.10650 | 0.10755 | | 0.10804 | 0.10790 | 0.10719 |
| 5000 | 0.10823 | 0.10720 | 0.10660 | 0.10849 | | 0.10861 | 0.10842 | 0.10768 |

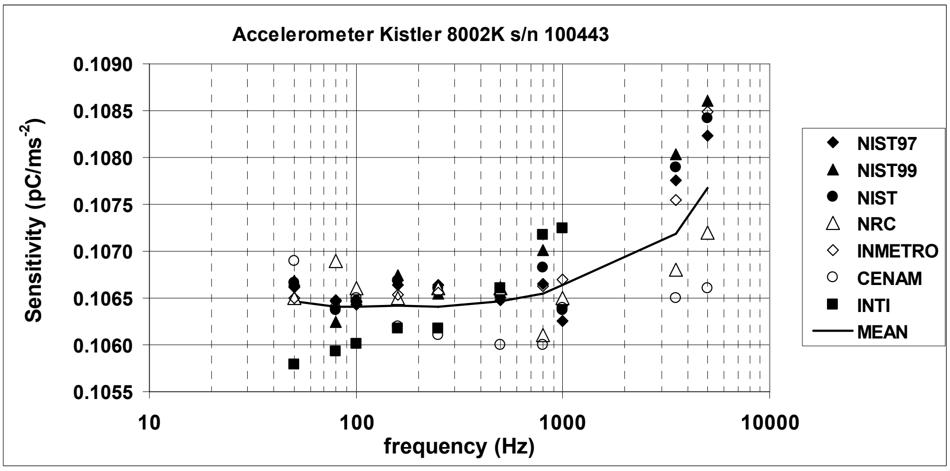
Table A-1. Charge sensitivity results for each accelerometer




(a) Endevco 2270M8 s/n 10472




(b) Brüel & Kjær 8305 s/n 1687773




(c) Kistler 8002K s/n 100443

Figure A-1. Charge sensitivity results for each accelerometer.

**Accelerometer Endevco 2270M8**

| Freq. (Hz) | NIST ${}_1d_1(f)$ | NRC ${}_2d_1(f)$ | CENAM ${}_3d_1(f)$ | INMETRO ${}_4d_1(f)$ | INTI ${}_5d_1(f)$ |
|---|---|---|---|---|---|
| 50 | 0.15 | -0.42 | -0.08 | 0.00 | 0.35 |
| 80 | -0.15 | 0.04 | -0.16 | 0.03 | 0.23 |
| 100 | -0.09 | -0.06 | -0.01 | 0.12 | 0.06 |
| 159.2 | 0.10 | -0.23 | -0.08 | 0.16 | 0.04 |
| 250 | -0.06 | -0.10 | -0.05 | 0.11 | 0.10 |
| 500 | -0.15 | -0.28 | -0.28 | -0.02 | 0.72 |
| 800 | -0.04 | -0.23 | -0.33 | 0.00 | 0.60 |
| 1000 | -0.39 | -0.37 | -0.08 | 0.01 | 0.83 |
| 3500 | 0.54 | -0.83 | 0.01 | 0.28 | |
| 5000 | 0.80 | -1.07 | -0.38 | 0.65 | |

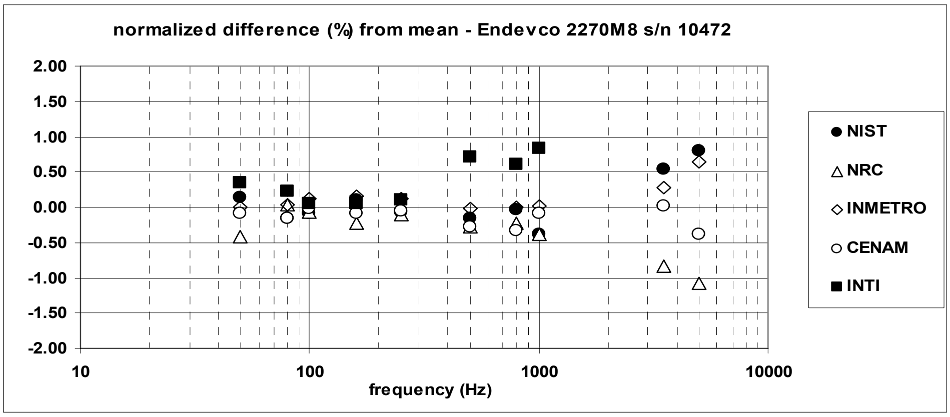
**Accelerometer Brüel & Kjær 8305**

| Freq. (Hz) | NIST ${}_1d_2(f)$ | NRC ${}_2d_2(f)$ | CENAM ${}_3d_2(f)$ | INMETRO ${}_4d_2(f)$ | INTI ${}_5d_2(f)$ |
|---|---|---|---|---|---|
| 50 | 0.19 | -0.04 | 0.12 | 0.16 | -0.43 |
| 80 | -0.01 | 0.29 | 0.13 | 0.07 | -0.48 |
| 100 | 0.02 | 0.02 | 0.18 | 0.11 | -0.34 |
| 159.2 | 0.04 | 0.06 | 0.14 | 0.07 | -0.30 |
| 250 | -0.02 | 0.05 | -0.03 | 0.16 | -0.15 |
| 500 | -0.02 | -0.12 | 0.04 | 0.06 | 0.06 |
| 800 | -0.26 | 0.46 | -0.02 | 0.07 | -0.26 |
| 1000 | -0.31 | 0.94 | -0.18 | -0.03 | -0.41 |
| 3500 | 0.80 | -0.24 | -0.48 | 0.33 | -0.41 |
| 5000 | 0.54 | -0.36 | -0.60 | 0.67 | -0.27 |

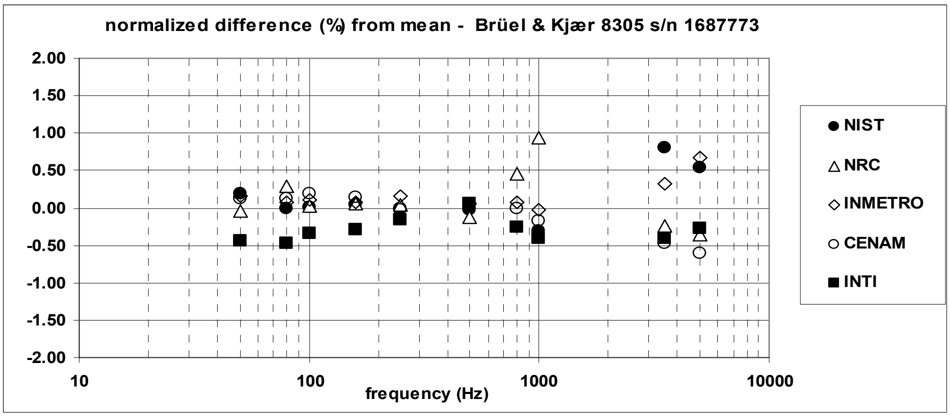
**Accelerometer Kistler 8002K**

| Freq. (Hz) | NIST ${}_1d_3(f)$ | NRC ${}_2d_3(f)$ | CENAM ${}_3d_3(f)$ | INMETRO ${}_4d_3(f)$ | INTI ${}_5d_3(f)$ |
|---|---|---|---|---|---|
| 50 | 0.18 | 0.03 | 0.40 | 0.03 | -0.64 |
| 80 | -0.04 | 0.46 | -0.01 | 0.05 | -0.45 |
| 100 | 0.06 | 0.18 | 0.08 | 0.05 | -0.38 |
| 159.2 | 0.25 | 0.08 | -0.21 | 0.10 | -0.23 |
| 250 | 0.18 | 0.18 | -0.29 | 0.14 | -0.22 |
| 500 | 0.06 | 0.13 | -0.43 | 0.08 | 0.14 |
| 800 | 0.26 | -0.42 | -0.52 | 0.08 | 0.59 |
| 1000 | -0.25 | -0.13 | -0.23 | 0.06 | 0.57 |
| 3500 | 0.66 | -0.36 | -0.64 | 0.34 | |
| 5000 | 0.69 | -0.45 | -1.00 | 0.75 | |

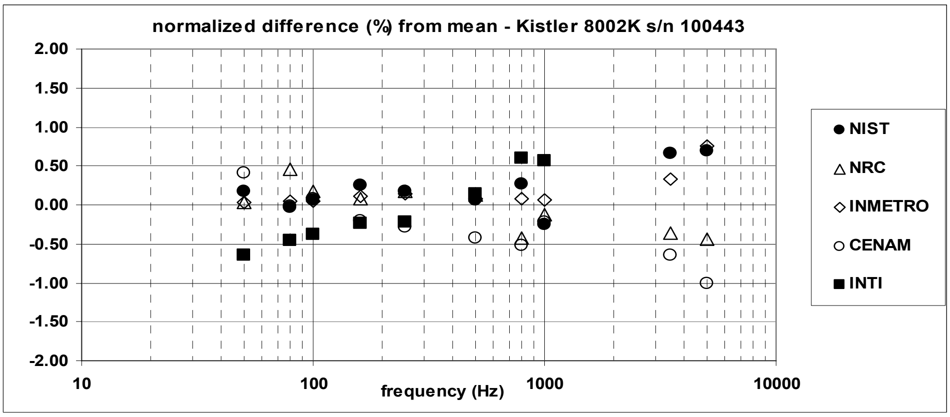
Table A-2. For each laboratory, ${}_ld_i(f)$ (%), normalized difference from the mean




(a) ${}_l d_1(f)$




(b) ${}_l d_2(f)$




(c) ${}_l d_3(f)$

Figure A-2. For each laboratory, ${}_l d_i(f)$ (%), normalized difference from the mean.

Tabulated in Table A-3 and plotted in Figure A-3, the standard deviation of the values of ${}_l d_i(f)$ from the *n* laboratories that reported data for accelerometer *i* at frequency *f* is given by:

$$s_{di}(f) = stddev({}_1 d_i(f),\ {}_2 d_i(f),\ \ldots\ {}_n d_i(f))$$

where,

$$stddev = \sqrt{\frac{n\sum x^2 - (\sum x)^2}{n(n-1)}}$$

Is the standard deviation of *n* samples of *x*

| Freq. (Hz) | Endevco $s_{d1}(f)$ | Brüel & Kjær $s_{d2}(f)$ | Kistler $s_{d3}(f)$ |
|---|---|---|---|
| 50 | 0.29 | 0.26 | 0.39 |
| 80 | 0.16 | 0.29 | 0.32 |
| 100 | 0.09 | 0.20 | 0.22 |
| 159.2 | 0.16 | 0.17 | 0.21 |
| 250 | 0.10 | 0.11 | 0.23 |
| 500 | 0.42 | 0.08 | 0.24 |
| 800 | 0.36 | 0.30 | 0.47 |
| 1000 | 0.50 | 0.54 | 0.34 |
| 3500 | 0.59 | 0.55 | 0.61 |
| 5000 | 0.89 | 0.57 | 0.86 |
| **AVG** | 0.36 | 0.31 | 0.39 |

Table A-3. For each accelerometer, $s_{di}(f)$, the standard deviation (%) of the normalized differences, where the last line of each column presents the average of the values shown in that column.

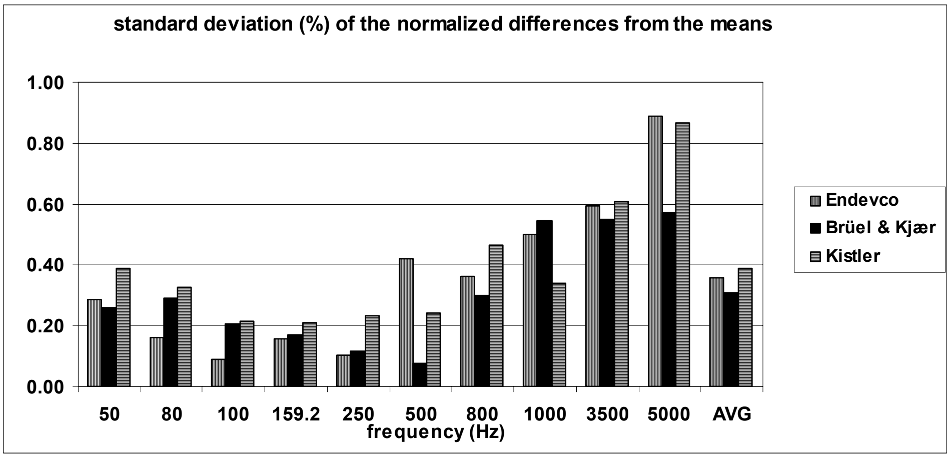



Figure A-3. For each accelerometer, $s_{di}(f)$, the standard deviation (%) of the normalized differences.

Tabulated in Table A-4 and plotted in Figure A-4, the root mean square of ${}_l d_i(f)$, is given by

$$ {}_l RMS_d(f) = \sqrt{\sum_{i=1}^{3} \left( {}_l d_i(f) \right)^2 / 3} $$

| Freq. (Hz) | NIST ${}_1 RMS_d(f)$ | NRC ${}_2 RMS_d(f)$ | CENAM ${}_3 RMS_d(f)$ | INMETRO ${}_4 RMS_d(f)$ | INTI ${}_5 RMS_d(f)$ |
|---|---|---|---|---|---|
| 50 | 0.17 | 0.25 | 0.25 | 0.09 | 0.49 |
| 80 | 0.09 | 0.31 | 0.12 | 0.05 | 0.40 |
| 100 | 0.06 | 0.11 | 0.12 | 0.10 | 0.30 |
| 159.2 | 0.16 | 0.14 | 0.15 | 0.12 | 0.22 |
| 250 | 0.11 | 0.12 | 0.17 | 0.14 | 0.16 |
| 500 | 0.09 | 0.19 | 0.30 | 0.06 | 0.42 |
| 800 | 0.21 | 0.39 | 0.35 | 0.06 | 0.51 |
| 1000 | 0.32 | 0.59 | 0.17 | 0.04 | 0.63 |
| 3500 | 0.68 | 0.54 | 0.46 | 0.31 | |
| 5000 | 0.68 | 0.70 | 0.71 | 0.69 | |

Table A-4. For each laboratory *l*, ${}_l RMS_d(f)$, the root mean square of the normalized differences from the mean for the 3 accelerometers

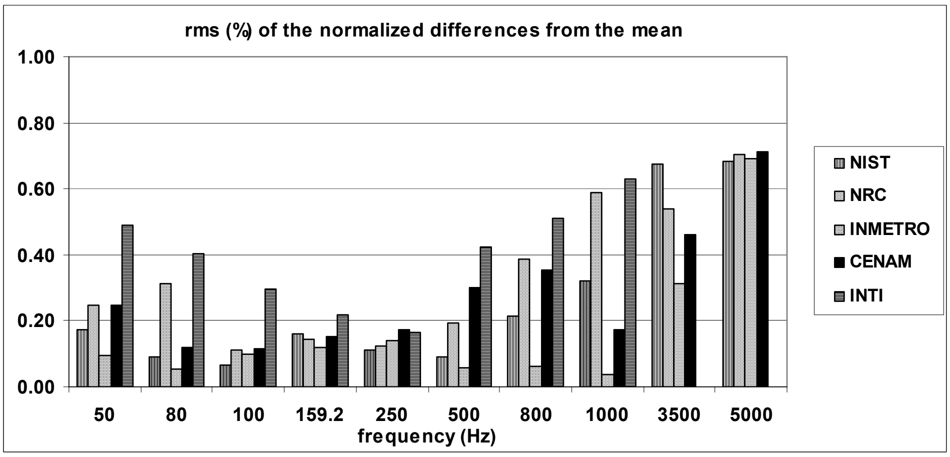



Figure A-4. For each laboratory *l*, ${}_l RMS_d(f)$, the root mean square of the normalized differences from the mean for the 3 accelerometers.

Tabulated in Table A-5 and plotted in Figure A-5, for laboratory *l* the standard deviation of the values of ${}_l d_i(f)$ for all 3 accelerometers is given by:

$${}_l s_d(f) = stddev({}_l d_1(f),\ {}_l d_2(f),\ {}_l d_3(f))$$

| Freq. (Hz) | NIST ${}_1 s_d(f)$ | NRC ${}_2 s_d(f)$ | CENAM ${}_3 s_d(f)$ | INMETRO ${}_4 s_d(f)$ | INTI ${}_5 s_d(f)$ |
|---|---|---|---|---|---|
| 50 | 0.02 | 0.24 | 0.24 | 0.09 | 0.52 |
| 80 | 0.08 | 0.21 | 0.14 | 0.02 | 0.40 |
| 100 | 0.08 | 0.12 | 0.10 | 0.04 | 0.24 |
| 159.2 | 0.11 | 0.17 | 0.17 | 0.05 | 0.18 |
| 250 | 0.13 | 0.14 | 0.14 | 0.02 | 0.17 |
| 500 | 0.10 | 0.21 | 0.24 | 0.05 | 0.36 |
| 800 | 0.26 | 0.47 | 0.25 | 0.05 | 0.50 |
| 1000 | 0.07 | 0.70 | 0.07 | 0.04 | 0.65 |
| 3500 | 0.13 | 0.31 | 0.34 | 0.03 | |
| 5000 | 0.13 | 0.39 | 0.31 | 0.05 | |

Table A-5. For each laboratory *l*, ${}_l s_d(f)$, the standard deviation of each accelerometers' normalized differences from $X_{mi}(f)$, the mean for all laboratories

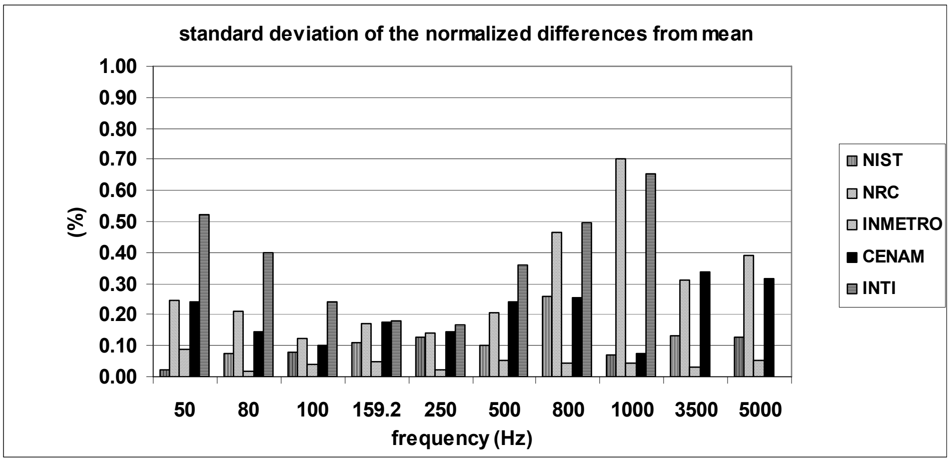



Figure A-5. For each laboratory *l*, ${}_l s_d(f)$, the standard deviation of each accelerometers' normalized differences from $X_{mi}(f)$, the mean for all laboratories

# APPENDIX B – Charge Amplifier

${}_{l}G(f)$ - gain result reported by laboratory *l* at frequency *f*

$G_m(f)$ - mean amplifier gain, the average of the gain results reported by each laboratory *l* at frequency *f*

where, *l* = 1, 3, 4, 5 for NIST, CENAM, INMETRO, INTI respectively (four laboratories)

$$G_m(f) = \frac{1}{4}\sum_{l=1,3,4,5} G(f)$$

The normalized difference, in percent, of the reported results by each laboratory *l* from the mean amplifier gain at frequency *f* is given as:

$${}_{l}D(f) = \left(\frac{{}_{l}G(f) - G_m(f)}{G_m(f)}\right)\times 100$$

| Freq. (Hz) | NIST97 | CENAM ${}_{3}G(f)$ | INMETRO ${}_{4}G(f)$ | INTI ${}_{5}G(f)$ | NIST99 | NIST ${}_{1}G(f)$ | Mean $G_m(f)$ |
|---|---|---|---|---|---|---|---|
| 50 | 9.968 | 9.960 | 9.942 | 9.980 | 9.964 | 9.966 | 9.9620 |
| 80 | 9.971 | 9.959 | 9.946 | 10.020 | 9.975 | 9.973 | 9.9745 |
| 100 | 9.972 | 9.965 | 9.947 | 10.010 | 9.980 | 9.976 | 9.9745 |
| 159.2 | 9.975 | 9.968 | 9.950 | 10.010 | 9.979 | 9.977 | 9.9763 |
| 250 | 9.975 | 9.971 | 9.953 | 9.990 | 9.993 | 9.984 | 9.9745 |
| 500 | 9.981 | 9.975 | 9.956 | 9.990 | 9.986 | 9.983 | 9.9761 |
| 800 | 9.983 | 9.979 | 9.959 | 10.000 | 10.000 | 9.992 | 9.9824 |
| 1000 | 9.983 | 9.980 | 9.960 | 10.000 | 9.982 | 9.983 | 9.9807 |
| 3500 | 9.996 | 9.985 | 9.971 | 9.980 | 9.992 | 9.994 | 9.9825 |
| 5000 | 9.996 | 9.978 | 9.971 | 9.950 | 10.003 | 10.000 | 9.9747 |

Table B-1. Amplifier gain results ${}_{l}G(f)$ (mV/pC) and mean amplifier gain $G_m(f)$ (mV/pC)

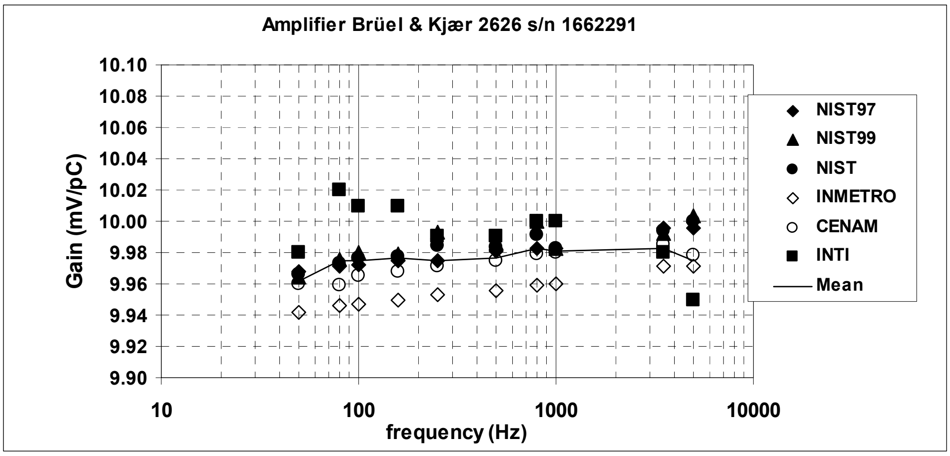



Figure B-1. Amplifier gain results ${}_{l}G(f)$ (mV/pC) and mean amplifier gain $G_m(f)$ (mV/pC)

| Freq. (Hz) | NIST $_1D(f)$ | CENAM $_3D(f)$ | INMETRO $_4D(f)$ | INTI $_5D(f)$ |
|---|---|---|---|---|
| 50 | 0.022 | -0.020 | -0.201 | 0.180 |
| 80 | 0.008 | -0.156 | -0.286 | 0.456 |
| 100 | 0.058 | -0.096 | -0.276 | 0.356 |
| 159.2 | 0.031 | -0.083 | -0.264 | 0.338 |
| 250 | 0.185 | -0.035 | -0.216 | 0.155 |
| 500 | 0.097 | -0.011 | -0.201 | 0.139 |
| 800 | 0.177 | -0.034 | -0.234 | 0.176 |
| 1000 | 0.016 | -0.007 | -0.207 | 0.194 |
| 3500 | 0.096 | 0.025 | -0.115 | -0.025 |
| 5000 | 0.287 | 0.033 | -0.037 | -0.247 |

Table B-2. Normalized difference $_lD(f)$ (%) of the reported results by each laboratory *l* from the mean amplifier gain at frequency *f.*

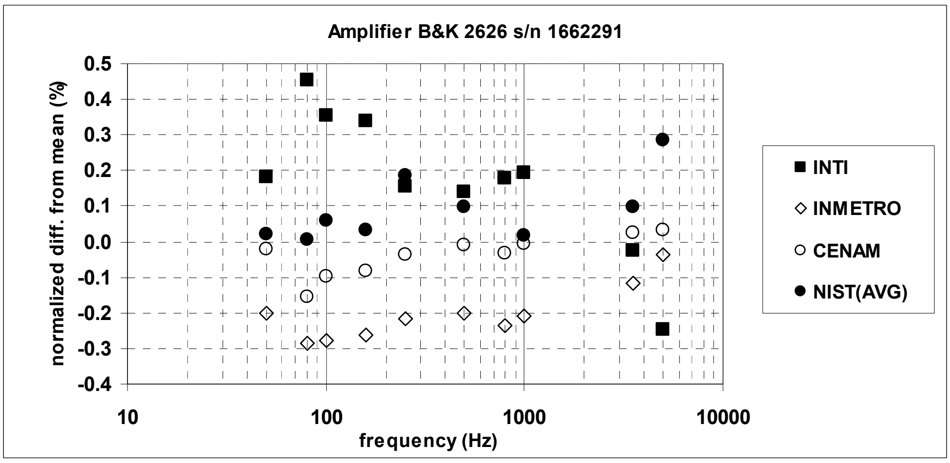



Figure B-2. Normalized difference $_lD(f)$ (%) of the reported results by each laboratory *l* from the mean amplifier gain at frequency *f.*

# APPENDIX II
# NRC Sensitivities and Relative Combined Uncertainties

The voltage sensitivities and associated relative combined uncertainties reported by NRC Canada are given below in Table II-1. Also included are the charge sensitivities and associated relative combined uncertainties evaluated for NRC Canada (see Section 4 of the report for an explanation of how these charge sensitivities and associated uncertainties were computed).

Table II-1. NRC Sensitivities and relative combined uncertainties ($k$ = 1).

| Frequency (Hz) | SE Transducer Endevco 2270M8 s/n 10472 | | | |
|---|---|---|---|---|
| | $x^a$ (mV/(m/s$^2$)) | $u^a$ (%) | $x^b$ (pC/(m/s$^2$)) | $u^b$ (%) |
| 50 | 2.014 | 0.45 | 0.2022 | 0.460 |
| 80 | 2.026 | 0.45 | 0.2031 | 0.461 |
| 100 | 2.021 | 0.45 | 0.2026 | 0.460 |
| 159.2 | 2.017 | 0.45 | 0.2022 | 0.461 |
| 250 | 2.019 | 0.46 | 0.2024 | 0.471 |
| 500 | 2.017 | 0.53 | 0.2022 | 0.539 |
| 800 | 2.020 | 0.92 | 0.2024 | 0.926 |
| 1000 | 2.017 | 0.92 | 0.2021 | 0.925 |
| 3500 | 2.008 | 0.92 | 0.2012 | 0.928 |
| 5000 | 2.005 | 0.94 | 0.2010 | 0.948 |
| | BB Transducer Brüel & Kjær 8305 s/n 1687773 | | | |
| 50 | 1.244 | 0.111 | 0.1249 | 0.145 |
| 80 | 1.251 | 0.104 | 0.1254 | 0.138 |
| 100 | 1.247 | 0.111 | 0.1250 | 0.145 |
| 159.2 | 1.248 | 0.1195 | 0.1251 | 0.154 |
| 250 | 1.248 | 0.139 | 0.1251 | 0.167 |
| 500 | 1.247 | 0.298 | 0.1250 | 0.314 |
| 800 | 1.256 | 0.380 | 0.1258 | 0.391 |
| 1000 | 1.264 | 0.386 | 0.1266 | 0.398 |
| 3500 | 1.254 | 0.381 | 0.1256 | 0.393 |
| 5000 | 1.260 | 0.429 | 0.1263 | 0.440 |
| | SE Transducer Kistler 8002K s/n 100443 | | | |
| 50 | 1.061 | 0.45 | 0.1065 | 0.460 |
| 80 | 1.066 | 0.45 | 0.1069 | 0.459 |
| 100 | 1.063 | 0.45 | 0.1066 | 0.459 |
| 159.2 | 1.062 | 0.45 | 0.1065 | 0.460 |
| 250 | 1.063 | 0.46 | 0.1066 | 0.471 |
| 500 | 1.063 | 0.53 | 0.1066 | 0.539 |
| 800 | 1.059 | 0.92 | 0.1061 | 0.926 |
| 1000 | 1.063 | 0.92 | 0.1065 | 0.926 |
| 3500 | 1.066 | 0.92 | 01.068 | 0.928 |
| 5000 | 1.069 | 0.94 | 0.1072 | 0.947 |

[a]Voltage sensitivities (x) and relative combined uncertainties (u) reported by NRC.

[b]Charge sensitivities (x) and relative combined uncertainties (u) computed for NRC. See Section 4 of the report for an explanation as to how these values were obtained.

# APPENDIX III
# Linkage to CCAUV.V-K1

## III-1. Introduction

One of the key objectives of the Mutual Recognition Arrangement (CIPM MRA) [III 1] is to establish the degree of equivalence of national measurement standards maintained by National Measurement Institutes. In order to accomplish this objective, key comparisons are conducted by the CIPM and the Regional Metrology Organizations (RMOs). Upon the completion of CIPM and Regional comparisons, the measurement results of the comparisons are "linked" when possible in order to establish the degrees of equivalence of national physical standards and metrological capability maintained by NMIs participating in the CIPM comparison with those maintained by NMIs participating in the Regional comparison. In this case, the results of the SIM regional comparison SIM.AUV.V-K1 are linked to those of the International Key Comparison CCAUV.V-K1 [III 2] which was conducted under the auspices of the Consultative Committee for Acoustics, Ultrasound and Vibration. The twelve National Metrology Institutes that participated in the CCAUV.V-K1 were [III 2]:

Germany: Physikalisch-Technische Bundesanstalt (PTB), Pilot Lab;
France: Bureau National de Métrology - C.E.A - C.E.S.T.A (BNM-CESTA);
Australia: CSIRO National Measurement Laboratory (CSIRO-NML);
Czech Republic: Czech Institute of Metrology (CMI);
South Africa: CSIR National Metrology Laboratory of South Africa (CSIR-NML);
Mexico: Centro Nacional de Metrología (CENAM);
Canada: National Research Council Canada (NRC);
Korea: Korea Research Institute of Science and Standards (KRISS);
Japan: National Metrology Institute of Japan (NMIJ);
Russian Federation: D. I. Mendeleyev Institute for Metrology (VNIIM);
United States: National Institute of Standards and Technology (NIST);
Netherlands: Netherlands Meetinstituut, Van Swinden Laboratorium (NMi-VSL).

Key comparison reference values (KCRVs) were not established at frequencies greater than 2 kHz for the single-ended accelerometer used in the CCAUV.V-K1 comparison. Furthermore, not all laboratory results were included in establishing the key comparison reference values for the back-to-back accelerometer used in the CCAUV.V-K1 comparison. Since the mathematical procedure that was used to link the results of SIM.AUV.V-K1 with those of CCAUV.V-K1 does not depend on the use of the KCRVs of the CCAUV.V-K1, the measurement results reported by all of the laboratories participating in both comparisons are linked when appropriate, regardless of transducer and frequency. Specifically, linkage is established at the frequencies of 50 Hz, 80 Hz, 100 Hz, 160 Hz, 250 Hz, 500 Hz, 800 Hz, 1 kHz, and 5 kHz for all single-ended to singled-ended transducers and for the back-to-back to back-to-back transducers.

The *Brief guidelines for linking RMO key comparisons to the CIPM KCRV* issued by the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV) [III 3] makes reference to a linking method based on a linear generalized least-squares estimation [III 4]. A linking method based on a linear additive model with contrast estimators is employed here to establish the degree of equivalence between the measurement results of the SIM.AUV.V-K1 and CCAUV.V-K1 comparisons. Degree of equivalence is expressed as an adjusted difference between the results obtained by two laboratories participating in one or more comparisons, with the variable $\psi$ representing the adjustment term for the effect of the difference in artifacts across comparisons, together with the expanded uncertainty of this difference.

### III-2. Mathematical Procedure for Linkage Calculations

A particular case of a linkage model is used to establish linkage between comparisons.

The model assumes that three laboratories serve as linking laboratories (CENAM, NIST, and NRC), and that both of two pairing artifacts (one in each of two different comparison studies) are measured by each of the linking laboratories. The non-linking laboratories measure only one of these artifacts. Data in each laboratory is assumed to have an additive error structure.

The model is:

$$X_{ijk} = L_i + A_j + e_{ijk} ,$$

where

$i$ is the index of the laboratories,

$j$ = 1 (CCAUV.V-K1) to 2 (SIM.AUV.V-K1) is the index of the comparisons,

$k$ is the index of the trial number of the $i$-th laboratory in the $j$-th comparison,

$L_i$ is the effect of the $i$-th laboratory,

$A_j$ is the effect of the artifact used in the $j$-th study,

and $e_{ijk}$ is the random noise of a given measurement result.

The errors, $e_{ijk}$ ~ Gaussian (0, $\tau_{ij}^2$) for $k$ = 1 to $n_{ij}$, are assumed to be mutually independent.

Here

$\tau_{ij}^2$ are the unknown variances of the Gaussians,

and $n_{ij}$ is the number of repeat trials of the $i$-th laboratory in the $j$-th study.

If $X_{ij} = \sum_k X_{ijk} / n_{ij}$ denotes the sample means, and $s_{ij}^2$ denotes the square of the standard uncertainties, with the standard uncertainties computed as the combined uncertainties $u_{ij}$ multiplied by the square roots of the numbers of repeat trials, $n_{ij}$, the model can be rewritten as:

$$X_{ij} = L_i + A_j + e_{ij} .$$

The data can be presented in a form of a $14 \times 2$ matrix (a total of 14 laboratories and 2 artifacts in this case) with some missing entries.

To simplify calculations of the degrees of equivalence, $L_i - L_{i'}$, first the effect in the difference in the studies given by the difference $A_1 - A_2$ is estimated where $L_i$ indicates results obtained in the international comparison and $L_{i'}$ indicates results obtained in the regional comparison. For this purpose, any of the linking laboratories (CENAM, NIST, or NRC) provides an unbiased estimator $X_{I1} - X_{I2}$ of $A_1 - A_2$. All of these independent statistics are combined to obtain the best unbiased estimator:

$$\psi = \sum_{I \text{ linking labs}} \hat{w}_I \left( X_{I1} - X_{I2} \right),$$

of the studies effect $A_1 - A_2$ with

$$\hat{w}_I = \frac{\left( s_{I1}^2 + s_{I2}^2 \right)^{-1}}{\sum_M \left( s_{M1}^2 + s_{M2}^2 \right)^{-1}},$$

where $M =$ 1 to 3 corresponds to the index of the linking laboratories.

It is stressed that this formula is simple, involving only three linking laboratories and their combined uncertainties. (Of course this calculation is to be performed for each frequency and each type of accelerometer.)

The variance of the adjustment factor $\psi$ can be approximated by [III 5]:

$$\mathrm{Var}(\psi) = \frac{1}{\sum_{I \text{ linking labs}} \left( s_{I1}^2 + s_{I2}^2 \right)^{-1}} .$$

To compute the degrees of equivalence, $L_i - L_{i'}$, use the estimator $X_{i1} - X_{i'2} - \psi$, where again the prime indicates results obtained in the regional comparison. This was suggested in Rukhin and Strawderman Section 7 [III 5], and it makes the calculation very simple. Corresponding approximations of variance are somewhat less straightforward, but tractable:

- when both $i$ and $i'$ are non-linking laboratories,

$$\mathrm{Var}(L_i - L_{i'}) = \mathrm{Var}(\psi) + s_{i1}^2 + s_{i'2}^2 ,$$

- when $i$ is a linking laboratory and $i'$ is a non-linking laboratory,

$$\mathrm{Var}(L_i - L_{i'}) = (1 + \hat{w}_i)^2 s_{i1}^2 + s_{i'2}^2 + \sum_{I \text{ linking labs}, I \neq i} \hat{w}_I^2 (s_{I1}^2 + s_{I2}^2)$$
$$= \mathrm{Var}(\psi) + (1 + 2\hat{w}_i) s_{i1}^2 + s_{i'2}^2 ,$$

- when both $i$ and $i'$ are linking laboratories,

$$\mathrm{Var}(\psi) + s_{i1}^2 + s_{i'2}^2 = (1 + \hat{w}_i)^2 s_{i1}^2 + (1 + \hat{w}_{i'})^2 s_{i'2}^2 + \sum_{I \text{ linking labs}, I \neq i,i'} \hat{w}_I^2 (s_{I1}^2 + s_{I2}^2)$$
$$= \mathrm{Var}(\psi) + (1 + 2\hat{w}_i) s_{i1}^2 + (1 + 2\hat{w}_{i'}) s_{i'2}^2 .$$

In summary:

$$\mathrm{Var}(L_i - L_{i'}) = \mathrm{Var}(\psi) + s_{i1}^2 + s_{i'2}^2 + \begin{array}{cc} 0 & i, i' \text{ are non-linking labs} \\ 2\hat{w}_i s_{i1}^2 & i \text{ linking}, i' \text{ non-linking labs} \\ 2\hat{w}_{i'} s_{i'2}^2 & i' \text{ linking}, i \text{ non-linking labs} \\ 2(\hat{w}_i s_{i1}^2 + \hat{w}_{i'} s_{i'2}^2) & i, i' \text{ are linking labs} \end{array}$$

When at least one laboratory is a linking laboratory, the simplified method, which does not include the $2\hat{w}_i s_i{}^2$ terms given above for calculating the variance $Var(L_i - L_{i'})$, will underestimate the best possible uncertainty in the degree of equivalence.

### III-3. Degrees of Interlaboratory Equivalence across Comparisons

The degrees of interlaboratory equivalence, or linkage, across the SIM.AUV.V-K1 and CCAUV.V-K1 key comparisons are given in tables below with linkage established between pairs of single-ended accelerometers and between pairs of back-to-back accelerometers. Linkage was not established between single-ended and back-to-back transducers, nor at frequencies of 3150 Hz and 3500 Hz. Linkage results were not obtained at 5 kHz for BNM-CESTA, or for INTI at 5 kHz in the case of single-ended accelerometers, due to a lack of data (see Tables 2a & 2b of the report on the CCAUV.V-K1 comparison [III 2] and Tables 3a & 3c of this report).

The notation of the indices has been changed from that given in Section III-2 above for consistency with notation used in the tables of degrees of equivalence in Section 5 of the report. Specifically, the notation used in the tables of interlaboratory equivalence across comparisons is:

$$L_{ij} = L_i - L_{i'} ,$$

$$U_{ij} = 2 \cdot \sqrt{\mathrm{Var}(L_i - L_{i'})} ,$$

where

$i$ is the index of the $i$-th laboratory participating in CCAUV.V-K1;

$j$ is the index of the $j$-th laboratory participating in SIM.AUV.V-K;

$\psi$ is the adjustment term for a particular set of transducers at a particular frequency;

and $u(\psi) = \sqrt{\mathrm{Var}(\psi)}$.

$U_{ij}$ is the expanded standard deviation of the adjusted difference $L_{ij}$ using a coverage factor of $k = 2$. These differences, $L_{ij}$, represent the difference in a measurement result obtained by a laboratory participating in the CCAUV.V-K1 comparison relative to that of the result that would have been obtained by a laboratory participating in the SIM.AUV.V-K1 comparison had it participated in the CCAUV.V-K1 comparison using the transducers of the CCAUV.V-K1.

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Kistler 8002K s/n 100443 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0226 pC/(m/s$^2$), u(ψ) 0.0006 pC/(m/s$^2$), Frequency 50 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | -0.0001 | 0.0050 | -0.0001 | 0.0022 | -0.0005 | 0.0059 | 0.0006 | 0.0031 | -0.0002 | 0.0019 |
| **BNM-CESTA** | 0.0001 | 0.0052 | 0.0001 | 0.0026 | -0.0003 | 0.0060 | 0.0008 | 0.0034 | -0.0001 | 0.0023 |
| **CSIRO-NML** | 0.0000 | 0.0051 | 0.0000 | 0.0025 | -0.0004 | 0.0060 | 0.0007 | 0.0033 | -0.0002 | 0.0022 |
| **CMI** | -0.0003 | 0.0052 | -0.0003 | 0.0025 | -0.0007 | 0.0060 | 0.0004 | 0.0033 | -0.0005 | 0.0023 |
| **CSIR-NML** | -0.0001 | 0.0054 | -0.0001 | 0.0030 | -0.0005 | 0.0062 | 0.0006 | 0.0037 | -0.0003 | 0.0027 |
| **CENAM** | -0.0002 | 0.0052 | -0.0002 | 0.0026 | -0.0006 | 0.0060 | 0.0005 | 0.0034 | -0.0003 | 0.0024 |
| **NRC** | -0.0003 | 0.0051 | -0.0003 | 0.0024 | -0.0007 | 0.0059 | 0.0004 | 0.0032 | -0.0005 | 0.0020 |
| **KRISS** | -0.0004 | 0.0051 | -0.0004 | 0.0023 | -0.0008 | 0.0059 | 0.0003 | 0.0032 | -0.0005 | 0.0020 |
| **NMIJ** | -0.0004 | 0.0051 | -0.0004 | 0.0024 | -0.0008 | 0.0059 | 0.0003 | 0.0033 | -0.0006 | 0.0021 |
| **VNIIM** | -0.0006 | 0.0051 | -0.0006 | 0.0025 | -0.0010 | 0.0060 | 0.0001 | 0.0033 | -0.0007 | 0.0022 |
| **NIST** | 0.0002 | 0.0052 | 0.0002 | 0.0026 | -0.0002 | 0.0060 | 0.0009 | 0.0034 | 0.0000 | 0.0023 |
| **NMi-VSL** | -0.0001 | 0.0053 | -0.0001 | 0.0027 | -0.0005 | 0.0061 | 0.0006 | 0.0035 | -0.0003 | 0.0025 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0226 pC/(m/s$^2$), u(ψ) 0.0006 pC/(m/s$^2$), Frequency 80 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | -0.0005 | 0.0050 | -0.0001 | 0.0022 | 0.0000 | 0.0058 | 0.0005 | 0.0031 | 0.0000 | 0.0019 |
| **BNM-CESTA** | -0.0002 | 0.0052 | 0.0002 | 0.0026 | 0.0003 | 0.0060 | 0.0008 | 0.0034 | 0.0003 | 0.0023 |
| **CSIRO-NML** | -0.0006 | 0.0051 | -0.0002 | 0.0023 | -0.0001 | 0.0059 | 0.0004 | 0.0032 | -0.0001 | 0.0020 |
| **CMI** | -0.0007 | 0.0052 | -0.0002 | 0.0025 | -0.0002 | 0.0060 | 0.0003 | 0.0034 | -0.0001 | 0.0023 |
| **CSIR-NML** | -0.0003 | 0.0054 | 0.0001 | 0.0030 | 0.0002 | 0.0062 | 0.0007 | 0.0037 | 0.0002 | 0.0027 |
| **CENAM** | -0.0006 | 0.0052 | -0.0001 | 0.0026 | -0.0001 | 0.0060 | 0.0004 | 0.0034 | 0.0000 | 0.0024 |
| **NRC** | -0.0001 | 0.0051 | 0.0003 | 0.0024 | 0.0004 | 0.0059 | 0.0008 | 0.0032 | 0.0004 | 0.0020 |
| **KRISS** | -0.0008 | 0.0051 | -0.0003 | 0.0023 | -0.0003 | 0.0059 | 0.0002 | 0.0032 | -0.0003 | 0.0020 |
| **NMIJ** | -0.0007 | 0.0052 | -0.0003 | 0.0025 | -0.0002 | 0.0059 | 0.0002 | 0.0033 | -0.0002 | 0.0022 |
| **VNIIM** | -0.0009 | 0.0051 | -0.0005 | 0.0025 | -0.0004 | 0.0059 | 0.0000 | 0.0033 | -0.0004 | 0.0022 |
| **NIST** | -0.0005 | 0.0052 | -0.0001 | 0.0026 | 0.0000 | 0.0060 | 0.0005 | 0.0034 | 0.0000 | 0.0023 |
| **NMi-VSL** | -0.0007 | 0.0051 | -0.0003 | 0.0023 | -0.0002 | 0.0059 | 0.0003 | 0.0032 | -0.0002 | 0.0019 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Kistler 8002K s/n 100443 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0226 pC/(m/s²), u(ψ) 0.0005 pC/(m/s²), Frequency 100 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | -0.0002 | 0.0050 | -0.0001 | 0.0022 | -0.0001 | 0.0058 | 0.0004 | 0.0031 | -0.0001 | 0.0018 |
| **BNM-CESTA** | 0.0000 | 0.0052 | 0.0001 | 0.0026 | 0.0001 | 0.0060 | 0.0006 | 0.0034 | 0.0001 | 0.0022 |
| **CSIRO-NML** | -0.0002 | 0.0050 | -0.0001 | 0.0023 | -0.0001 | 0.0058 | 0.0004 | 0.0032 | -0.0001 | 0.0019 |
| **CMI** | -0.0003 | 0.0051 | -0.0002 | 0.0025 | -0.0002 | 0.0059 | 0.0003 | 0.0033 | -0.0002 | 0.0022 |
| **CSIR-NML** | 0.0003 | 0.0052 | 0.0004 | 0.0028 | 0.0004 | 0.0060 | 0.0009 | 0.0035 | 0.0004 | 0.0024 |
| **CENAM** | -0.0003 | 0.0052 | -0.0001 | 0.0026 | -0.0002 | 0.0060 | 0.0003 | 0.0034 | -0.0002 | 0.0023 |
| **NRC** | -0.0002 | 0.0050 | -0.0001 | 0.0023 | -0.0001 | 0.0059 | 0.0004 | 0.0032 | -0.0001 | 0.0019 |
| **KRISS** | -0.0005 | 0.0050 | -0.0003 | 0.0023 | -0.0004 | 0.0058 | 0.0001 | 0.0032 | -0.0003 | 0.0019 |
| **NMIJ** | -0.0005 | 0.0051 | -0.0004 | 0.0024 | -0.0004 | 0.0059 | 0.0001 | 0.0033 | -0.0004 | 0.0021 |
| **VNIIM** | -0.0007 | 0.0051 | -0.0005 | 0.0024 | -0.0006 | 0.0059 | -0.0001 | 0.0033 | -0.0005 | 0.0021 |
| **NIST** | -0.0001 | 0.0051 | 0.0000 | 0.0025 | 0.0000 | 0.0059 | 0.0005 | 0.0033 | 0.0000 | 0.0022 |
| **NMi-VSL** | -0.0004 | 0.0050 | -0.0003 | 0.0022 | -0.0003 | 0.0058 | 0.0002 | 0.0031 | -0.0003 | 0.0018 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0224 pC/(m/s²), u(ψ) 0.0006 pC/(m/s²), Frequency 160 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | 0.0001 | 0.0050 | 0.0001 | 0.0022 | 0.0004 | 0.0058 | 0.0004 | 0.0031 | -0.0001 | 0.0019 |
| **BNM-CESTA** | 0.0004 | 0.0052 | 0.0003 | 0.0026 | 0.0007 | 0.0060 | 0.0007 | 0.0034 | 0.0002 | 0.0023 |
| **CSIRO-NML** | 0.0000 | 0.0051 | -0.0001 | 0.0023 | 0.0003 | 0.0059 | 0.0003 | 0.0032 | -0.0002 | 0.0020 |
| **CMI** | 0.0001 | 0.0052 | 0.0000 | 0.0025 | 0.0004 | 0.0060 | 0.0004 | 0.0034 | -0.0001 | 0.0023 |
| **CSIR-NML** | -0.0002 | 0.0052 | -0.0003 | 0.0026 | 0.0001 | 0.0060 | 0.0001 | 0.0034 | -0.0004 | 0.0023 |
| **CENAM** | -0.0001 | 0.0052 | -0.0001 | 0.0026 | 0.0002 | 0.0060 | 0.0003 | 0.0034 | -0.0003 | 0.0024 |
| **NRC** | 0.0002 | 0.0051 | 0.0002 | 0.0024 | 0.0005 | 0.0059 | 0.0005 | 0.0032 | 0.0000 | 0.0020 |
| **KRISS** | -0.0001 | 0.0051 | -0.0002 | 0.0023 | 0.0002 | 0.0059 | 0.0002 | 0.0032 | -0.0003 | 0.0020 |
| **NMIJ** | -0.0002 | 0.0051 | -0.0002 | 0.0025 | 0.0001 | 0.0059 | 0.0002 | 0.0033 | -0.0003 | 0.0021 |
| **VNIIM** | -0.0001 | 0.0051 | -0.0001 | 0.0025 | 0.0002 | 0.0059 | 0.0002 | 0.0033 | -0.0003 | 0.0022 |
| **NIST** | 0.0002 | 0.0052 | 0.0001 | 0.0026 | 0.0005 | 0.0060 | 0.0005 | 0.0034 | 0.0000 | 0.0023 |
| **NMi-VSL** | 0.0000 | 0.0051 | 0.0000 | 0.0024 | 0.0003 | 0.0059 | 0.0003 | 0.0032 | -0.0002 | 0.0021 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Kistler 8002K s/n 100443 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0225 pC/(m/s²), u(ψ) 0.0006 pC/(m/s²), Frequency 250 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | -0.0001 | 0.0051 | 0.0000 | 0.0022 | 0.0004 | 0.0090 | 0.0004 | 0.0036 | -0.0001 | 0.0019 |
| **BNM-CESTA** | 0.0000 | 0.0053 | 0.0000 | 0.0026 | 0.0005 | 0.0091 | 0.0004 | 0.0039 | 0.0000 | 0.0023 |
| **CSIRO-NML** | 0.0000 | 0.0052 | 0.0000 | 0.0023 | 0.0005 | 0.0090 | 0.0004 | 0.0037 | 0.0000 | 0.0020 |
| **CMI** | 0.0000 | 0.0053 | 0.0000 | 0.0026 | 0.0005 | 0.0091 | 0.0004 | 0.0038 | 0.0000 | 0.0023 |
| **CSIR-NML** | -0.0002 | 0.0053 | -0.0002 | 0.0026 | 0.0003 | 0.0091 | 0.0002 | 0.0039 | -0.0002 | 0.0023 |
| **CENAM** | -0.0002 | 0.0053 | -0.0001 | 0.0026 | 0.0003 | 0.0091 | 0.0003 | 0.0039 | -0.0002 | 0.0024 |
| **NRC** | 0.0001 | 0.0052 | 0.0001 | 0.0024 | 0.0006 | 0.0090 | 0.0005 | 0.0037 | 0.0001 | 0.0021 |
| **KRISS** | -0.0003 | 0.0052 | -0.0002 | 0.0023 | 0.0002 | 0.0090 | 0.0001 | 0.0037 | -0.0003 | 0.0020 |
| **NMIJ** | -0.0003 | 0.0053 | -0.0002 | 0.0026 | 0.0002 | 0.0091 | 0.0001 | 0.0038 | -0.0003 | 0.0023 |
| **VNIIM** | -0.0003 | 0.0053 | -0.0003 | 0.0025 | 0.0002 | 0.0091 | 0.0001 | 0.0038 | -0.0003 | 0.0022 |
| **NIST** | 0.0000 | 0.0053 | 0.0000 | 0.0026 | 0.0005 | 0.0091 | 0.0004 | 0.0039 | 0.0000 | 0.0024 |
| **NMi-VSL** | -0.0002 | 0.0052 | -0.0001 | 0.0023 | 0.0003 | 0.0090 | 0.0002 | 0.0036 | -0.0002 | 0.0019 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0227 pC/(m/s²), u(ψ) 0.0007 pC/(m/s²), Frequency 500 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | -0.0002 | 0.0058 | -0.0001 | 0.0023 | 0.0004 | 0.0090 | -0.0002 | 0.0037 | -0.0001 | 0.0021 |
| **BNM-CESTA** | 0.0001 | 0.0060 | 0.0002 | 0.0027 | 0.0007 | 0.0091 | 0.0001 | 0.0039 | 0.0002 | 0.0025 |
| **CSIRO-NML** | -0.0002 | 0.0059 | -0.0001 | 0.0024 | 0.0004 | 0.0091 | -0.0002 | 0.0037 | -0.0001 | 0.0023 |
| **CMI** | -0.0001 | 0.0060 | 0.0000 | 0.0027 | 0.0005 | 0.0091 | -0.0001 | 0.0039 | 0.0000 | 0.0026 |
| **CSIR-NML** | 0.0000 | 0.0061 | 0.0001 | 0.0029 | 0.0006 | 0.0092 | 0.0000 | 0.0040 | 0.0001 | 0.0027 |
| **CENAM** | -0.0001 | 0.0060 | -0.0001 | 0.0027 | 0.0005 | 0.0091 | -0.0001 | 0.0039 | 0.0000 | 0.0026 |
| **NRC** | -0.0003 | 0.0060 | -0.0003 | 0.0027 | 0.0003 | 0.0091 | -0.0003 | 0.0039 | -0.0002 | 0.0025 |
| **KRISS** | -0.0004 | 0.0059 | -0.0003 | 0.0024 | 0.0002 | 0.0091 | -0.0004 | 0.0037 | -0.0003 | 0.0022 |
| **NMIJ** | -0.0003 | 0.0070 | -0.0003 | 0.0045 | 0.0003 | 0.0098 | -0.0004 | 0.0053 | -0.0003 | 0.0044 |
| **VNIIM** | -0.0007 | 0.0060 | -0.0006 | 0.0026 | -0.0001 | 0.0091 | -0.0007 | 0.0039 | -0.0006 | 0.0024 |
| **NIST** | -0.0001 | 0.0061 | 0.0000 | 0.0028 | 0.0005 | 0.0092 | -0.0001 | 0.0040 | 0.0000 | 0.0027 |
| **NMi-VSL** | 0.0000 | 0.0059 | 0.0001 | 0.0024 | 0.0006 | 0.0091 | 0.0000 | 0.0037 | 0.0001 | 0.0022 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Kistler 8002K s/n 100443 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0227 pC/(m/s²), u(ψ) 0.0015 pC/(m/s²), Frequency 800 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | 0.0003 | 0.0106 | -0.0002 | 0.0036 | 0.0004 | 0.0102 | -0.0008 | 0.0046 | -0.0004 | 0.0050 |
| **BNM-CESTA** | 0.0007 | 0.0107 | 0.0001 | 0.0039 | 0.0008 | 0.0103 | -0.0004 | 0.0048 | -0.0001 | 0.0051 |
| **CSIRO-NML** | 0.0003 | 0.0106 | -0.0003 | 0.0037 | 0.0004 | 0.0102 | -0.0008 | 0.0047 | -0.0005 | 0.0050 |
| **CMI** | 0.0006 | 0.0108 | 0.0000 | 0.0041 | 0.0007 | 0.0104 | -0.0005 | 0.0050 | -0.0002 | 0.0053 |
| **CSIR-NML** | 0.0008 | 0.0108 | 0.0002 | 0.0040 | 0.0009 | 0.0103 | -0.0003 | 0.0049 | 0.0000 | 0.0052 |
| **CENAM** | 0.0004 | 0.0107 | -0.0001 | 0.0039 | 0.0005 | 0.0103 | -0.0007 | 0.0049 | -0.0003 | 0.0052 |
| **NRC** | 0.0006 | 0.0107 | 0.0001 | 0.0038 | 0.0007 | 0.0103 | -0.0005 | 0.0048 | -0.0001 | 0.0051 |
| **KRISS** | 0.0002 | 0.0106 | -0.0004 | 0.0037 | 0.0003 | 0.0102 | -0.0009 | 0.0047 | -0.0006 | 0.0050 |
| **NMIJ** | 0.0001 | 0.0108 | -0.0005 | 0.0040 | 0.0002 | 0.0103 | -0.0010 | 0.0049 | -0.0007 | 0.0052 |
| **VNIIM** | -0.0001 | 0.0107 | -0.0006 | 0.0038 | 0.0000 | 0.0103 | -0.0012 | 0.0048 | -0.0008 | 0.0051 |
| **NIST** | 0.0006 | 0.0113 | 0.0000 | 0.0053 | 0.0007 | 0.0109 | -0.0005 | 0.0061 | -0.0002 | 0.0063 |
| **NMi-VSL** | 0.0010 | 0.0107 | 0.0004 | 0.0038 | 0.0011 | 0.0103 | -0.0001 | 0.0047 | 0.0002 | 0.0051 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0231 pC/(m/s²), u(ψ) 0.0009 pC/(m/s²), Frequency 1000 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | -0.0004 | 0.0097 | -0.0006 | 0.0026 | -0.0003 | 0.0157 | -0.0011 | 0.0039 | -0.0002 | 0.0028 |
| **BNM-CESTA** | -0.0003 | 0.0098 | -0.0005 | 0.0029 | -0.0002 | 0.0158 | -0.0011 | 0.0041 | -0.0002 | 0.0032 |
| **CSIRO-NML** | -0.0004 | 0.0098 | -0.0006 | 0.0027 | -0.0003 | 0.0157 | -0.0012 | 0.0039 | -0.0003 | 0.0030 |
| **CMI** | -0.0002 | 0.0099 | -0.0004 | 0.0032 | -0.0001 | 0.0158 | -0.0009 | 0.0043 | -0.0001 | 0.0034 |
| **CSIR-NML** | -0.0001 | 0.0099 | -0.0003 | 0.0031 | 0.0000 | 0.0158 | -0.0009 | 0.0042 | 0.0000 | 0.0033 |
| **CENAM** | -0.0002 | 0.0100 | -0.0004 | 0.0035 | -0.0001 | 0.0159 | -0.0010 | 0.0045 | -0.0001 | 0.0037 |
| **NRC** | -0.0003 | 0.0099 | -0.0005 | 0.0030 | -0.0002 | 0.0158 | -0.0010 | 0.0042 | -0.0001 | 0.0033 |
| **KRISS** | -0.0006 | 0.0098 | -0.0008 | 0.0028 | -0.0005 | 0.0157 | -0.0013 | 0.0040 | -0.0004 | 0.0030 |
| **NMIJ** | -0.0001 | 0.0098 | -0.0003 | 0.0028 | 0.0000 | 0.0157 | -0.0008 | 0.0040 | 0.0001 | 0.0031 |
| **VNIIM** | -0.0008 | 0.0098 | -0.0010 | 0.0029 | -0.0007 | 0.0157 | -0.0015 | 0.0041 | -0.0007 | 0.0031 |
| **NIST** | -0.0001 | 0.0100 | -0.0003 | 0.0034 | 0.0000 | 0.0158 | -0.0009 | 0.0044 | 0.0000 | 0.0036 |
| **NMi-VSL** | 0.0001 | 0.0108 | -0.0001 | 0.0053 | 0.0002 | 0.0164 | -0.0006 | 0.0060 | 0.0002 | 0.0054 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Kistler 8002K s/n 100443 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0251 pC/(m/s$^2$), u(ψ) 0.0025 pC/(m/s$^2$), Frequency 5000 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | 0.0010 | 0.0127 | -0.0003 | 0.0053 | 0.0016 | 0.0180 | | | -0.0002 | 0.0092 |
| **BNM-CESTA** | | | | | | | | | | |
| **CSIRO-NML** | 0.0013 | 0.0127 | 0.0000 | 0.0054 | 0.0019 | 0.0180 | | | 0.0001 | 0.0092 |
| **CMI** | 0.0005 | 0.0129 | -0.0008 | 0.0057 | 0.0011 | 0.0181 | | | -0.0007 | 0.0094 |
| **CSIR-NML** | 0.0043 | 0.0130 | 0.0030 | 0.0061 | 0.0049 | 0.0182 | | | 0.0031 | 0.0096 |
| **CENAM** | -0.0003 | 0.0129 | -0.0016 | 0.0058 | 0.0003 | 0.0181 | | | -0.0015 | 0.0095 |
| **NRC** | -0.0003 | 0.0133 | -0.0016 | 0.0065 | 0.0003 | 0.0184 | | | -0.0015 | 0.0099 |
| **KRISS** | -0.0005 | 0.0128 | -0.0017 | 0.0054 | 0.0001 | 0.0180 | | | -0.0017 | 0.0093 |
| **NMIJ** | 0.0092 | 0.0134 | 0.0079 | 0.0068 | 0.0098 | 0.0185 | | | 0.0080 | 0.0101 |
| **VNIIM** | 0.0000 | 0.0128 | -0.0013 | 0.0056 | 0.0006 | 0.0181 | | | -0.0012 | 0.0094 |
| **NIST** | 0.0013 | 0.0138 | 0.0000 | 0.0076 | 0.0019 | 0.0188 | | | 0.0001 | 0.0106 |
| **NMi-VSL** | 0.0058 | 0.0135 | 0.0045 | 0.0070 | 0.0064 | 0.0186 | | | 0.0046 | 0.0103 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Endevco 2270M8 s/n 10472 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ -0.0740 pC/(m/s$^2$), u(ψ) 0.0008 pC/(m/s$^2$), Frequency 50 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | 0.0008 | 0.0092 | 0.0000 | 0.0036 | 0.0001 | 0.0102 | -0.0007 | 0.0058 | -0.0003 | 0.0031 |
| **BNM-CESTA** | 0.0010 | 0.0093 | 0.0002 | 0.0039 | 0.0003 | 0.0103 | -0.0005 | 0.0059 | -0.0001 | 0.0034 |
| **CSIRO-NML** | 0.0009 | 0.0093 | 0.0001 | 0.0038 | 0.0002 | 0.0102 | -0.0006 | 0.0059 | -0.0002 | 0.0032 |
| **CMI** | 0.0006 | 0.0093 | -0.0002 | 0.0039 | -0.0001 | 0.0102 | -0.0009 | 0.0059 | -0.0005 | 0.0033 |
| **CSIR-NML** | 0.0008 | 0.0094 | 0.0000 | 0.0041 | 0.0001 | 0.0104 | -0.0007 | 0.0061 | -0.0003 | 0.0036 |
| **CENAM** | 0.0008 | 0.0093 | -0.0001 | 0.0039 | 0.0001 | 0.0103 | -0.0008 | 0.0059 | -0.0004 | 0.0034 |
| **NRC** | 0.0006 | 0.0092 | -0.0003 | 0.0037 | -0.0001 | 0.0102 | -0.0010 | 0.0058 | -0.0006 | 0.0032 |
| **KRISS** | 0.0006 | 0.0092 | -0.0003 | 0.0037 | -0.0001 | 0.0102 | -0.0010 | 0.0058 | -0.0006 | 0.0031 |
| **NMIJ** | 0.0005 | 0.0093 | -0.0004 | 0.0038 | -0.0002 | 0.0102 | -0.0011 | 0.0058 | -0.0007 | 0.0032 |
| **VNIIM** | 0.0003 | 0.0093 | -0.0005 | 0.0038 | -0.0004 | 0.0102 | -0.0012 | 0.0059 | -0.0008 | 0.0032 |
| **NIST** | 0.0011 | 0.0093 | 0.0003 | 0.0039 | 0.0004 | 0.0103 | -0.0004 | 0.0059 | 0.0000 | 0.0034 |
| **NMi-VSL** | 0.0008 | 0.0093 | 0.0000 | 0.0040 | 0.0001 | 0.0103 | -0.0008 | 0.0060 | -0.0003 | 0.0035 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ -0.0737 pC/(m/s$^2$), u(ψ) 0.0008 pC/(m/s$^2$), Frequency 80 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | -0.0004 | 0.0093 | -0.0004 | 0.0039 | 0.0000 | 0.0102 | -0.0008 | 0.0057 | 0.0000 | 0.0031 |
| **BNM-CESTA** | -0.0001 | 0.0094 | -0.0001 | 0.0042 | 0.0003 | 0.0102 | -0.0005 | 0.0059 | 0.0003 | 0.0034 |
| **CSIRO-NML** | -0.0005 | 0.0093 | -0.0005 | 0.0040 | -0.0001 | 0.0102 | -0.0009 | 0.0058 | -0.0001 | 0.0031 |
| **CMI** | -0.0005 | 0.0093 | -0.0005 | 0.0041 | -0.0001 | 0.0102 | -0.0009 | 0.0059 | -0.0001 | 0.0033 |
| **CSIR-NML** | -0.0002 | 0.0095 | -0.0002 | 0.0044 | 0.0002 | 0.0103 | -0.0006 | 0.0061 | 0.0002 | 0.0036 |
| **CENAM** | -0.0004 | 0.0094 | -0.0004 | 0.0042 | 0.0000 | 0.0103 | -0.0008 | 0.0059 | 0.0000 | 0.0034 |
| **NRC** | 0.0000 | 0.0093 | 0.0000 | 0.0040 | 0.0004 | 0.0102 | -0.0004 | 0.0058 | 0.0004 | 0.0032 |
| **KRISS** | -0.0007 | 0.0093 | -0.0006 | 0.0040 | -0.0003 | 0.0102 | -0.0010 | 0.0058 | -0.0003 | 0.0031 |
| **NMIJ** | -0.0006 | 0.0093 | -0.0006 | 0.0041 | -0.0002 | 0.0102 | -0.0010 | 0.0059 | -0.0002 | 0.0033 |
| **VNIIM** | -0.0008 | 0.0093 | -0.0008 | 0.0041 | -0.0004 | 0.0102 | -0.0012 | 0.0058 | -0.0004 | 0.0032 |
| **NIST** | -0.0004 | 0.0094 | -0.0004 | 0.0042 | 0.0000 | 0.0102 | -0.0008 | 0.0059 | 0.0000 | 0.0034 |
| **NMi-VSL** | -0.0006 | 0.0093 | -0.0006 | 0.0040 | -0.0002 | 0.0102 | -0.0010 | 0.0058 | -0.0002 | 0.0031 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Endevco 2270M8 s/n 10472 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ -0.0735 pC/(m/s$^2$), u(ψ) 0.0009 pC/(m/s$^2$), Frequency 100 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | -0.0001 | 0.0092 | -0.0005 | 0.0023 | -0.0002 | 0.0102 | -0.0004 | 0.0057 | -0.0001 | 0.0032 |
| **BNM-CESTA** | 0.0001 | 0.0094 | -0.0003 | 0.0027 | 0.0000 | 0.0103 | -0.0002 | 0.0059 | 0.0001 | 0.0035 |
| **CSIRO-NML** | -0.0001 | 0.0093 | -0.0005 | 0.0024 | -0.0002 | 0.0102 | -0.0004 | 0.0058 | -0.0001 | 0.0033 |
| **CMI** | -0.0002 | 0.0093 | -0.0006 | 0.0026 | -0.0003 | 0.0103 | -0.0005 | 0.0059 | -0.0002 | 0.0035 |
| **CSIR-NML** | 0.0004 | 0.0094 | 0.0000 | 0.0028 | 0.0003 | 0.0103 | 0.0001 | 0.0060 | 0.0004 | 0.0037 |
| **CENAM** | -0.0002 | 0.0094 | -0.0006 | 0.0027 | -0.0003 | 0.0103 | -0.0005 | 0.0059 | -0.0002 | 0.0035 |
| **NRC** | -0.0001 | 0.0093 | -0.0005 | 0.0024 | -0.0002 | 0.0102 | -0.0004 | 0.0058 | -0.0001 | 0.0033 |
| **KRISS** | -0.0004 | 0.0093 | -0.0008 | 0.0024 | -0.0005 | 0.0102 | -0.0006 | 0.0058 | -0.0003 | 0.0033 |
| **NMIJ** | -0.0004 | 0.0093 | -0.0008 | 0.0025 | -0.0005 | 0.0102 | -0.0007 | 0.0059 | -0.0004 | 0.0034 |
| **VNIIM** | -0.0006 | 0.0093 | -0.0010 | 0.0025 | -0.0007 | 0.0102 | -0.0008 | 0.0058 | -0.0005 | 0.0034 |
| **NIST** | 0.0000 | 0.0093 | -0.0004 | 0.0026 | -0.0001 | 0.0103 | -0.0003 | 0.0059 | 0.0000 | 0.0035 |
| **NMi-VSL** | -0.0004 | 0.0093 | -0.0007 | 0.0023 | -0.0005 | 0.0102 | -0.0006 | 0.0058 | -0.0003 | 0.0033 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ -0.0737 pC/(m/s$^2$), u(ψ) 0.0009 pC/(m/s$^2$), Frequency 160 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | 0.0006 | 0.0093 | -0.0002 | 0.0040 | 0.0003 | 0.0102 | 0.0000 | 0.0058 | -0.0001 | 0.0035 |
| **BNM-CESTA** | 0.0008 | 0.0094 | 0.0000 | 0.0042 | 0.0005 | 0.0103 | 0.0003 | 0.0059 | 0.0002 | 0.0037 |
| **CSIRO-NML** | 0.0004 | 0.0093 | -0.0004 | 0.0041 | 0.0001 | 0.0103 | -0.0001 | 0.0058 | -0.0002 | 0.0035 |
| **CMI** | 0.0005 | 0.0094 | -0.0003 | 0.0042 | 0.0002 | 0.0103 | 0.0000 | 0.0059 | -0.0001 | 0.0037 |
| **CSIR-NML** | 0.0002 | 0.0094 | -0.0006 | 0.0042 | -0.0001 | 0.0103 | -0.0003 | 0.0059 | -0.0004 | 0.0037 |
| **CENAM** | 0.0004 | 0.0094 | -0.0004 | 0.0042 | 0.0001 | 0.0103 | -0.0002 | 0.0060 | -0.0003 | 0.0038 |
| **NRC** | 0.0007 | 0.0094 | -0.0001 | 0.0041 | 0.0004 | 0.0103 | 0.0001 | 0.0058 | 0.0000 | 0.0036 |
| **KRISS** | 0.0003 | 0.0093 | -0.0005 | 0.0041 | 0.0000 | 0.0103 | -0.0002 | 0.0058 | -0.0003 | 0.0035 |
| **NMIJ** | 0.0003 | 0.0094 | -0.0005 | 0.0041 | 0.0000 | 0.0103 | -0.0002 | 0.0059 | -0.0004 | 0.0036 |
| **VNIIM** | 0.0004 | 0.0094 | -0.0004 | 0.0041 | 0.0001 | 0.0103 | -0.0002 | 0.0059 | -0.0003 | 0.0036 |
| **NIST** | 0.0006 | 0.0094 | -0.0002 | 0.0042 | 0.0003 | 0.0103 | 0.0001 | 0.0060 | 0.0000 | 0.0037 |
| **NMi-VSL** | 0.0005 | 0.0094 | -0.0003 | 0.0041 | 0.0002 | 0.0103 | -0.0001 | 0.0059 | -0.0002 | 0.0036 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Endevco 2270M8 s/n 10472 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ -0.0734 pC/(m/s$^2$), u(ψ) 0.0009 pC/(m/s$^2$), Frequency 250 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | 0.0000 | 0.0095 | -0.0004 | 0.0040 | -0.0001 | 0.0159 | -0.0004 | 0.0067 | -0.0001 | 0.0035 |
| **BNM-CESTA** | 0.0001 | 0.0096 | -0.0004 | 0.0042 | 0.0000 | 0.0159 | -0.0003 | 0.0069 | 0.0000 | 0.0038 |
| **CSIRO-NML** | 0.0001 | 0.0095 | -0.0004 | 0.0041 | 0.0000 | 0.0159 | -0.0003 | 0.0068 | 0.0000 | 0.0036 |
| **CMI** | 0.0001 | 0.0096 | -0.0004 | 0.0042 | 0.0000 | 0.0159 | -0.0003 | 0.0069 | 0.0000 | 0.0037 |
| **CSIR-NML** | -0.0001 | 0.0096 | -0.0006 | 0.0042 | -0.0002 | 0.0159 | -0.0005 | 0.0069 | -0.0002 | 0.0038 |
| **CENAM** | -0.0001 | 0.0096 | -0.0005 | 0.0042 | -0.0002 | 0.0159 | -0.0005 | 0.0069 | -0.0002 | 0.0038 |
| **NRC** | 0.0001 | 0.0096 | -0.0003 | 0.0041 | 0.0000 | 0.0159 | -0.0003 | 0.0068 | 0.0001 | 0.0036 |
| **KRISS** | -0.0002 | 0.0095 | -0.0006 | 0.0041 | -0.0003 | 0.0159 | -0.0006 | 0.0068 | -0.0003 | 0.0036 |
| **NMIJ** | -0.0002 | 0.0096 | -0.0006 | 0.0042 | -0.0003 | 0.0159 | -0.0006 | 0.0069 | -0.0003 | 0.0037 |
| **VNIIM** | -0.0002 | 0.0096 | -0.0007 | 0.0042 | -0.0003 | 0.0159 | -0.0006 | 0.0068 | -0.0003 | 0.0037 |
| **NIST** | 0.0001 | 0.0096 | -0.0004 | 0.0042 | 0.0000 | 0.0159 | -0.0003 | 0.0069 | 0.0000 | 0.0038 |
| **NMi-VSL** | -0.0001 | 0.0095 | -0.0005 | 0.0040 | -0.0002 | 0.0159 | -0.0005 | 0.0068 | -0.0002 | 0.0035 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ -0.0733 pC/(m/s$^2$), u(ψ) 0.0011 pC/(m/s$^2$), Frequency 500 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | 0.0001 | 0.0109 | -0.0004 | 0.0041 | 0.0001 | 0.0159 | -0.0019 | 0.0069 | -0.0001 | 0.0039 |
| **BNM-CESTA** | 0.0005 | 0.0109 | -0.0001 | 0.0043 | 0.0005 | 0.0160 | -0.0016 | 0.0070 | 0.0002 | 0.0042 |
| **CSIRO-NML** | 0.0002 | 0.0109 | -0.0004 | 0.0042 | 0.0002 | 0.0159 | -0.0019 | 0.0069 | -0.0001 | 0.0040 |
| **CMI** | 0.0003 | 0.0110 | -0.0003 | 0.0044 | 0.0003 | 0.0160 | -0.0018 | 0.0070 | 0.0000 | 0.0042 |
| **CSIR-NML** | 0.0004 | 0.0110 | -0.0002 | 0.0045 | 0.0004 | 0.0160 | -0.0017 | 0.0071 | 0.0001 | 0.0043 |
| **CENAM** | 0.0002 | 0.0110 | -0.0003 | 0.0044 | 0.0002 | 0.0160 | -0.0018 | 0.0070 | -0.0001 | 0.0042 |
| **NRC** | 0.0000 | 0.0109 | -0.0005 | 0.0043 | 0.0000 | 0.0160 | -0.0020 | 0.0070 | -0.0002 | 0.0042 |
| **KRISS** | 0.0000 | 0.0109 | -0.0005 | 0.0042 | 0.0000 | 0.0159 | -0.0020 | 0.0069 | -0.0003 | 0.0040 |
| **NMIJ** | 0.0000 | 0.0115 | -0.0005 | 0.0056 | 0.0000 | 0.0164 | -0.0020 | 0.0079 | -0.0003 | 0.0055 |
| **VNIIM** | -0.0004 | 0.0109 | -0.0009 | 0.0043 | -0.0004 | 0.0160 | -0.0024 | 0.0070 | -0.0006 | 0.0041 |
| **NIST** | 0.0003 | 0.0110 | -0.0003 | 0.0044 | 0.0003 | 0.0160 | -0.0018 | 0.0070 | 0.0000 | 0.0043 |
| **NMi-VSL** | 0.0004 | 0.0109 | -0.0002 | 0.0042 | 0.0004 | 0.0159 | -0.0017 | 0.0069 | 0.0001 | 0.0040 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Endevco 2270M8 s/n 10472 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ -0.0733 pC/(m/s²), u(ψ) 0.0025 pC/(m/s²), Frequency 800 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | 0.0001 | 0.0196 | -0.0004 | 0.0061 | 0.0003 | 0.0177 | -0.0016 | 0.0082 | -0.0003 | 0.0094 |
| **BNM-CESTA** | 0.0004 | 0.0196 | 0.0000 | 0.0063 | 0.0006 | 0.0178 | -0.0013 | 0.0083 | 0.0000 | 0.0095 |
| **CSIRO-NML** | 0.0000 | 0.0196 | -0.0004 | 0.0062 | 0.0002 | 0.0178 | -0.0017 | 0.0082 | -0.0004 | 0.0095 |
| **CMI** | 0.0003 | 0.0197 | -0.0001 | 0.0064 | 0.0005 | 0.0178 | -0.0014 | 0.0084 | -0.0001 | 0.0096 |
| **CSIR-NML** | 0.0005 | 0.0197 | 0.0001 | 0.0063 | 0.0007 | 0.0178 | -0.0012 | 0.0084 | 0.0001 | 0.0096 |
| **CENAM** | 0.0001 | 0.0197 | -0.0003 | 0.0063 | 0.0003 | 0.0178 | -0.0015 | 0.0083 | -0.0002 | 0.0096 |
| **NRC** | 0.0004 | 0.0196 | -0.0001 | 0.0063 | 0.0006 | 0.0178 | -0.0013 | 0.0083 | 0.0000 | 0.0095 |
| **KRISS** | -0.0001 | 0.0196 | -0.0005 | 0.0062 | 0.0001 | 0.0178 | -0.0018 | 0.0082 | -0.0005 | 0.0095 |
| **NMIJ** | -0.0002 | 0.0197 | -0.0006 | 0.0064 | 0.0000 | 0.0178 | -0.0019 | 0.0084 | -0.0006 | 0.0096 |
| **VNIIM** | -0.0004 | 0.0196 | -0.0008 | 0.0062 | -0.0002 | 0.0178 | -0.0021 | 0.0083 | -0.0008 | 0.0095 |
| **NIST** | 0.0003 | 0.0200 | -0.0001 | 0.0073 | 0.0005 | 0.0182 | -0.0014 | 0.0091 | -0.0001 | 0.0103 |
| **NMi-VSL** | 0.0007 | 0.0196 | 0.0003 | 0.0062 | 0.0009 | 0.0178 | -0.0010 | 0.0083 | 0.0003 | 0.0095 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ -0.0726 pC/(m/s²), u(ψ) 0.0014 pC/(m/s²), Frequency 1000 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | -0.0003 | 0.0182 | -0.0010 | 0.0045 | -0.0009 | 0.0255 | -0.0027 | 0.0071 | -0.0002 | 0.0053 |
| **BNM-CESTA** | -0.0002 | 0.0183 | -0.0010 | 0.0048 | -0.0008 | 0.0255 | -0.0027 | 0.0073 | -0.0002 | 0.0055 |
| **CSIRO-NML** | -0.0003 | 0.0182 | -0.0011 | 0.0046 | -0.0009 | 0.0255 | -0.0028 | 0.0072 | -0.0003 | 0.0054 |
| **CMI** | -0.0001 | 0.0183 | -0.0009 | 0.0049 | -0.0007 | 0.0255 | -0.0025 | 0.0074 | -0.0001 | 0.0057 |
| **CSIR-NML** | 0.0000 | 0.0183 | -0.0008 | 0.0049 | -0.0006 | 0.0255 | -0.0025 | 0.0073 | 0.0000 | 0.0056 |
| **CENAM** | -0.0001 | 0.0184 | -0.0009 | 0.0051 | -0.0007 | 0.0256 | -0.0026 | 0.0075 | -0.0001 | 0.0058 |
| **NRC** | -0.0002 | 0.0183 | -0.0010 | 0.0048 | -0.0008 | 0.0255 | -0.0026 | 0.0073 | -0.0001 | 0.0056 |
| **KRISS** | -0.0005 | 0.0183 | -0.0013 | 0.0047 | -0.0011 | 0.0255 | -0.0029 | 0.0072 | -0.0004 | 0.0054 |
| **NMIJ** | 0.0000 | 0.0183 | -0.0008 | 0.0047 | -0.0006 | 0.0255 | -0.0024 | 0.0072 | 0.0001 | 0.0055 |
| **VNIIM** | -0.0007 | 0.0183 | -0.0015 | 0.0047 | -0.0013 | 0.0255 | -0.0031 | 0.0072 | -0.0007 | 0.0055 |
| **NIST** | 0.0000 | 0.0184 | -0.0008 | 0.0050 | -0.0006 | 0.0256 | -0.0025 | 0.0074 | 0.0000 | 0.0058 |
| **NMi-VSL** | 0.0002 | 0.0188 | -0.0006 | 0.0065 | -0.0004 | 0.0259 | -0.0022 | 0.0085 | 0.0002 | 0.0071 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Endevco 2270M8 s/n 10472 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ -0.0708 pC/(m/s$^2$), u(ψ) 0.0037 pC/(m/s$^2$), Frequency 5000 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | 0.0031 | 0.0219 | -0.0004 | 0.0080 | 0.0017 | 0.0523 | | | -0.0006 | 0.0141 |
| **BNM-CESTA** | | | | | | | | | | |
| **CSIRO-NML** | 0.0034 | 0.0219 | -0.0001 | 0.0080 | 0.0020 | 0.0523 | | | -0.0004 | 0.0141 |
| **CMI** | 0.0026 | 0.0220 | -0.0009 | 0.0083 | 0.0012 | 0.0523 | | | -0.0012 | 0.0142 |
| **CSIR-NML** | 0.0064 | 0.0221 | 0.0029 | 0.0085 | 0.0050 | 0.0524 | | | 0.0026 | 0.0144 |
| **CENAM** | 0.0018 | 0.0220 | -0.0017 | 0.0083 | 0.0004 | 0.0523 | | | -0.0020 | 0.0143 |
| **NRC** | 0.0018 | 0.0222 | -0.0017 | 0.0087 | 0.0004 | 0.0524 | | | -0.0020 | 0.0145 |
| **KRISS** | 0.0017 | 0.0220 | -0.0018 | 0.0081 | 0.0003 | 0.0523 | | | -0.0021 | 0.0141 |
| **NMIJ** | 0.0113 | 0.0223 | 0.0078 | 0.0090 | 0.0099 | 0.0525 | | | 0.0075 | 0.0147 |
| **VNIIM** | 0.0021 | 0.0220 | -0.0014 | 0.0082 | 0.0007 | 0.0523 | | | -0.0017 | 0.0142 |
| **NIST** | 0.0034 | 0.0227 | -0.0001 | 0.0098 | 0.0020 | 0.0526 | | | -0.0004 | 0.0152 |
| **NMi-VSL** | 0.0079 | 0.0224 | 0.0044 | 0.0092 | 0.0065 | 0.0525 | | | 0.0041 | 0.0148 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Back-to-Back Accelerometers

**Brüel & Kjær 8305 s/n 1687773 (SIM.AUV.V-K1) & Brüel & Kjær 8305, s/n 1483337 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0015 pC/(m/s²), u(ψ) 0.0005 pC/(m/s²), Frequency 50 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | 0.0003 | 0.0024 | 0.0000 | 0.0030 | 0.0001 | 0.0059 | 0.0008 | 0.0035 | 0.0000 | 0.0020 |
| **BNM-CESTA** | 0.0003 | 0.0028 | 0.0001 | 0.0033 | 0.0001 | 0.0060 | 0.0008 | 0.0038 | 0.0001 | 0.0024 |
| **CSIRO-NML** | 0.0003 | 0.0026 | 0.0001 | 0.0032 | 0.0001 | 0.0060 | 0.0008 | 0.0037 | 0.0001 | 0.0022 |
| **CMI** | 0.0002 | 0.0027 | -0.0001 | 0.0032 | 0.0000 | 0.0060 | 0.0007 | 0.0037 | -0.0001 | 0.0023 |
| **CSIR-NML** | 0.0006 | 0.0031 | 0.0004 | 0.0036 | 0.0004 | 0.0062 | 0.0011 | 0.0040 | 0.0004 | 0.0028 |
| **CENAM** | 0.0000 | 0.0028 | -0.0002 | 0.0033 | -0.0002 | 0.0061 | 0.0005 | 0.0038 | -0.0003 | 0.0024 |
| **NRC** | 0.0001 | 0.0026 | -0.0001 | 0.0032 | -0.0001 | 0.0060 | 0.0006 | 0.0037 | -0.0002 | 0.0022 |
| **KRISS** | 0.0001 | 0.0026 | -0.0001 | 0.0032 | -0.0001 | 0.0060 | 0.0006 | 0.0037 | -0.0002 | 0.0022 |
| **NMIJ** | 0.0001 | 0.0026 | -0.0001 | 0.0032 | -0.0001 | 0.0060 | 0.0006 | 0.0037 | -0.0002 | 0.0022 |
| **VNIIM** | -0.0002 | 0.0026 | -0.0004 | 0.0032 | -0.0004 | 0.0060 | 0.0003 | 0.0037 | -0.0005 | 0.0022 |
| **NIST** | 0.0002 | 0.0027 | 0.0000 | 0.0033 | 0.0000 | 0.0060 | 0.0007 | 0.0037 | 0.0000 | 0.0023 |
| **NMi-VSL** | 0.0002 | 0.0025 | -0.0001 | 0.0031 | 0.0000 | 0.0059 | 0.0006 | 0.0036 | -0.0001 | 0.0020 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0015 pC/(m/s²), u(ψ) 0.0005 pC/(m/s²), Frequency 80 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | -0.0003 | 0.0023 | 0.0000 | 0.0030 | -0.0001 | 0.0059 | 0.0007 | 0.0035 | 0.0001 | 0.0019 |
| **BNM-CESTA** | -0.0001 | 0.0027 | 0.0002 | 0.0033 | 0.0001 | 0.0060 | 0.0009 | 0.0038 | 0.0003 | 0.0024 |
| **CSIRO-NML** | -0.0003 | 0.0024 | 0.0000 | 0.0031 | -0.0001 | 0.0059 | 0.0007 | 0.0036 | 0.0001 | 0.0021 |
| **CMI** | -0.0003 | 0.0026 | 0.0000 | 0.0032 | -0.0001 | 0.0060 | 0.0007 | 0.0037 | 0.0001 | 0.0023 |
| **CSIR-NML** | -0.0008 | 0.0030 | -0.0005 | 0.0036 | -0.0006 | 0.0062 | 0.0002 | 0.0040 | -0.0004 | 0.0027 |
| **CENAM** | -0.0004 | 0.0027 | -0.0002 | 0.0033 | -0.0002 | 0.0061 | 0.0005 | 0.0038 | -0.0001 | 0.0024 |
| **NRC** | 0.0001 | 0.0025 | 0.0003 | 0.0032 | 0.0003 | 0.0060 | 0.0010 | 0.0037 | 0.0004 | 0.0022 |
| **KRISS** | -0.0004 | 0.0025 | -0.0002 | 0.0032 | -0.0002 | 0.0060 | 0.0005 | 0.0037 | -0.0001 | 0.0022 |
| **NMIJ** | -0.0003 | 0.0026 | -0.0001 | 0.0032 | -0.0001 | 0.0060 | 0.0006 | 0.0037 | 0.0000 | 0.0023 |
| **VNIIM** | -0.0008 | 0.0026 | -0.0005 | 0.0032 | -0.0006 | 0.0060 | 0.0002 | 0.0037 | -0.0004 | 0.0022 |
| **NIST** | -0.0004 | 0.0026 | -0.0001 | 0.0032 | -0.0002 | 0.0060 | 0.0006 | 0.0037 | 0.0000 | 0.0023 |
| **NMi-VSL** | -0.0005 | 0.0024 | -0.0002 | 0.0031 | -0.0003 | 0.0059 | 0.0005 | 0.0036 | -0.0001 | 0.0020 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Back-to-Back Accelerometers

**Brüel & Kjær 8305 s/n 1687773 (SIM.AUV.V-K1) & Brüel & Kjær 8305, s/n 1483337 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0017 pC/(m/s$^2$), u(ψ) 0.0005 pC/(m/s$^2$), Frequency 100 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | -0.0001 | 0.0023 | -0.0002 | 0.0030 | -0.0003 | 0.0059 | 0.0004 | 0.0035 | -0.0001 | 0.0019 |
| **BNM-CESTA** | 0.0001 | 0.0027 | 0.0000 | 0.0033 | -0.0001 | 0.0060 | 0.0006 | 0.0038 | 0.0001 | 0.0023 |
| **CSIRO-NML** | -0.0001 | 0.0025 | -0.0002 | 0.0031 | -0.0003 | 0.0059 | 0.0004 | 0.0036 | -0.0001 | 0.0020 |
| **CMI** | -0.0001 | 0.0027 | -0.0002 | 0.0033 | -0.0003 | 0.0060 | 0.0004 | 0.0037 | -0.0001 | 0.0022 |
| **CSIR-NML** | -0.0003 | 0.0029 | -0.0004 | 0.0034 | -0.0005 | 0.0061 | 0.0002 | 0.0039 | -0.0003 | 0.0025 |
| **CENAM** | -0.0002 | 0.0027 | -0.0003 | 0.0033 | -0.0004 | 0.0060 | 0.0002 | 0.0038 | -0.0002 | 0.0023 |
| **NRC** | 0.0000 | 0.0026 | -0.0001 | 0.0032 | -0.0002 | 0.0060 | 0.0004 | 0.0037 | 0.0000 | 0.0021 |
| **KRISS** | -0.0002 | 0.0026 | -0.0004 | 0.0032 | -0.0004 | 0.0060 | 0.0002 | 0.0037 | -0.0002 | 0.0021 |
| **NMIJ** | -0.0001 | 0.0026 | -0.0002 | 0.0032 | -0.0003 | 0.0060 | 0.0004 | 0.0037 | -0.0001 | 0.0022 |
| **VNIIM** | -0.0006 | 0.0026 | -0.0007 | 0.0032 | -0.0008 | 0.0060 | -0.0001 | 0.0037 | -0.0006 | 0.0021 |
| **NIST** | 0.0000 | 0.0026 | -0.0001 | 0.0032 | -0.0002 | 0.0060 | 0.0005 | 0.0037 | 0.0000 | 0.0022 |
| **NMi-VSL** | -0.0002 | 0.0024 | -0.0003 | 0.0030 | -0.0004 | 0.0059 | 0.0002 | 0.0036 | -0.0002 | 0.0019 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0015 pC/(m/s$^2$), u(ψ) 0.0005 pC/(m/s$^2$), Frequency 160 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | 0.0000 | 0.0025 | 0.0000 | 0.0030 | -0.0001 | 0.0059 | 0.0005 | 0.0036 | 0.0001 | 0.0020 |
| **BNM-CESTA** | 0.0001 | 0.0028 | 0.0001 | 0.0033 | 0.0000 | 0.0061 | 0.0005 | 0.0038 | 0.0001 | 0.0024 |
| **CSIRO-NML** | 0.0000 | 0.0026 | 0.0000 | 0.0031 | -0.0001 | 0.0060 | 0.0004 | 0.0036 | 0.0000 | 0.0021 |
| **CMI** | 0.0000 | 0.0028 | 0.0000 | 0.0033 | -0.0001 | 0.0060 | 0.0004 | 0.0038 | 0.0000 | 0.0023 |
| **CSIR-NML** | 0.0000 | 0.0028 | 0.0000 | 0.0033 | -0.0001 | 0.0061 | 0.0004 | 0.0038 | 0.0000 | 0.0024 |
| **CENAM** | 0.0000 | 0.0029 | 0.0000 | 0.0033 | -0.0001 | 0.0061 | 0.0004 | 0.0038 | 0.0000 | 0.0024 |
| **NRC** | 0.0002 | 0.0027 | 0.0001 | 0.0032 | 0.0001 | 0.0060 | 0.0006 | 0.0037 | 0.0002 | 0.0022 |
| **KRISS** | -0.0001 | 0.0027 | -0.0001 | 0.0032 | -0.0002 | 0.0060 | 0.0003 | 0.0037 | -0.0001 | 0.0022 |
| **NMIJ** | 0.0000 | 0.0027 | 0.0000 | 0.0032 | -0.0001 | 0.0060 | 0.0004 | 0.0037 | 0.0000 | 0.0022 |
| **VNIIM** | 0.0002 | 0.0027 | 0.0002 | 0.0032 | 0.0001 | 0.0060 | 0.0007 | 0.0037 | 0.0003 | 0.0022 |
| **NIST** | -0.0001 | 0.0028 | -0.0001 | 0.0033 | -0.0002 | 0.0060 | 0.0003 | 0.0038 | -0.0001 | 0.0023 |
| **NMi-VSL** | 0.0000 | 0.0026 | 0.0000 | 0.0032 | -0.0001 | 0.0060 | 0.0004 | 0.0037 | 0.0000 | 0.0022 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Back-to-Back Accelerometers

**Brüel & Kjær 8305 s/n 1687773 (SIM.AUV.V-K1) & Brüel & Kjær 8305, s/n 1483337 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0016 pC/(m/s²), u(ψ) 0.0006 pC/(m/s²), Frequency 250 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | 0.0000 | 0.0026 | -0.0002 | 0.0030 | 0.0001 | 0.0059 | 0.0002 | 0.0041 | 0.0001 | 0.0020 |
| **BNM-CESTA** | 0.0001 | 0.0030 | 0.0000 | 0.0033 | 0.0002 | 0.0061 | 0.0004 | 0.0044 | 0.0002 | 0.0024 |
| **CSIRO-NML** | -0.0001 | 0.0027 | -0.0002 | 0.0031 | 0.0000 | 0.0060 | 0.0002 | 0.0042 | 0.0000 | 0.0021 |
| **CMI** | 0.0000 | 0.0030 | -0.0002 | 0.0033 | 0.0001 | 0.0061 | 0.0002 | 0.0044 | 0.0001 | 0.0024 |
| **CSIR-NML** | -0.0002 | 0.0030 | -0.0003 | 0.0033 | -0.0001 | 0.0061 | 0.0001 | 0.0044 | -0.0001 | 0.0024 |
| **CENAM** | -0.0002 | 0.0030 | -0.0003 | 0.0034 | -0.0001 | 0.0061 | 0.0001 | 0.0044 | -0.0001 | 0.0025 |
| **NRC** | 0.0000 | 0.0028 | -0.0001 | 0.0032 | 0.0001 | 0.0060 | 0.0003 | 0.0043 | 0.0001 | 0.0022 |
| **KRISS** | -0.0001 | 0.0028 | -0.0003 | 0.0032 | 0.0000 | 0.0060 | 0.0001 | 0.0043 | -0.0001 | 0.0023 |
| **NMIJ** | -0.0002 | 0.0028 | -0.0003 | 0.0032 | -0.0001 | 0.0060 | 0.0001 | 0.0043 | -0.0001 | 0.0023 |
| **VNIIM** | 0.0000 | 0.0029 | -0.0001 | 0.0033 | 0.0001 | 0.0060 | 0.0003 | 0.0043 | 0.0001 | 0.0023 |
| **NIST** | -0.0001 | 0.0029 | -0.0002 | 0.0033 | 0.0000 | 0.0060 | 0.0002 | 0.0043 | 0.0000 | 0.0024 |
| **NMi-VSL** | -0.0001 | 0.0027 | -0.0002 | 0.0031 | 0.0000 | 0.0059 | 0.0002 | 0.0042 | 0.0000 | 0.0021 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0013 pC/(m/s²), u(ψ) 0.0007 pC/(m/s²), Frequency 500 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | | pC/(m/s²) | |
| **PTB** | 0.0003 | 0.0042 | 0.0001 | 0.0031 | 0.0001 | 0.0061 | 0.0001 | 0.0042 | 0.0002 | 0.0024 |
| **BNM-CESTA** | 0.0006 | 0.0044 | 0.0004 | 0.0034 | 0.0004 | 0.0062 | 0.0004 | 0.0045 | 0.0005 | 0.0028 |
| **CSIRO-NML** | 0.0004 | 0.0043 | 0.0002 | 0.0032 | 0.0002 | 0.0061 | 0.0002 | 0.0043 | 0.0003 | 0.0025 |
| **CMI** | 0.0004 | 0.0045 | 0.0002 | 0.0035 | 0.0002 | 0.0063 | 0.0002 | 0.0045 | 0.0003 | 0.0028 |
| **CSIR-NML** | 0.0008 | 0.0045 | 0.0006 | 0.0036 | 0.0006 | 0.0063 | 0.0006 | 0.0046 | 0.0007 | 0.0029 |
| **CENAM** | 0.0002 | 0.0045 | 0.0000 | 0.0035 | 0.0000 | 0.0062 | 0.0000 | 0.0045 | 0.0001 | 0.0028 |
| **NRC** | 0.0002 | 0.0044 | 0.0000 | 0.0035 | 0.0000 | 0.0062 | 0.0000 | 0.0045 | 0.0001 | 0.0028 |
| **KRISS** | 0.0003 | 0.0043 | 0.0000 | 0.0033 | 0.0001 | 0.0062 | 0.0000 | 0.0044 | 0.0002 | 0.0026 |
| **NMIJ** | 0.0002 | 0.0044 | 0.0000 | 0.0034 | 0.0000 | 0.0062 | 0.0000 | 0.0044 | 0.0001 | 0.0027 |
| **VNIIM** | 0.0006 | 0.0044 | 0.0004 | 0.0034 | 0.0004 | 0.0062 | 0.0004 | 0.0044 | 0.0005 | 0.0027 |
| **NIST** | 0.0001 | 0.0045 | -0.0001 | 0.0035 | -0.0001 | 0.0063 | -0.0001 | 0.0045 | 0.0000 | 0.0028 |
| **NMi-VSL** | 0.0003 | 0.0043 | 0.0001 | 0.0032 | 0.0001 | 0.0061 | 0.0001 | 0.0043 | 0.0002 | 0.0025 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Back-to-Back Accelerometers

**Brüel & Kjær 8305 s/n 1687773 (SIM.AUV.V-K1) & Brüel & Kjær 8305, s/n 1483337 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0014 pC/(m/s$^2$), u(ψ) 0.0013 pC/(m/s$^2$), Frequency 800 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | -0.0005 | 0.0063 | 0.0000 | 0.0039 | 0.0001 | 0.0072 | 0.0004 | 0.0048 | 0.0004 | 0.0050 |
| **BNM-CESTA** | -0.0002 | 0.0064 | 0.0003 | 0.0041 | 0.0004 | 0.0073 | 0.0008 | 0.0050 | 0.0007 | 0.0052 |
| **CSIRO-NML** | -0.0005 | 0.0063 | 0.0000 | 0.0039 | 0.0001 | 0.0072 | 0.0005 | 0.0048 | 0.0004 | 0.0050 |
| **CMI** | -0.0005 | 0.0064 | 0.0000 | 0.0041 | 0.0001 | 0.0073 | 0.0005 | 0.0050 | 0.0004 | 0.0052 |
| **CSIR-NML** | -0.0003 | 0.0064 | 0.0002 | 0.0041 | 0.0003 | 0.0073 | 0.0007 | 0.0050 | 0.0006 | 0.0052 |
| **CENAM** | -0.0005 | 0.0065 | 0.0000 | 0.0042 | 0.0001 | 0.0074 | 0.0004 | 0.0051 | 0.0004 | 0.0052 |
| **NRC** | -0.0003 | 0.0065 | 0.0002 | 0.0042 | 0.0003 | 0.0073 | 0.0006 | 0.0050 | 0.0006 | 0.0052 |
| **KRISS** | -0.0005 | 0.0064 | 0.0000 | 0.0040 | 0.0001 | 0.0073 | 0.0004 | 0.0049 | 0.0004 | 0.0051 |
| **NMIJ** | -0.0005 | 0.0064 | -0.0001 | 0.0041 | 0.0001 | 0.0073 | 0.0004 | 0.0050 | 0.0004 | 0.0051 |
| **VNIIM** | -0.0001 | 0.0064 | 0.0004 | 0.0040 | 0.0005 | 0.0073 | 0.0008 | 0.0049 | 0.0008 | 0.0051 |
| **NIST** | -0.0008 | 0.0071 | -0.0003 | 0.0051 | -0.0002 | 0.0079 | 0.0002 | 0.0058 | 0.0001 | 0.0060 |
| **NMi-VSL** | 0.0001 | 0.0064 | 0.0005 | 0.0041 | 0.0007 | 0.0073 | 0.0010 | 0.0050 | 0.0010 | 0.0052 |

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0012 pC/(m/s$^2$), u(ψ) 0.0009 pC/(m/s$^2$), Frequency 1000 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | -0.0010 | 0.0055 | 0.0002 | 0.0034 | 0.0004 | 0.0078 | 0.0006 | 0.0044 | 0.0005 | 0.0032 |
| **BNM-CESTA** | -0.0008 | 0.0056 | 0.0004 | 0.0036 | 0.0006 | 0.0079 | 0.0009 | 0.0046 | 0.0007 | 0.0035 |
| **CSIRO-NML** | -0.0009 | 0.0055 | 0.0003 | 0.0035 | 0.0005 | 0.0078 | 0.0008 | 0.0045 | 0.0006 | 0.0033 |
| **CMI** | -0.0011 | 0.0057 | 0.0001 | 0.0037 | 0.0003 | 0.0079 | 0.0006 | 0.0046 | 0.0005 | 0.0035 |
| **CSIR-NML** | -0.0010 | 0.0057 | 0.0002 | 0.0038 | 0.0004 | 0.0079 | 0.0007 | 0.0047 | 0.0005 | 0.0036 |
| **CENAM** | -0.0011 | 0.0059 | 0.0001 | 0.0041 | 0.0003 | 0.0081 | 0.0006 | 0.0050 | 0.0005 | 0.0040 |
| **NRC** | -0.0009 | 0.0057 | 0.0003 | 0.0038 | 0.0005 | 0.0079 | 0.0008 | 0.0047 | 0.0006 | 0.0036 |
| **KRISS** | -0.0011 | 0.0056 | 0.0001 | 0.0035 | 0.0003 | 0.0078 | 0.0006 | 0.0045 | 0.0004 | 0.0034 |
| **NMIJ** | -0.0011 | 0.0055 | 0.0001 | 0.0034 | 0.0003 | 0.0078 | 0.0006 | 0.0045 | 0.0005 | 0.0033 |
| **VNIIM** | -0.0004 | 0.0056 | 0.0008 | 0.0036 | 0.0010 | 0.0078 | 0.0013 | 0.0046 | 0.0012 | 0.0034 |
| **NIST** | -0.0014 | 0.0058 | -0.0002 | 0.0039 | 0.0000 | 0.0080 | 0.0003 | 0.0048 | 0.0001 | 0.0038 |
| **NMi-VSL** | -0.0008 | 0.0062 | 0.0004 | 0.0045 | 0.0006 | 0.0083 | 0.0009 | 0.0053 | 0.0008 | 0.0044 |

## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Back-to-Back Accelerometers

**Brüel & Kjær 8305 s/n 1687773 (SIM.AUV.V-K1) & Brüel & Kjær 8305, s/n 1483337 (CCAUV.V-K1)**

**Degrees of Interlaboratory Equivalence across Comparisons, ψ 0.0027 pC/(m/s$^2$), u(ψ) 0.0018 pC/(m/s$^2$), Frequency 5000 Hz**

| | NRC | | INMETRO | | CENAM | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ | $L_{ij}$ | $U_{ij}$ |
| | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **PTB** | 0.0003 | 0.0076 | -0.0010 | 0.0068 | 0.0006 | 0.0085 | 0.0002 | 0.0050 | -0.0008 | 0.0081 |
| **BNM-CESTA** | | | | | | | | | | |
| **CSIRO-NML** | 0.0005 | 0.0076 | -0.0008 | 0.0069 | 0.0008 | 0.0085 | 0.0003 | 0.0050 | -0.0007 | 0.0082 |
| **CMI** | 0.0003 | 0.0077 | -0.0010 | 0.0070 | 0.0006 | 0.0086 | 0.0002 | 0.0052 | -0.0008 | 0.0083 |
| **CSIR-NML** | 0.0002 | 0.0078 | -0.0011 | 0.0071 | 0.0005 | 0.0087 | 0.0000 | 0.0053 | -0.0010 | 0.0083 |
| **CENAM** | 0.0003 | 0.0081 | -0.0010 | 0.0074 | 0.0006 | 0.0089 | 0.0002 | 0.0057 | -0.0009 | 0.0086 |
| **NRC** | 0.0003 | 0.0086 | -0.0010 | 0.0079 | 0.0006 | 0.0094 | 0.0001 | 0.0064 | -0.0009 | 0.0091 |
| **KRISS** | 0.0004 | 0.0077 | -0.0009 | 0.0069 | 0.0007 | 0.0085 | 0.0003 | 0.0051 | -0.0007 | 0.0082 |
| **NMIJ** | 0.0003 | 0.0083 | -0.0010 | 0.0076 | 0.0006 | 0.0091 | 0.0002 | 0.0060 | -0.0009 | 0.0088 |
| **VNIIM** | 0.0017 | 0.0078 | 0.0004 | 0.0070 | 0.0020 | 0.0087 | 0.0016 | 0.0053 | 0.0006 | 0.0083 |
| **NIST** | 0.0002 | 0.0087 | -0.0011 | 0.0080 | 0.0005 | 0.0095 | 0.0000 | 0.0066 | -0.0010 | 0.0092 |
| **NMi-VSL** | 0.0003 | 0.0090 | -0.0011 | 0.0083 | 0.0006 | 0.0097 | 0.0001 | 0.0069 | -0.0009 | 0.0094 |

## III-4. Degrees of Equivalence between the SIM Results and the Key Comparison Reference Values of the CCAUV.V-K1 comparison

The degrees of equivalence, or linkage, between the results of the SIM comparison and the KCRVs of the CCAUV.V-K1 comparison are expressed as the difference between the adjusted SIM results and the KCRV of the CCAUV.V-K1 comparison for a particular set of transducers at a particular frequency using the notation:

$$L_{Rj} = x_j + \psi - x_{KCRV} \,,$$

$$U_{Rj} = 2 \cdot \sqrt{u_j^2 + \mathrm{u}^2(\psi) + u_{KCRV}^2} \,,$$

where

> $j$ is the index of the $j$-th laboratory participating in the SIM.AUV.V-K1 comparison;
>
> $x_j$ is the measurement result obtained by the $j$-th laboratory participating in the SIM.AUV.V-K1 comparison;
>
> $\psi$ is the adjustment term for a particular set of transducers at a particular frequency;
>
> $x_{KCRV}$ is the Key Comparison Reference Value of the CCAUV.V-K1 comparison;
>
> $u_j$ is the combined standard uncertainty $(k = 1)$ reported by the $j$-th laboratory participating in the SIM.AUV.V-K1 comparison;
>
> $u(\psi) = \sqrt{\mathrm{Var}(\psi)}$;
>
> and $u_{KCRV}$ is the combined standard uncertainty $(k = 1)$ of the Key Comparison Reference Value.

$U_{Rj}$ is the expanded standard deviation of the adjusted difference $L_{Rj}$ using a coverage factor of $k = 2$. $L_{Rj}$ represents the difference between an adjusted measurement result obtained by a laboratory participating in the SIM.AUV.V-K1 comparison and the corresponding Key Comparison Reference Value of the CCAUV.V-K1. The adjusted differences between the SIM results and the KCRVs of the CCAUV.V-K1 comparison are those that would have been obtained had the SIM laboratory participated in the CCAUV.V-K1 comparison. The numbers used for the Key Comparison Reference Values and their combined standard uncertainties $(k = 1)$ are taken from Table B1ab of the final report of the CCAUV.V-K1 dated October 1, 2002 and are tabulated below.

| | Single Ended | | Back - to - Back | |
|---|---|---|---|---|
| Frequency | KCRV | $u_{KCRV}$ | KCRV | $u_{KCRV}$ |
| Hz | pC/(m/s²) | | pC/(m/s²) | |
| **50** | 0.12897 | 0.00005 | 0.12658 | 0.00005 |
| **80** | 0.12898 | 0.00005 | 0.12658 | 0.00005 |
| **100** | 0.12896 | 0.00005 | 0.12658 | 0.00005 |
| **160** | 0.12899 | 0.00005 | 0.12663 | 0.00005 |
| **250** | 0.12902 | 0.00005 | 0.12663 | 0.00005 |
| **500** | 0.12910 | 0.00005 | 0.12663 | 0.00005 |
| **800** | 0.12919 | 0.00005 | 0.12673 | 0.00005 |
| **1000** | 0.12926 | 0.00005 | 0.12680 | 0.00005 |
| **5000** | | | 0.12936 | 0.00010 |

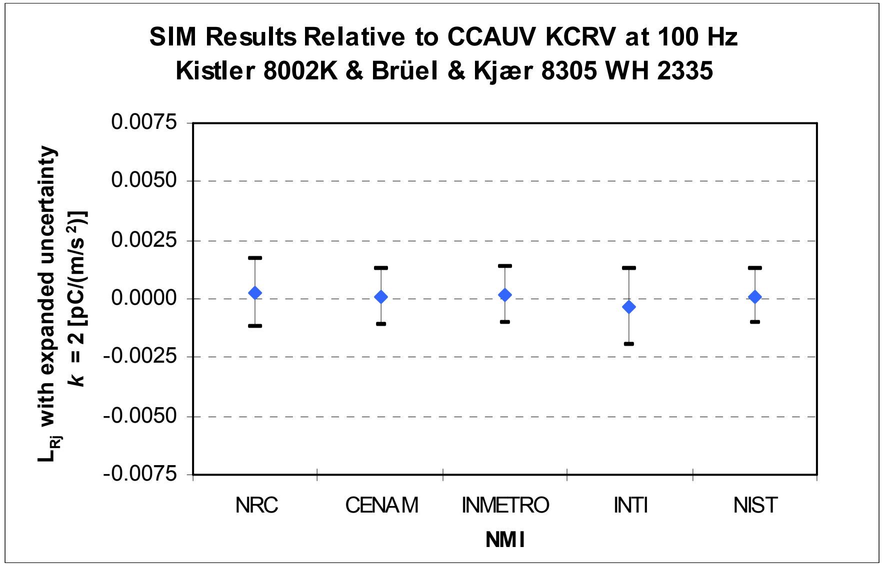
Tables and plots of the degrees of equivalence, or linkage, between the results of the SIM comparison and the KCRVs of the CCAUV.V-K1 comparison are given below for sets of transducers as a function of frequency.

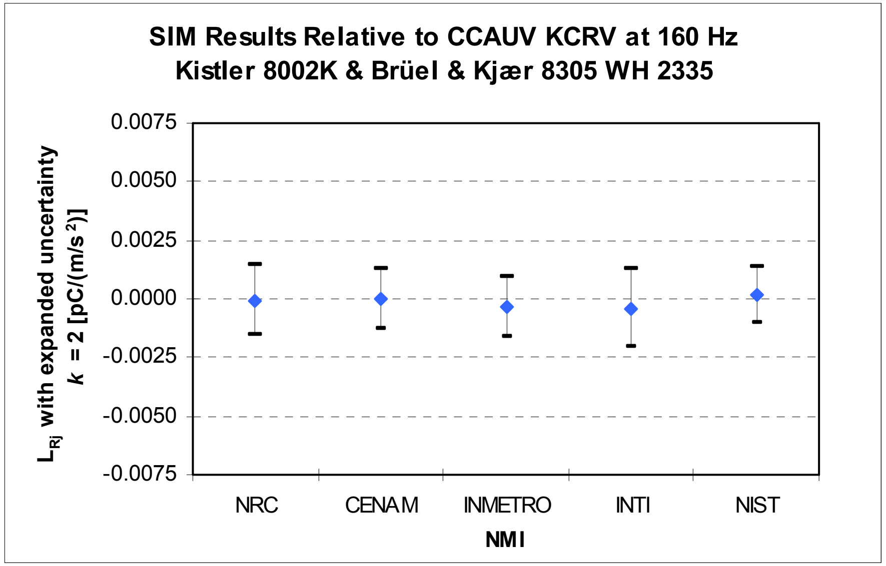
**Degrees of Equivalence between Laboratory Results of SIM.AUV.V-K1 and Key Comparison Reference Values of CCAUV.V-K1**

| | NRC | | CENAM | | INMETRO | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Frequency** | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ |
| Hz | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **50** | 0.0001 | 0.0015 | 0.0001 | 0.0013 | 0.0005 | 0.0013 | -0.0006 | 0.0016 | 0.0003 | 0.0012 |
| **80** | 0.0005 | 0.0015 | 0.0001 | 0.0013 | 0.0000 | 0.0013 | -0.0004 | 0.0016 | 0.0000 | 0.0012 |
| **100** | 0.0003 | 0.0015 | 0.0001 | 0.0012 | 0.0002 | 0.0012 | -0.0003 | 0.0016 | 0.0001 | 0.0011 |
| **160** | -0.0001 | 0.0015 | 0.0000 | 0.0013 | -0.0004 | 0.0013 | -0.0004 | 0.0016 | 0.0001 | 0.0012 |
| **250** | 0.0001 | 0.0015 | 0.0000 | 0.0013 | -0.0004 | 0.0015 | -0.0003 | 0.0018 | 0.0001 | 0.0012 |
| **500** | 0.0002 | 0.0018 | 0.0001 | 0.0014 | -0.0004 | 0.0016 | 0.0002 | 0.0019 | 0.0001 | 0.0014 |
| **800** | -0.0004 | 0.0036 | 0.0002 | 0.0031 | -0.0005 | 0.0032 | 0.0007 | 0.0034 | 0.0004 | 0.0032 |
| **1000** | 0.0004 | 0.0027 | 0.0006 | 0.0019 | 0.0003 | 0.0020 | 0.0011 | 0.0023 | 0.0002 | 0.0018 |

The difference ($L_{Rj}$) of each laboratory relative to the Key Comparison Reference Value is given by: $L_{Rj} = x_j + \psi - x_{KCRV}$

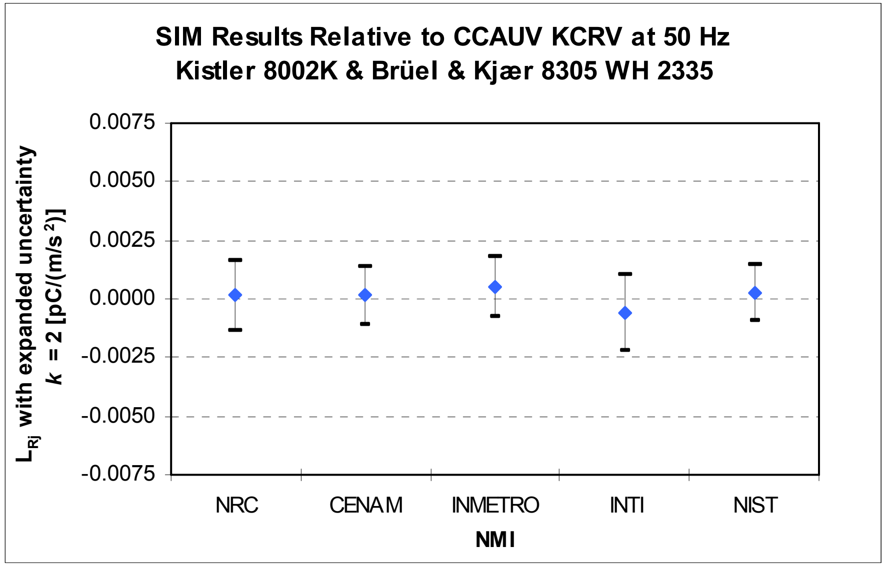
The expanded uncertainty [$U(L)_{Rj}$] for $k$ = 2 of the value of the difference $L_{Rj}$ is given by: $U_{Rj} = 2\sqrt{u_j^2 + u^2(\psi) + u_{KCRV}^2}$

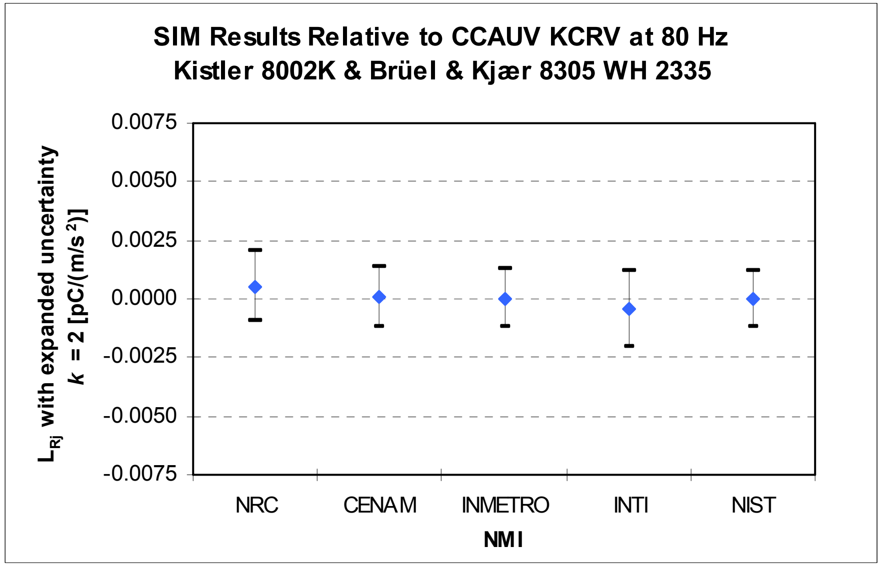


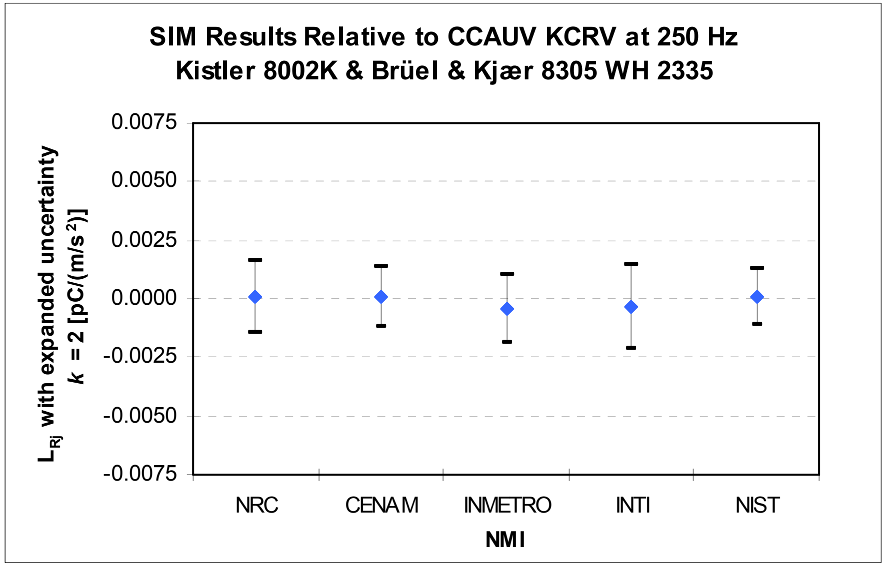



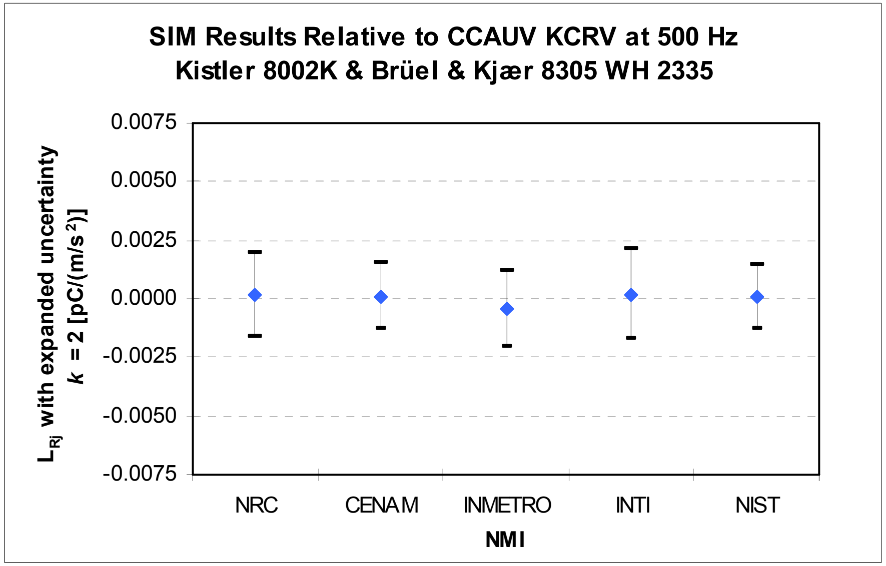
## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Kistler 8002K s/n 100443 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335 s/n 1610174 (CCAUV.V-K1)**

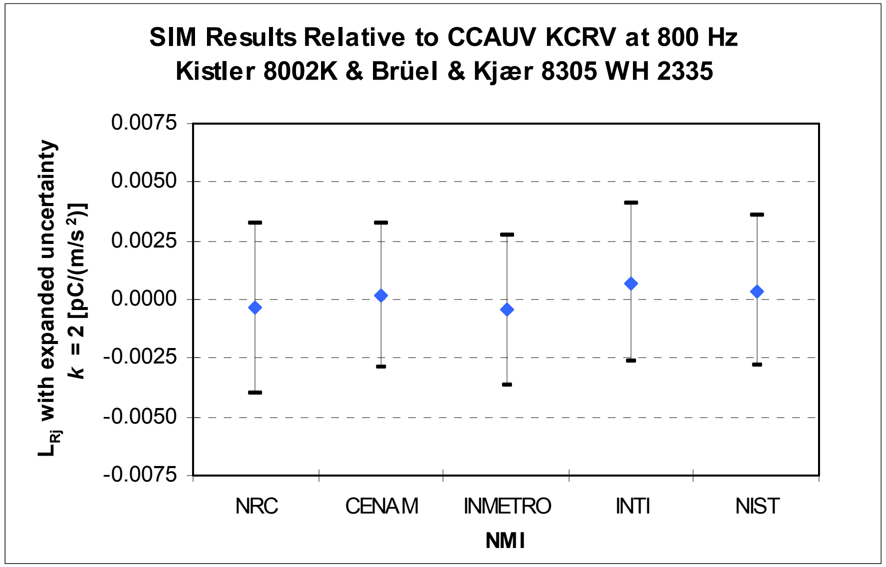


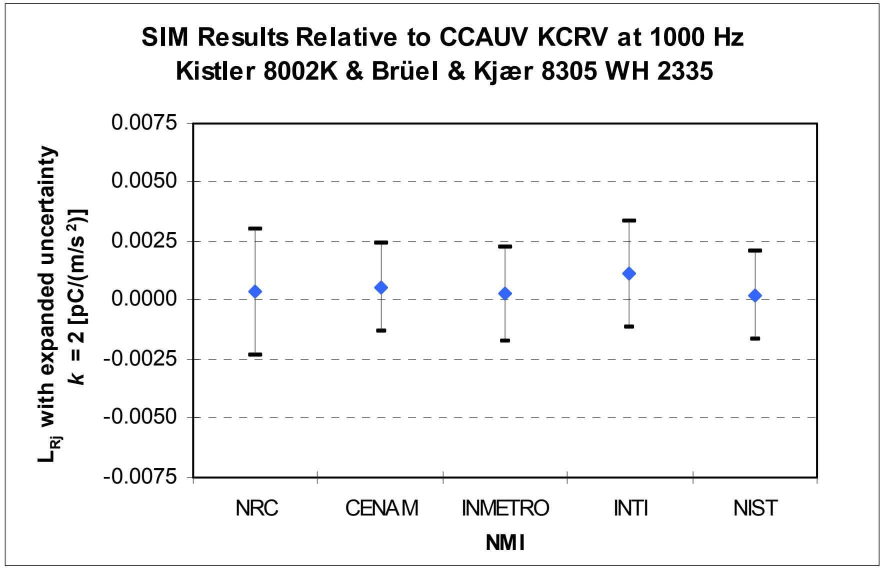



**SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers**
**Kistler 8002K s/n 100443 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335 s/n 1610174 (CCAUV.V-K1)**



## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Endevco 2270M8 s/n 10472 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Equivalence between Laboratory Results of SIM.AUV.V-K1 and Key Comparison Reference Values of CCAUV.V-K1**

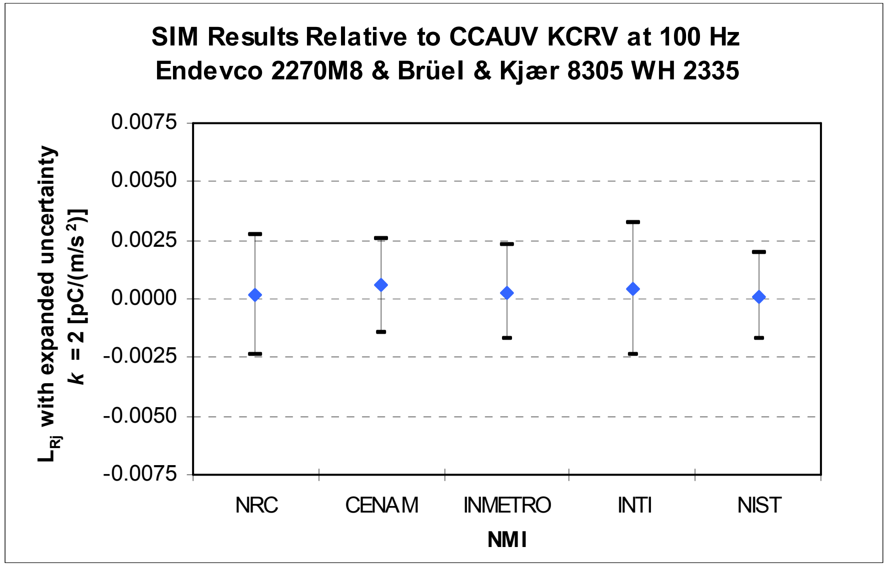
| | NRC | | CENAM | | INMETRO | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Frequency** | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ |
| Hz | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **50** | -0.0008 | 0.0025 | 0.0001 | 0.0020 | -0.0001 | 0.0020 | 0.0008 | 0.0028 | 0.0004 | 0.0018 |
| **80** | 0.0004 | 0.0025 | 0.0004 | 0.0020 | 0.0000 | 0.0020 | 0.0008 | 0.0028 | 0.0000 | 0.0018 |
| **100** | 0.0002 | 0.0025 | 0.0006 | 0.0020 | 0.0003 | 0.0020 | 0.0004 | 0.0028 | 0.0001 | 0.0018 |
| **160** | -0.0005 | 0.0026 | 0.0003 | 0.0021 | -0.0002 | 0.0021 | 0.0000 | 0.0029 | 0.0001 | 0.0019 |
| **250** | 0.0000 | 0.0027 | 0.0004 | 0.0021 | 0.0001 | 0.0025 | 0.0004 | 0.0032 | 0.0001 | 0.0020 |
| **500** | -0.0002 | 0.0030 | 0.0004 | 0.0023 | -0.0002 | 0.0027 | 0.0019 | 0.0034 | 0.0001 | 0.0022 |
| **800** | -0.0001 | 0.0062 | 0.0004 | 0.0051 | -0.0003 | 0.0053 | 0.0016 | 0.0057 | 0.0003 | 0.0053 |
| **1000** | 0.0003 | 0.0047 | 0.0010 | 0.0030 | 0.0009 | 0.0033 | 0.0027 | 0.0039 | 0.0002 | 0.0030 |

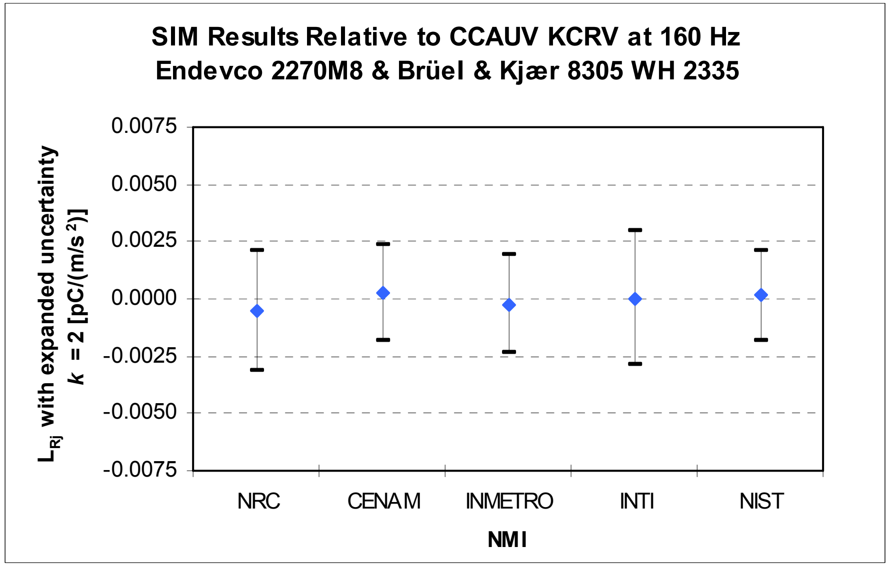
The difference ($L_{Rj}$) of each laboratory relative to the Key Comparison Reference Value is given by:

$$L_{Rj} = x_j + \psi - x_{KCRV}$$

The expanded uncertainty $[U(L)_{Rj}]$ for $k$ = 2 of the value of the difference $L_{Rj}$ is given by:

$$U_{Rj} = 2\sqrt{u_j^2 + u^2(\psi) + u_{KCRV}^2}$$

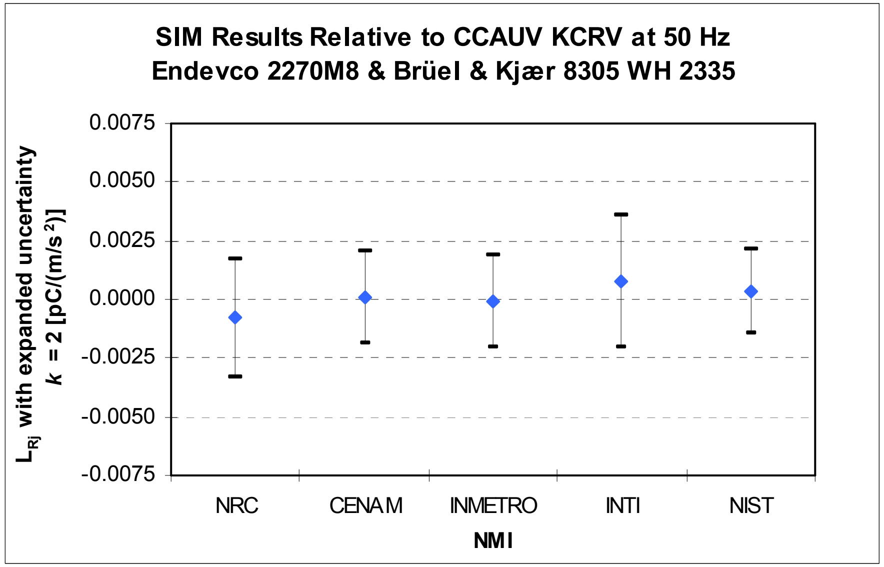


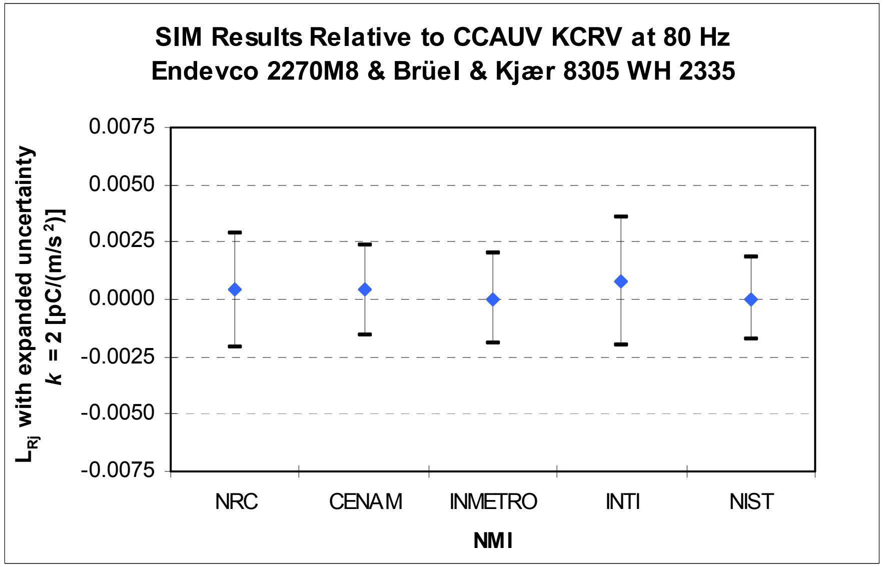



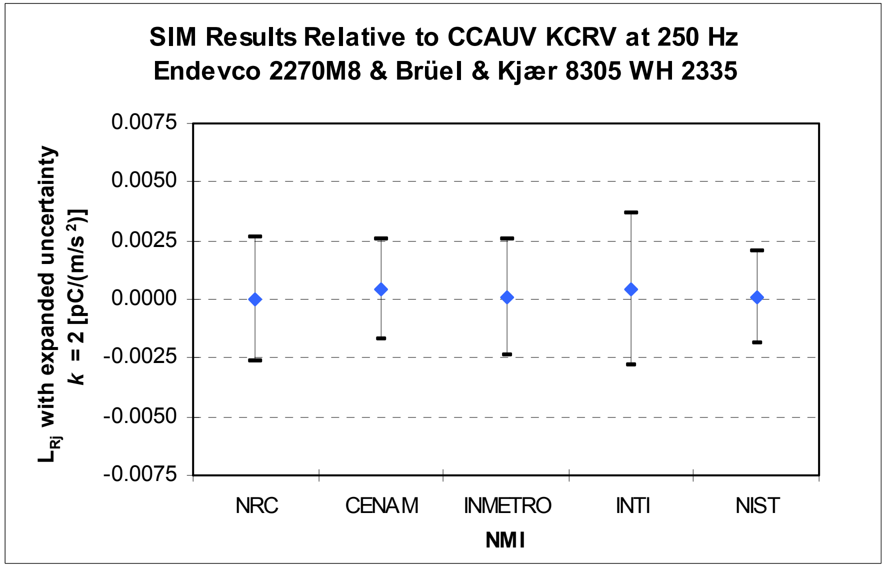
## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

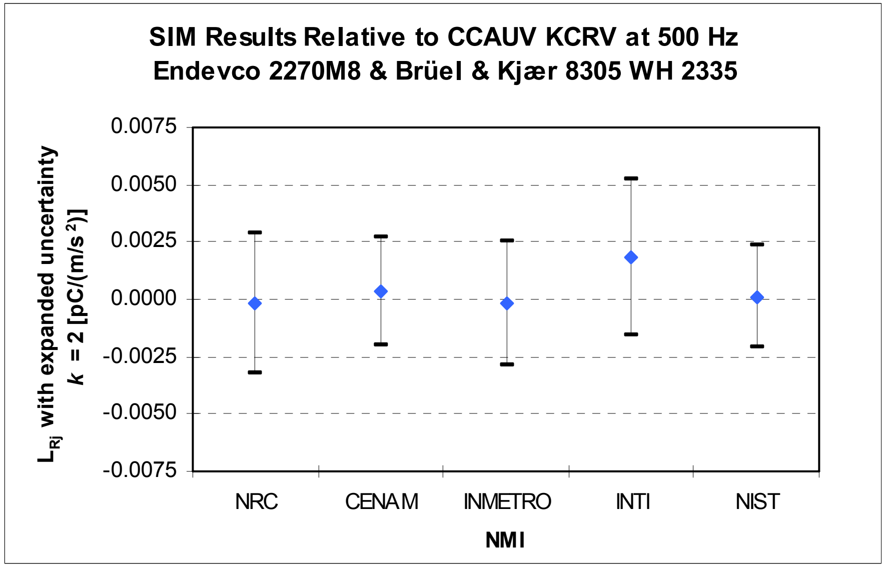
**Endevco 2270M8 s/n 10472 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Equivalence between Laboratory Results of SIM.AUV.V-K1 and Key Comparison Reference Values of CCAUV.V-K1**



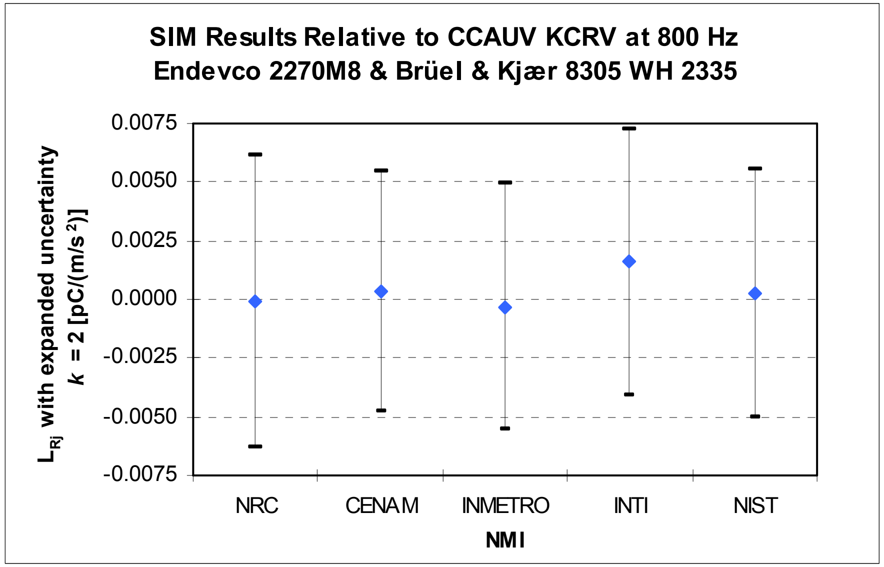



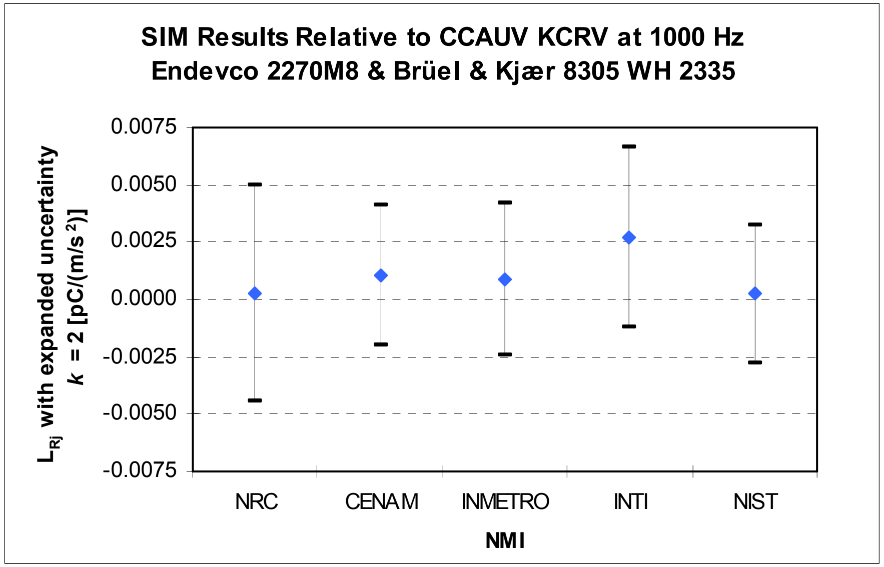



## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Single-Ended Accelerometers

**Endevco 2270M8 s/n 10472 (SIM.AUV.V-K1) & Brüel & Kjær 8305 WH 2335, s/n 1610174 (CCAUV.V-K1)**

**Degrees of Equivalence between Laboratory Results of SIM.AUV.V-K1 and Key Comparison Reference Values of CCAUV.V-K1**



## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Back-to-Back Accelerometers

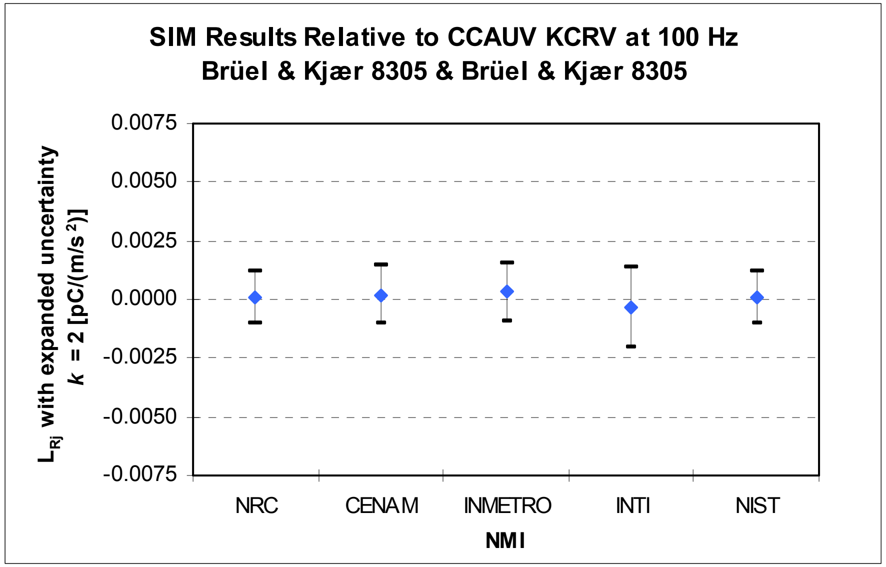
**Brüel & Kjær 8305 s/n 1687773 (SIM.AUV.V-K1) & Brüel & Kjær 8305, s/n 1483337 (CCAUV.V-K1)**

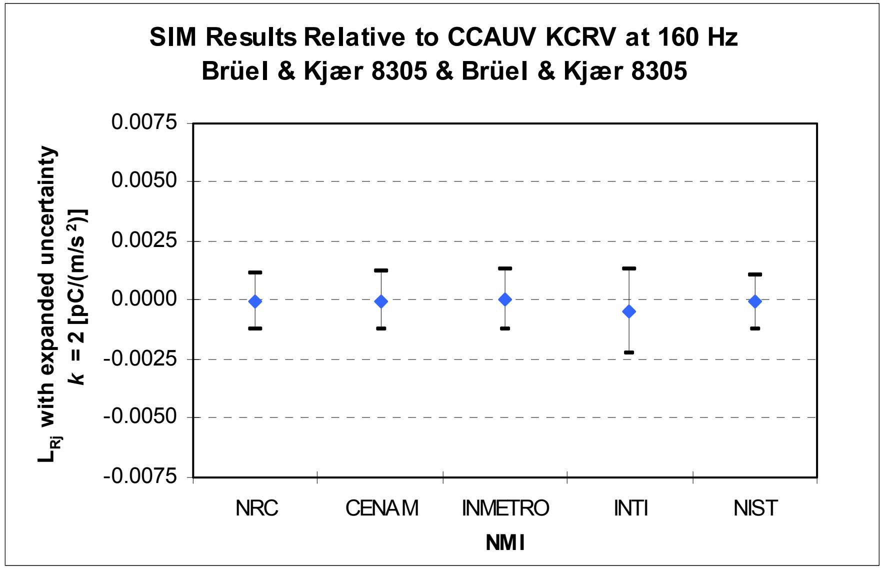
**Degrees of Equivalence between Laboratory Results of SIM.AUV.V-K1 and Key Comparison Reference Values of CCAUV.V-K1**

| | NRC | | CENAM | | INMETRO | | INTI | | NIST | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Frequency** | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ | $L_{Rj}$ | $U_{Rj}$ |
| Hz | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | | pC/(m/s$^2$) | |
| **50** | -0.0002 | 0.0011 | 0.0000 | 0.0012 | 0.0000 | 0.0012 | -0.0007 | 0.0017 | 0.0001 | 0.0011 |
| **80** | 0.0003 | 0.0011 | 0.0000 | 0.0012 | 0.0001 | 0.0012 | -0.0006 | 0.0017 | -0.0001 | 0.0011 |
| **100** | 0.0001 | 0.0011 | 0.0002 | 0.0012 | 0.0003 | 0.0012 | -0.0004 | 0.0017 | 0.0001 | 0.0011 |
| **160** | 0.0000 | 0.0012 | 0.0000 | 0.0013 | 0.0001 | 0.0013 | -0.0005 | 0.0018 | -0.0001 | 0.0012 |
| **250** | 0.0000 | 0.0012 | 0.0002 | 0.0013 | 0.0000 | 0.0013 | -0.0002 | 0.0020 | 0.0000 | 0.0012 |
| **500** | -0.0003 | 0.0016 | -0.0001 | 0.0015 | -0.0001 | 0.0015 | -0.0001 | 0.0021 | -0.0002 | 0.0015 |
| **800** | 0.0004 | 0.0028 | -0.0001 | 0.0027 | -0.0002 | 0.0027 | -0.0005 | 0.0031 | -0.0005 | 0.0028 |
| **1000** | 0.0010 | 0.0021 | -0.0002 | 0.0019 | -0.0004 | 0.0019 | -0.0007 | 0.0024 | -0.0005 | 0.0019 |
| **5000** | -0.0003 | 0.0038 | 0.0010 | 0.0038 | -0.0006 | 0.0037 | -0.0002 | 0.0041 | 0.0008 | 0.0039 |

The difference ($L_{Rj}$) of each laboratory relative to the Key Comparison Reference Value is given by: $L_{Rj} = x_j + \psi - x_{KCRV}$

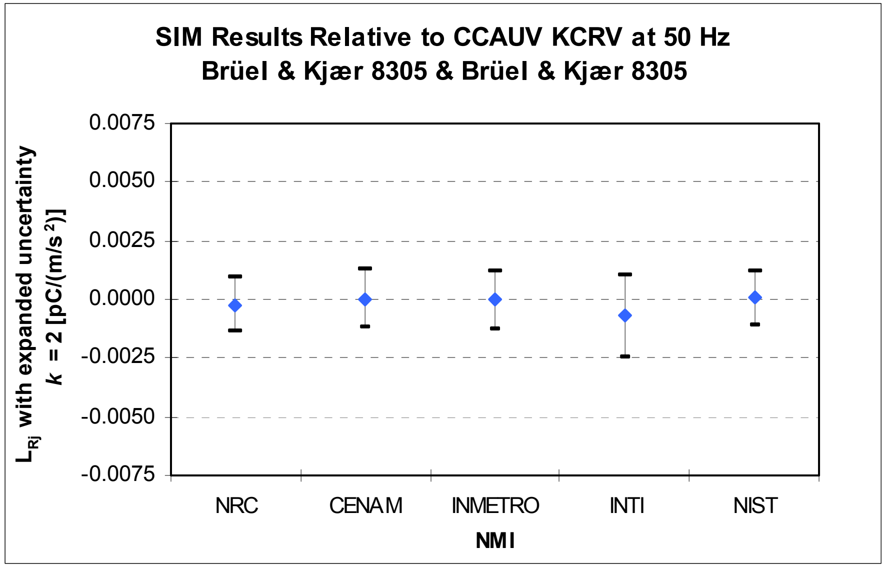
The expanded uncertainty [$U(L)_{Rj}$] for $k$ = 2 of the value of the difference $L_{Rj}$ is given by: $U_{Rj} = 2\sqrt{u_j^2 + u^2(\psi) + u_{KCRV}^2}$

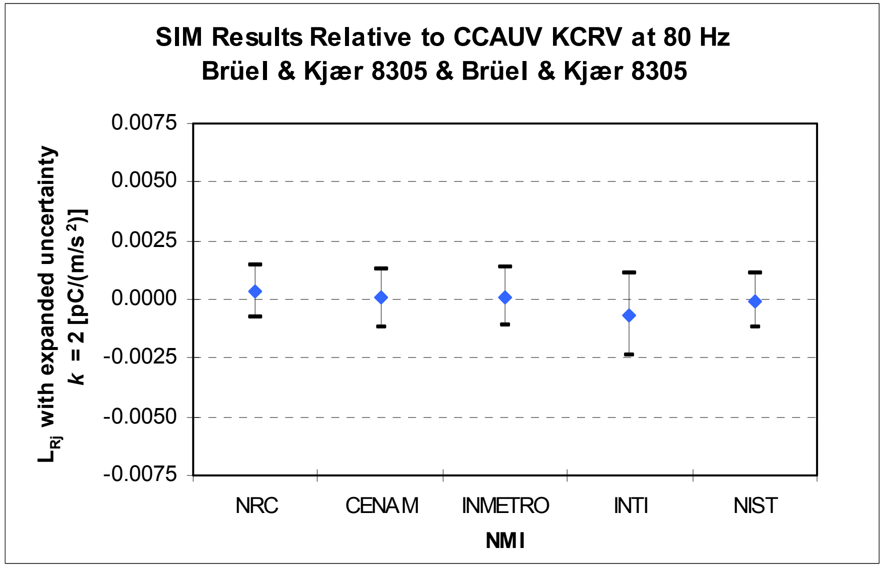


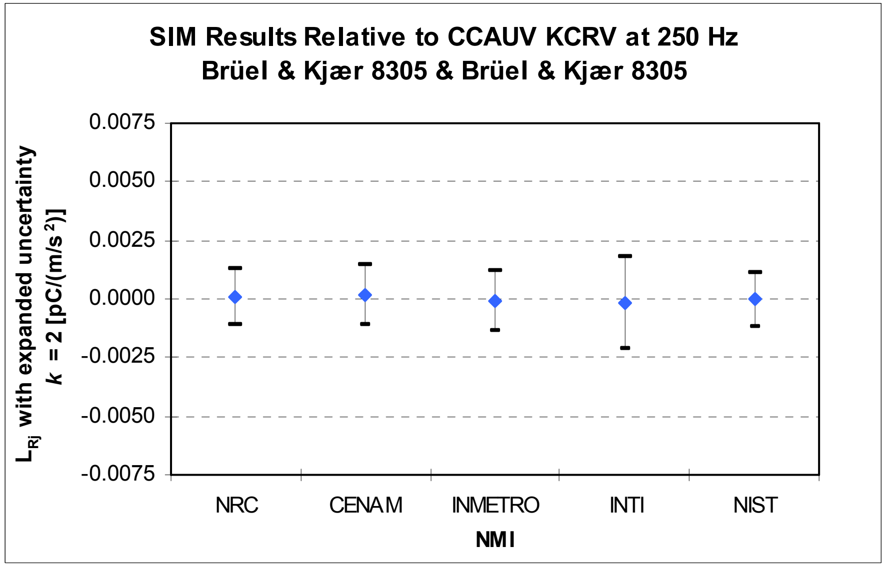



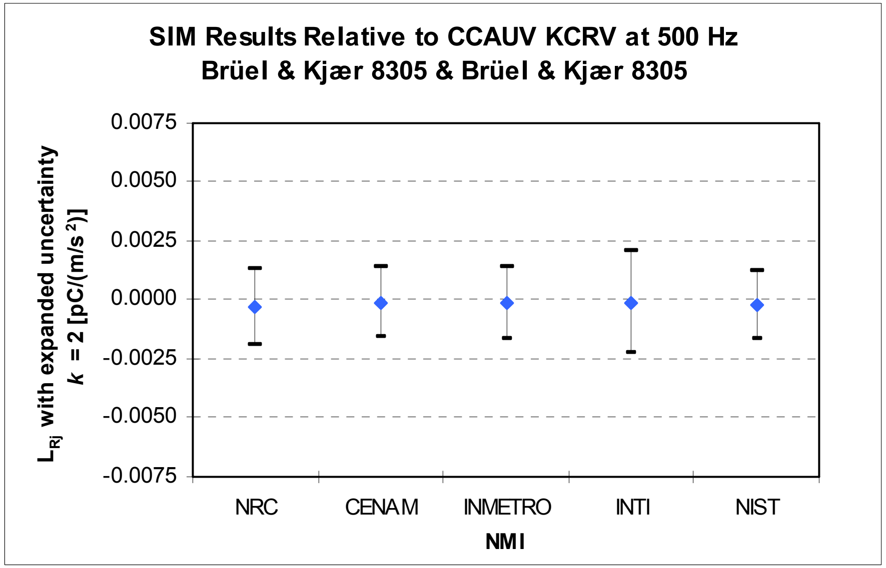
## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Back-to-Back Accelerometers
**Brüel & Kjær 8305 s/n 1687773 (SIM.AUV.V-K1) & Brüel & Kjær 8305, s/n 1483337 (CCAUV.V-K1)**

**Degrees of Equivalence between Laboratory Results of SIM.AUV.V-K1 and Key Comparison Reference Values of CCAUV.V-K1**



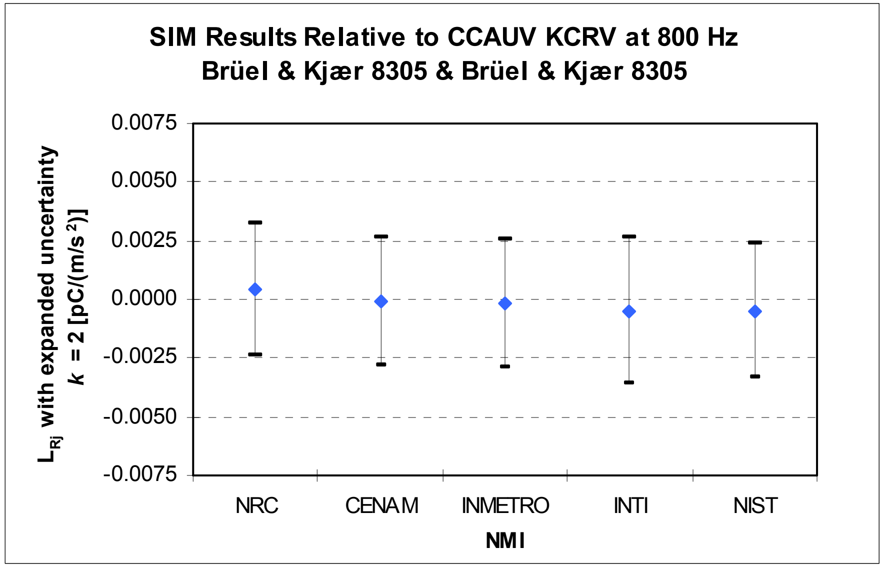



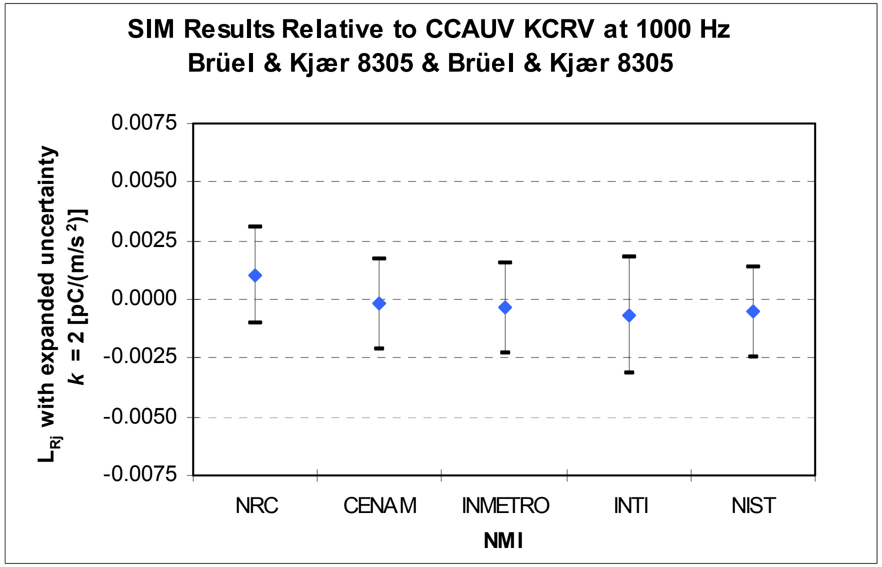



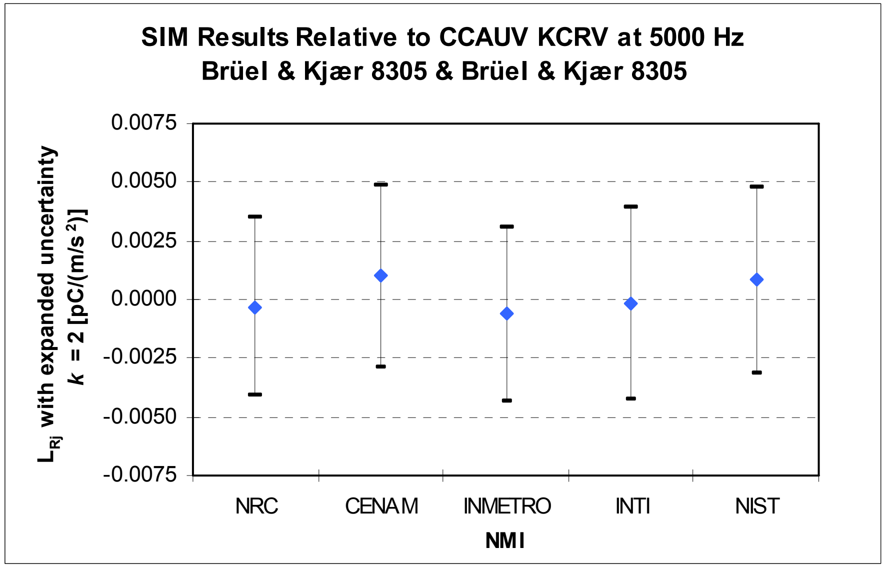
## SIM.AUV.V-K1 Regional Comparison to CCAUV.V-K1 Key Comparison Linkage—Back-to-Back Accelerometers

**Brüel & Kjær 8305 s/n 1687773 (SIM.AUV.V-K1) & Brüel & Kjær 8305, s/n 1483337 (CCAUV.V-K1)**

**Degrees of Equivalence between Laboratory Results of SIM.AUV.V-K1 and Key Comparison Reference Values of CCAUV.V-K1**



## III-5. Conclusions

A linking method based on a linear additive model with contrast estimators is employed here to establish the degree of equivalence between the measurement results of the SIM.AUV.V-K1 and CCAUV.V-K1 comparisons. Degree of equivalence is expressed as an adjusted difference between the results obtained by two laboratories participating in one or more comparisons, with the variable $\psi$ representing the adjustment term for the effect of the difference in artifacts across comparisons. Degrees of Interlaboratory Equivalence which include the expanded uncertainties have been tabulated between the laboratories participating in the SIM.AUV-K1 Regional Comparison and those participating in the CCAUV.V-K1 Key Comparison. The differences between laboratories participating in the two comparisons are typically an order of magnitude smaller than the expanded uncertainties associated with the differences. The SIM results expressed relative to the KCRVs of the CCAUV are plotted for each accelerometer with the upper and lower expanded uncertainty limits shown for a coverage factor of $k = 2$. These plots typically indicate robust overlap among the expanded uncertainties of the measurement results reported by the NMIs participating in SIM.AUV-K1, and the SIM results expressed relative to the KCRVs of the CCAUV.

## III-6. References


[III 1] CIPM MRA, *Mutual Recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes with Technical Supplement revised in October 2003*, Paris 14 October 1999.

[III 2] von Martens H.-J., Elster C., Link A., Täubner A., Wabinski W. [PTB], *Key Comparison CCAUV.V-K1 Final Report*, Metrologia, 2003, 40,Tech. Suppl., 09001.

[III 3] Allisy-Roberts, P., *Brief guidelines for linking RMO key comparisons to the CIPM KCRV*, CCAUV/04-27, BIPM, 26 May 2004.

[III 4] Sutton, C.M., *Analysis and linking of international measurement comparisons*, Metrologia, 2004, 41, 272–277.

[III 5] Rukhin, A. L., Strawderman, W. E., *Statistical aspects of linkage analysis in interlaboratory studies*, Journal of Statistical Planning and Inference, 137 (1), 1 January 2007, 264-278.