COMPASS BIRD
CALIBRATION REQUIREMENTS
FOR WORLDWIDE PERFORMANCE
IN STREAMER POSITION SOLUTIONS

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Figure 1. A measure of calibration process error based on 370 bird verification spins. Data inclusive of tests conducted under abnormal ambient magnetic activity.

Figure 2. Calibration Process Flow.

Figure 3. This chart is based on data from more than 1550 DigiCOURSE Model 5011 birds calibrated in 1993. The average peak error is ± 0.22°, with a standard deviation of 0.04°. Based on the data, 0.35° peak error performance at New Orleans represents 3.33 standard deviations or 99.92%.

Figure 4. Data from more than 8000 field verifications from around the globe. The standard deviation of 0.198 is approximately ½ bin width of a 10-bit compass code card.

Figure 5. Long term data of 73 birds in use taken from two vessels. Data was tracked over two years. Some birds were calibrated three times or more. All birds were calibrated at least twice in the two-year period.

Figure 6. Statistical analysis of seven smaller samples, showing that the smaller samples were not significantly different from the entire suite.

Figure 7. Recent performance verification test of birds returned to DigiCOURSE for various reasons. The data is based on about 30 birds picked from repair returns.

Figure 8. Data exhibits no measurable changes based on 100 calibration iterations. "Delta A" is the difference between the "A" coefficient of the bird calibration and the corresponding "A" coefficient of the compass module.

Repeatable and durable worldwide cable compass performance is achieved through an integrated strategy in the design, manufacture, and calibration of cable compasses. First, the heading sensor or the compass must be insensitive to changes in operating magnetic latitudes. Second, the body (bird housing) used to mount the compass must be mechanically stable and nonmagnetic to the extent that the compass is able to perform within its accuracy specifications at all operating latitudes. Third, a calibration process is required which can:

- accurately determine compass correction coefficients,
- ensure world wide compass accuracy, and
- repeatably measure performance and stability of the calibration correction coefficients on a long-term basis.

From 1990 to 1993, DigiCOURSE conducted a comprehensive study of its Model 5011 compass birds. The objective of the study was to determine the accuracy and stability of the compass calibration coefficients, and thereby bird performance. To ensure the study integrity, a calibration process with a well-defined, measurable process error was imperative. The DigiCOURSE calibration facility located in New Orleans, in a magnetically isolated area, ensures a highly repeatable, accurate, and measurable calibration process. The ambient magnetic field is continuously monitored by a multitude of tri-axial sensors to ensure that nonlinearities and temporary anomalies do not affect the calibration process. A measure of the calibration process error (± 0.08°) is displayed in Figure 1. The results are based on 370 performance verification tests, performed on two control birds, over a period of eight months. The data includes a few test results which occurred during abnormal ambient magnetic activity, conditions which would cause a normal production calibration test to automatically abort.

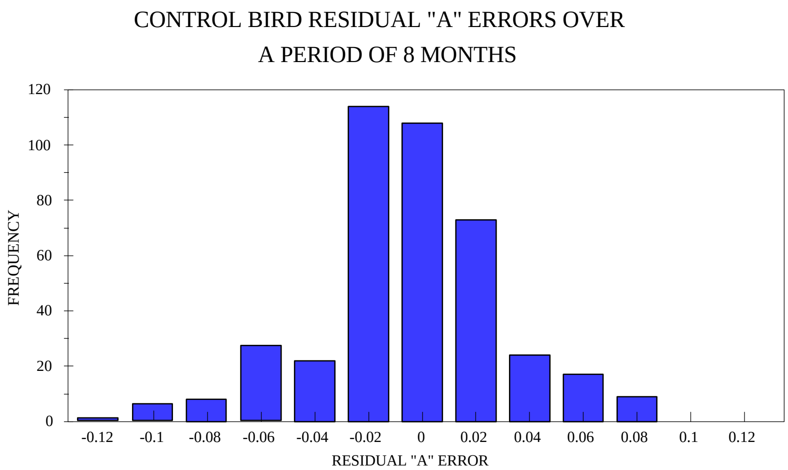

Figure 1. A measure of calibration process error based on 370 bird verification spins. Data inclusive of tests conducted under abnormal ambient magnetic activity.

Every compass and compass bird is subjected to an identical process thereby ensuring unit-to-unit repeatable performance. An abbreviated representation of the calibration process flow is illustrated in Figure 2.

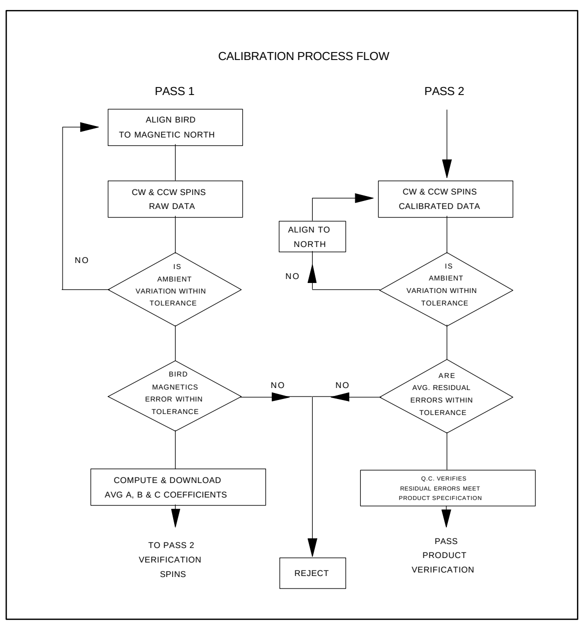

Figure 2. Calibration Process Flow.

Individual compasses are calibrated and resulting performance parameters are stored in the calibration data base. When installed in the birds, the stored parameters are retrieved and compared to the total bird performance. Using this technique, it is possible to accurately predict and screen birds for acceptable worldwide performance. Factory calibration parameters are set such that the birds will meet a 0.5° heading accuracy specification wherever marine seismic surveys are conducted. Figure 3 shows the measured peak errors from 1550 bird calibrations, as observed in New Orleans. The average peak error is ± 0.22°, with a standard deviation of 0.04°. The maximum acceptable peak error is 0.35°, which represents 99.92% of the birds. (i.e. 0.08% of the birds are rejected based on this criterion.) This average peak error (0.22°) is an inherent nonmagnetic error due to the 10-bit code card used in the optical heading sensor.

0.17°(½ bin uncertainty in a 0.35° res code card) + 0.05° (process uncertainty) = 0.22°

Process uncertainty is the non-magnetic component of the total calibration process error (0.08°).

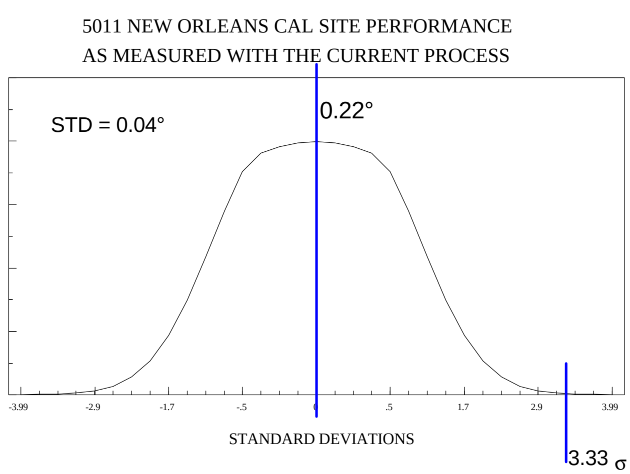

Figure 3. This chart is based on data from more than 1550 DigiCOURSE Model 5011 birds calibrated in 1993. The average peak error is ± 0.22°, with a standard deviation of 0.04°. Based on the data, 0.35° peak error performance at New Orleans represents 3.33 standard deviations or 99.92%.

Since the acceptance peak error criterion at New Orleans is 0.35°, birds with magnetic errors of up to 0.13° will pass the criterion:

0.35° (allowable peak error) - 0.22° (inherent non magnetic error component) = 0.13°

Accounting for possible calibration process error, it is conceivable that birds with peak errors of up to 0.43° may pass the 0.35° peak error acceptance standard. This in turn means that birds with errors, other than the inherent code card resolution error, of up to 0.21° (0.13° + 0.08°) may pass the New Orleans peak acceptance criterion. Not all of the 0.08° total process error is magnetic in nature, it can be assumed that 0.03° is the magnetic component of the total process error.

0.08° (total calibration process error) = 0.05° (non magnetic component) + 0.03° (magnetic component)

Data compiled from 1550 bird calibrations, implying 0.05° process uncertainty validate this assumption. Therefore, it can be inferred that birds with a total magnetic error component of 0.16° (0.13° + 0.03°) may pass the 0.35° peak error criterion in New Orleans. The 0.16° magnetic component of the total error translates into 0.33° at high latitudes with horizontal magnetic field strength down to 12,460 nT, from 25,700 nT at New Orleans. Therefore, these borderline acceptable birds with peak errors of up to 0.35° at New Orleans will meet the peak error specification of 0.5° at higher latitudes where some marine seismic surveys are conducted.

0.17°(½ bin uncertainty in a 0.35° resolution code card) + 0.33° (magnetic error) = 0.5°

Field verification data of Model 5011 birds from around the globe authenticates the above analysis. Data from 8617 field verifications is illustrated in Figure 4. The field verifications were performed in Norway, Scotland, Australia, Singapore, Congo, and the Gulf Coast of Mexico. The observed heading error also includes the field verification process error. The results displayed are the errors observed at the first, of a minimum of two, reference headings. Only 0.4% of the birds were found to be outside the accuracy specification limits.

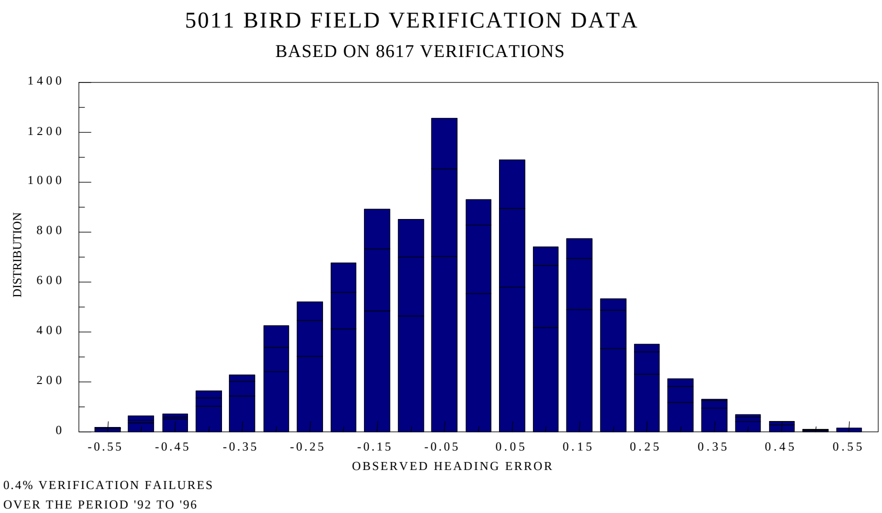

Figure 4. Data from more than 8000 field verifications from around the globe. The standard deviation of 0.198 is approximately ½ bin width of a 10-bit compass code card.

The results illustrate the inherent stability of the Model 5011 bird. By comparison, some models of compass birds employed in the marine seismic surveys exhibit field verification failure rates in excess of 10% during post survey verifications. In such cases the validity of the data acquired is questionable. For example,

- When did the compass birds go out of specification?
- What percentage of the birds that passed were stable enough to remain so during the survey?
- Does a field recalibration ensure future stability of the product that just failed accuracy verification?

The answers to the above questions may be disconcerting.

The study shows the Model 5011 bird to be stable and reliable, not only throughout the survey period, but for at least two years, or over the period of time this study was conducted. The study shows that the calibration correction coefficients remain stable for at least this period, and it is not necessary to recalibrate the Model 5011 birds during a two-year period. Data from frequent recalibrations performed over two years on 73 birds is illustrated in Figure 5. The 73 birds constitute an entire inventory of birds that have been in use for at least two years, on two vessels that frequently returned birds to DigiCOURSE for recalibrations. The data represents approximately 200 calibrations. Some birds were calibrated three times or more. All birds were calibrated at least twice in this two-year period.

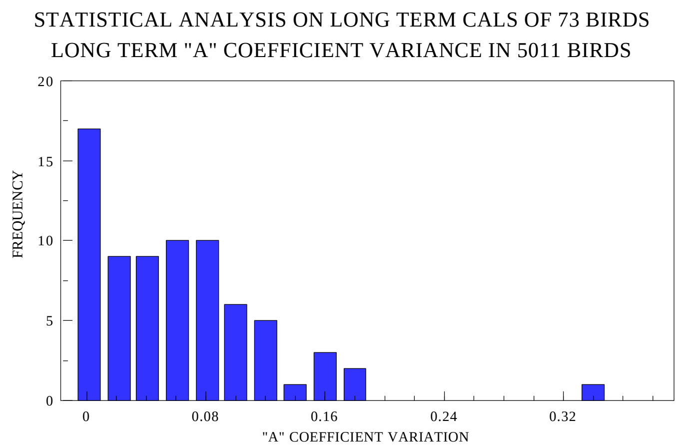

Figure 5. Long term data of 73 birds in use taken from two vessels. Data was tracked over two years. Some birds were calibrated three times or more. All birds were calibrated at least twice in the two-year period.

The DigiCOURSE calibration process error has improved significantly during this two-year period, from 0.15° to 0.08°. The x-axis in Figure 5 represents the magnitude of observed variations in the "A" coefficient. The data demonstrates that the calibration variations were well within the ability of the process to measure such variations, thereby implying that there was no change in calibration coefficients over the two-year period. The one data point around 0.36° represents a change attributed to compass repair. Although 73 birds may appear to be a small sample or representation of the entire suite of Model 5011 birds in use in marine seismic surveys, statistical analysis of the data establishes that the sample is an adequate representation of the entire suite of Model 5011 birds. For the analysis, seven sets of 33 birds were selected at random from the larger sample of 73 birds. Inferential statistical analysis of the smaller random sets is shown in Figure 6. Since the performance characterized in the smaller sets is similar to the larger set, the larger sample must be a good representation of the entire suite of Model 5011 birds.

STATISTICAL ANALYSIS ON LONG TERM CALS OF 73 BIRDS

STATISTICS BASED ON RANDOM SELECTION OF 33 DATA INPUTS FROM THE SUITE OF 73 BIRDS

	ENTIRE SUITE	SAMPLE1	SAMPLE2	SAMPLE3	SAMPLE4	SAMPLE5	SAMPLE6	SAMPLE7
		0.04	0.11	0.03	0.18	0.03	0.03	0.18
		0.04	0.05	0.18	0.05	0.18	0.1	0.09
		0.11	0.13	0.1	0.05	0.1	0.06	0.11
		0.07	0.05	0.09	0.02	0.09	0.01	0.07
		0.07	0.01	0.06	0.2	0.06	0.07	0.18
		0.05	0.07	0.11	0.14	0.11	0.02	0.18
		0.07	0.2	0.01	0.1	0.01	0.05	0.05
		0.01	0.07	0.07	0.13	0.07	0.02	0.2
		0.02	0.11	0.07	0.07	0.07	0.14	0.1
		0	0.09	0.18	0.04	0.18	0.13	0.07
		0.06	0.11	0.02	0.04	0.02	0.04	0.04
		0.15	0.03	0.18	0.11	0.18	0.11	0.07
		0.02	0.06	0.05	0.07	0.05	0.07	0.05
		0.02	0.04	0.05	0.07	0.05	0.07	0.01
		0.02	0.06	0.02	0.05	0.14	0.02	0
		0.1	0.12	0.2	0.07	0.1	0.06	0.15
		0.02	0.04	0.14	0.01	0.14	0.02	0.02
		0	0.07	0.1	0.02	0.01	0.02	0.1
		0.11	0.14	0.13	0	0.09	0.02	0
		0.05	0.1	0.07	0.06	0.36	0.11	0.05
		0.13	0.14	0.04	0.15	0.02	0.13	0.05
		0.05	0.01	0.04	0.02	0.01	0.01	0.07
		0.01	0.09	0.11	0.02	0.1	0.2	0.07
		0.07	0.36	0.07	0.02	0.03	0.11	0.09
		0.2	0.02	0.07	0.1	0.03	0.11	0.03
		0.07	0.01	0.05	0.02	0.07	0.06	0.04
		0.11	0.1	0.07	0	0.09	0.06	0.12
		0.09	0.03	0.01	0.11	0	0.04	0.07
		0.11	0.03	0.02	0.05	0.01	0.14	0.1
		0.03	0.07	0	0.13	0.1	0.14	0.01
		0.06	0.09	0.06	0.05	0.03	0.09	0.36
		0.04	0	0.15	0.01	0.11	0.02	0.01
		0.06	0.01	0.02	0.07	0.07	0.1	0.03
Avg.	0.075068	0.062424	0.079394	0.077879	0.067576	0.082121	0.072121	0.083939
Std.	0.060639	0.045396	0.067686	0.054593	0.0517	0.0707	0.048038	0.072736
Var.	0.003677	0.002061	0.004581	0.00298	0.002673	0.004999	0.002308	0.005291

Figure 6. Statistical analysis of seven smaller samples, showing that the smaller samples were not significantly different from the entire suite.

Anecdotal evidence from performance verifications of birds returned to DigiCOURSE for repairs is a further demonstration of Model 5011 bird calibration stability. Figure 7 shows the results from 30 birds picked from repair returns during the time of the study. Included is data from birds returned for specific compass problems. In one case, though the compass bird exhibited some performance degradation and verification errors, the "A" error co-efficient remained stable, with the residual "A" error of only 0.01°. The peak errors for all the birds were well within the DigiCOURSE acceptance limits of ± 0.35°. Most birds were calibrated before the 1991 implementation of process error enhancement in the calibration process from 0.15° to 0.08°.

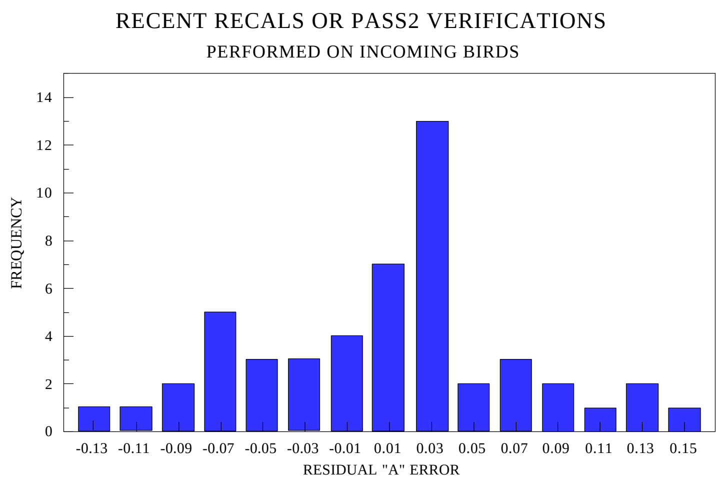

Figure 7. Recent performance verification test of birds returned to DigiCOURSE for various reasons. The data is based on about 30 birds picked from repair returns.

This study would be incomplete without discussing the effects of repairs on the compass calibration. Any long-term calibration stability depends on the ability to successfully conduct most maintenance repairs without affecting calibration stability. The modular design of the bird enables easy repair or replacement of most individual modules without affecting the compass calibration. Extensive tests were conducted to characterize the magnetic effects of such repairs or replacements. Removing, replacing, or interchanging wing, battery, motor modules and replacing electronic cards were part of this extensive testing. No measurable effects on the calibration stability were detected. Figure 8 displays the results of one such test, in which the compass module removal and replacement effects on the calibration stability were noted. The data is based on 50 compass and 50 bird calibrations. Five compass modules were repeatedly removed and calibrated individually before being reassembled and recalibrated in the bird. The maximum change observed in the 100 iterations was 0.07°, which is less than the process error of 0.08°.

COMPASS REMOVAL AND REPLACEMENT TESTS ON 5011 BIRD

TEST RESULTS BASED ON 10 ITERATIONS WITH EACH COMPASS

	"A" COEFFICIENT		DELTA "A"	
	± RANGE	STD	± RANGE	STD
COMP 1	0.04	0.024	0.04	0.025
COMP 2	0.07	0.043	0.06	0.037
COMP 3	0.06	0.029	0.05	0.03
COMP 4	0.05	0.024	0.05	0.03
COMP 5	0.04	0.024	0.06	0.03

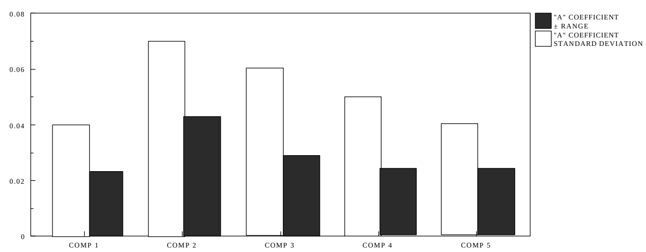

Figure 8. Data exhibits no measurable changes based on 100 calibration iterations. "Delta A" is the difference between the "A" coefficient of the bird calibration and the corresponding "A" coefficient of the compass module.

The results, again, were within the ability of the process to measure such a change, thus implying no change in calibration coefficients. In the following cases, however, compass calibration is affected and recalibration is typically required:

- Latch mechanism or latch housing damaged
- Deformed bird housing

- Compass fault or failure.

Summary. The study establishes that the Model 5011 bird is, by design, inherently stable and insensitive to latitude changes. These design characteristics result in highly repeatable performance. The robust modular design allows for quick field repairs of most components without affecting compass calibration. Since no calibration change was observed throughout the study period of two years, DigiCOURSE offers a two-year calibration warranty. Negligible field verification failures demonstrate excellent correlation between the field verifications and the factory calibration process. These features of the Model 5011 bird reduce the cost of ownership and provide worldwide, consistently dependable performance. A repeatable calibration process allows for continued accurate monitoring of the long-term compass performance.