Performance Programs
What Do We Know About Cattle Today

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The concept of beef cattle genetic improvement programs began with research in the 1930's. Central to the concept has been the transfer of genetic change in the purebred industry to the commercial industry. Research continued through the 1940's and the first central bull test stations were established in the early 1950's. Central test stations provided commercial producers as well as purebred producers a method of comparison for bulls tested under the same environmental conditions. One problem with central test stations was, and is today, that only a number of bulls can be tested each year. State Beef Cattle Improvement Associations were organized in the mid 1950's within herd information which provided an educational system and computerized record systems. In the 1960's ranch performance testing programs were nurtured and began to flourish providing sound objective within herd information which breeders could use in making selection decisions. In 1968 the Beef Improvement Federation (BIF) was formed and this organization began to provide the framework for standardized and systematic procedures for collecting beef cattle performance data. BIF Guidelines became the performance "bible" for the beef industry.

In 1971-72 the first National Sire Summary was published by a national beef cattle breed association. At this time the idea of extending beef performance records into a national progeny testing program was indeed revolutionary. Only a few far ranging thinkers really understood what the publication of this document would mean to the future of the beef industry. Until 1972 truly accurate comparisons of bulls could only be made within a herd-year-season contemporary group. The first and subsequent National Sire Summaries compared bulls across herds and/or generations. Beef cattle breeding had entered the twentieth century! Today almost all major breeds of beef cattle publish a National Sire Evaluation (NSE) which was just the beginning of a rapid technological development leading to complete breed genetic evaluation programs.

Most researchers working in the area of national genetic evaluation had contended National Sire Evaluation was a means to an end rather than the ultimate in a genetic improvement program. Three major problems existed with NSE from the industry's point of view. First, bulls had to produce progeny before entering the program which resulted in published evaluations of old bulls. Older bulls were usually available only through AI which made them impractical for use in much of the commercial industry. Furthermore, the purebred industry tends to seek young bulls rather than old bulls in an attempt to reduce the generation interval and make faster genetic change. Thus, while the evaluations in National Sire Summaries were and still are very accurate, both the purebred and commercial industry struggled in the late 70's and early 80's with how to effectively use the published results. A second problem with NSE was breeders, particularly purebred breeders, contended some bulls in NSE were being mated to superior cows causing a serious bias in the evaluation of those bulls. Fortunately, research has shown this second problem was more perception than reality. The third problem was NSE programs did not use the individual's own performance record in the analysis. The third problem was not serious for bulls with a substantial number of progeny; however, for a young bull with only a few progeny it meant neglecting a very important piece of performance information. Another deficiency of NSE was that it provided genetic values on males only, thus the females which provide half the genes in the population were ignored.

In 1984-85 a major breakthrough was accomplished with application of something called the "Reduced Animal Model" termed RAM for short. Application of this mathematical model to beef cattle performance records provided genetic evaluations free of all problems associated with National Sire Evaluation. Application of this model merged on farm and ranch testing programs with NSE to form what is now called National Cattle Evaluation (NCE). Today, NCE is a reality for most of the major beef breeds in the United States.

National Cattle Evaluation programs have several distinct advantages over NSE programs:

1) NCE provides a genetic value for an individual which incorporates any combination of progeny, pedigree (sire and dam) and individual record information. Thus, the individual's own record, if available, is incorporated into the analysis.
2) The procedure adjusts for the superiority or inferiority of the mates of the individual. This reduces, if not totally eliminates, bias introduced by specific matings for both sires and dams.
3) The program provides maternal genetic values for those traits which are maternally influenced such as weaning weight.
4) The procedure accounts for genetic change over time in a breed providing more precise comparisons of individuals from different generations.
5) National Cattle Evaluation computes genetic values for all animals in the breed, i.e. for sires and dams plus young animals (males and females) which have not yet produced progeny.

It is of <u>major importance</u> that producers realize that the genetic values for young animals not yet producing progeny and for dams are <u>comparable across herds and/or generations</u> just like sire values from NSE programs.

Commercial producers may be asking, "What is an EPD?" or "How can I use an EPD in making selection decisions?". For a complete explanation producers should consult the National Sire Summary for the breed they wish to use in their operation. The following brief example will provide some insight into the usefulness of the EPD. Expected Progeny Differences are plus or minus values of original measurement (eg. weaning weight in pounds). The EPDs are used to make comparisons among bulls from which the breeder wishes to make a selection. The comparisons are made one pair of bulls at a time. For example, two bulls, A and B, where bull A has a weaning weight EPD of +20 pounds and bull B has a weaning weight EPD of +5 pounds. The EPDs for these two bulls tell the producer that if he were to select both bulls for this breeding program and mate them to a large number of comparable cows he could expect a 15 pound difference between the average weaning weights of the calves from the two bulls. Thus, if weaning weight is important in the producer's program, selection of bull A is obvious. The EPDs provide the producer a means of predicting differences between any two bulls without having to breed the bulls in his program. The difference between EPD's for bull A and B (20 - 5 = 15 pounds) is the difference a producer would expect in his own herd. In breeds which have NCE programs, there are thousands of bulls evaluated and it is possible, although, perhaps not practical to make this pairwise comparison for all of them. Expected progeny difference provide a prediction of future performance of progeny from an individual is based on information currently available.

Traits available for comparison vary from breed to breed. Traits evaluated are birth weight, weaning weight, milking ability expressed as pounds of weaned calf, yearling weight, hip height, scrotal circumference and calving ease. Other traits such as carcass traits will be added in the near future.

Best linear unbiased prediction procedures (BLUP) used in National Cattle Evaluation programs are complex to say the least. Let us now examine how factors such as the contemporary group influence the computation of an individual's expected progeny difference (EPD).

First, an example of a contemporary group effect. Remember the definition of a contemporary group is a set of animals of the same sex and similar age which have had equal opportunity to perform (same management, pasture, year, etc.). As an example, suppose we have two contemporary groups (these could be herds also) which have the same two sires, say A and B, represented. Each sire produces ten bull calves in each contemporary group. The performance of each sire's progeny in each group is summarized in the following table:

	Contemporary groups (herds)		
Sires	1	2	Average
A	$500^{(10)}$	$550^{(10)}$	525
B	$400^{(10)}$	$450^{(10)}$	425
Average	450	500	

The averages by sire across contemporary groups gives one the difference in progeny performance for the two bulls A (525) and B (425) with bull A's progeny having a 100 pound advantage (sire differences). The averages by group across sires quantitates the difference between contemporary groups. As you can see there is a 50 pound advantage for group 2. This is the contemporary group effect. If one assumes the females are similar for both groups then the 50 pound advantage for group 2 must come from some environ-mental source. Whatever the cause of differences between contemporary groups is of little concern; however, these differences may bias the evaluation of animals in those contemporary groups. Therefore, analysis procedures used in NCE adjust for these contemporary group differences which result in genetic evaluations (EPDs) computed as though all the cattle were raised in one giant contemporary group. If the contemporary groups were for some reason improperly identified, say for example, 5 of bull B's progeny in group 2 were in a different pasture, the estimate of the contemporary group effect could be wrong and perhaps bias the sire evaluations.

In order to understand the computation of an individual's weaning EPDs for growth let us examine several of the factors involved. First, remember all that is available to us for the identification of superior genetics are the records on individual animals. All of the analytical procedures are designed to separate the environmental and genetic factors affecting an individual's record thus providing a prediction of the individual's genetic worth. Thus, as one thinks about factors affecting the EPD of an individual we are actually considering the genetic and environmental effects on the record of the individual.

The first factor to consider is the genetic makeup of the individual which is referred to as its breeding value (EPD = 1/2 Breeding Value). Obviously, this is the factor one is most concerned about because it is directly related to the EPD of the individual. Another factor which comes to mind immediately with respect to a weaning record is the milking ability of the individual's dam. The milking ability of the individual's dam can be represented by her milk breeding value (2 times her milk EPD). Milking ability EPDs or breeding values are expressed as pounds of weaned calf. The milk breeding value of the dam represents her genetic potential for milking ability. A cow may have tremendous genetic potential for milking ability but may never exhibit that ability due to environmental effects (eg. suppose a high milking cow contracts mastitis). Thus, a third factor affecting an individual's weaning record might be any permanent environmental effect decreasing or increasing the milking ability of the individual's dam. The final factor which was discussed above is the contemporary group effect. These four factors explain much of the variability in weaning weight records; however, not all of the variation is explained by these factors thus there is a fifth factor which we will simply refer to as unknown or error.

Now that the factors affecting the weaning record of an individual have been identified it is possible to develop a mathematical model representing the record in terms of these factors:

Weaning Weight Record = Contemporary Group Effect
+ Breeding Value of the Individual
+ Milk Breeding Value of the Individual's Dam
+ Permanent Environmental Factors Affecting the Milking Ability of the Individual's Dam
+ Unexplained Factors or Random Error

This equation can be expanded to the following:

Weaning Weight Record = Contemporary Group Effect
+ EPD of the Individual's Sire } Breeding
+ EPD of the Individual's Dam } Value of
+ Mendelian Sampling Effect } the Individual
+ Milk Breeding Value
+ Permanent Environmental Effect
+ Unexplained Factors or Random Error

Notice in this second equation that the individual's breeding value is represented by the sum of its parental EPDs and a Mendelian sampling effect. The mendelian sampling effect accounts for the fact that an individual receives 1/2 of his genetic makeup from each parent in a random fashion. The Mendelian sampling effect is the reason that even full-sibs (offspring of the same parents) show considerable differences.

An equation similar to the above is developed for every individual in the breed which has a legitimate weaning record. These equations are solved by iterative techniques providing values for each entry in the equation to the right of the equals sign including the breeding value of the individual. The EPD is given by dividing the breeding value of the individual by two.

Keeping in mind that an individual's EPD is equal to 1/2 his breeding value, the following gives an individual's weaning growth breeding value:

Breeding Value =	Weighting Factor	x	Record of the individual - contemporary group effect - milk breeding value of dam - permanent environmental effect of the dam.
+	Weighting Factor	x	Sum of breeding values for relatives of the individual (note: this includes sire and dam and/or any progeny of the individual).
-	Weighting Factor	x 1/2	Sum of breeding values for mates of the individual (note: this applies when progeny are available).
+	Weighting Factor	-	adjustment for the relationship between growth and milk (note: in some breeds assumed to be zero).

Subtracting the contemporary group effect, milk breeding value of the dam and the permanent environmental effect of the dam adjusts the record for those environmental factors. After these factors are subtracted the portion remaining more adequately reflects the genetic makeup of the individual for growth. Weighting factors provide for the proper relationship between each piece of information contributing to the individual's breeding value. Note that any combination of the possible information may be used to compute the breeding value. Notice also the procedure goes backwards in the pedigree to the sire and dam of the individual or forward in the pedigree to any progeny available. Mates of the individual are adjusted for by subtracting 1/2 of the mate's breeding value when progeny records are available. Finally if there is a relationship between milk and growth it can be accounted for in the procedure.

A numerical example will show the importance of each factor in computations of an individual's EPD. The following example is for two young calves not yet producing progeny which are full-sibs (same sire and dam) and it is data taken from one of the breeds presently being analyzed at the University of Georgia:

	Weaning weight (lb)	Ratio	Contemporary group effect (lb)	Breeding Sire (lb)	Values Dam (lb)	Dam's Milk breeding value (lb)	Dam's P.E. (lb)
calf A	645	120.9	469.96	70.0	14.2	15.6	15.5
calf B	570	102.9	486.96	70.0	14.2	15.6	15.5

Breeding
Value = {.143 (645 - 469.96 - 15.6 - 15.5) <-----Record contribution
calf A
+ .429 (70 + 14.2) <-----Pedigree contribution

= (20.56 + 36.09) = 56.65

$$EPD_A = \frac{56.65}{2} = 29.32 \text{ lb}$$

Breeding
Value = {.143 (570 - 486.30 - 15.6 - 15.5) <-----Record contribution
calf B
+ .429 (70 + 14.2)} <-----Pedigree contribution

= (7.44 + 36.09) = 43.53

$$EPD_B = \frac{43.53}{2} = 21.76 \text{ lb}$$

As you can see only individual records and parental values enter into the computations since these two animals have not yet produced progeny. In the case of these full-sibs the only differences in the computations are the records and the contemporary group effects. Calf A has a larger weight (645) than calf B (570) but in addition the contemporary group effect (which might be thought of as an adjusted contemporary group average) for calf A (469.96) is smaller than the one for B (486.80). Calves in B's contemporary group had a 16.84 pound environmental advantage which is given by the difference between the contemporary group effects (486.80 - 469.96). Thus calf B had a somewhat better environment in which to make his record. The effect of this better environment is adjusted out when the contemporary group effect is subtracted from the calf's record. Calf B did not grow as well as calf A, plus B had a better environment than A, therefore the record contribution to the breeding values for the two calves was 20.56 versus 7.44 pounds for A and B, respectively. Notice the pedigree contribution for both calves is larger than either record contribution which may not always be the case. Obviously, the pedigree contribution to an individual's EPD depends on how large the EPDs (breeding values) are for its parents. Breeders should also note that the 18% difference between performance ratios translates to only a 6.56 pound difference in EPDs for these two calves. Ratios and weights may be misleading with respect to actual transmitting ability. In the case of these two animals selection on weight or ratio would have retained the genetically superior individuals selection based on EPDs will more often retain the genetically superior individual than either weights or ratio.

The following table contains information for sire A (breeding value = 88.4; EPD = 44.2 lb) and sire B (breeding value = 132.2; EPD = 66.1 lb).

Individual bull ID	Average weaning ratios of progeny: Number	Average weaning ratios of progeny: Average	Number Weaning Contemporary Group	Individual Weaning Performance Pounds (Ratio)	Sire Breeding Value (lb)	Dam Breeding Value (lb)
A	408 males 369 females	105.0 103.9	178(9703)*	703(124.5)	65.4	20.0
B	424 males	105.8	71(3547)*	729(136.5)	150.4	45.8

*Number of contemporaries raised with progeny of A and B.

Notice the average progeny ratios do not reflect the difference in EPDs for sires A and B. The following will show why these averages are not indicative of the EPDs for the two sires. First, examine the following table which gives the contribution (in pounds) of each available piece of information to the sires' breeding value and subsequent EPD:

Sire ID	Sire's own record	Sire's parents	Progeny	Adjustment for mates	Breeding value (lb)*	EPD (lb)
A	.1103	.2219	94.4230	- 6.3611	88.3941	44.2
B	.1813	.5179	171.0545	-39.5536	132.2000	66.1

*Sum of the previous four columns, EPD = 1/2 Breeding Value.

The EPD for A is given by (.1103 + .2219 + 94.4230 - 6.3611) - 2 - 44.2. The EPD for B is given by (.1813 + .5179 + 171.0545 - 39.5536) - 2 + 66.1. It is readily seen that the major contribution to each sire's EPD comes from their progeny (94.4230 and 171.0545). A sire's own record and his ancestor's account for a very small part of his EPD when large numbers of progeny are available and particularly when the progeny are far above or far below average.

Note there is a larger adjustment for mates of sire B than sire A (-39.5536 vs -6.3611, respectively). The reason for this is that sire B was mated to cows superior to those of sire A. The average breeding value for sire B's mates was 39.8 lb whereas sire A's mates averaged 6.4 lb. Even after adjustment for superior mates B still had the best EPD.

Observation of the table including the adjustment for mates does not yet answer our question as to exactly why B's EPD is so much larger than A's. The answer is found in the genetic competition within the contemporary groups in which the progeny of these two sires were raised. Average breeding values for the sires and dams of other progeny in the contemporary groups in which sire A's progeny were raised are 40.6 and 13.4 lb, respectively. The averages for sires and dams of progeny raised contemporarily with sire B's progeny are 61.4 and 34.4 lb, respectively. This simply says that the genetic merit (measured as breeding value) of the contemporary groups in which sire B's progeny were raised was greater than those in which sire A's progeny were raised. This coupled with the fact that sire B's progeny averaged 46.1 lb more than their contemporaries while sire A's progeny averaged only 2.2 lb more than their contemporaries results in the large difference seen in progeny contribution to their EPDs. This genetic competition within contemporary groups is not reflected in performance ratios thus reducing their value as an aid to selection, particularly in comparisons across herds. Clearly, NCE accounts for this and other factors making the EPDs more precise for across herd comparisons.

The following, outlines the complexity of weaning weight by showing the various factors influencing the trait:

I. Genes received from the individual's sire
II. Genes received from the individual's dam
III. Milking ability of the individual's dam
    A. Dam's genetic makeup for milking ability
        1. Genes received form her sire (maternal grandsire of the individual)
        2. Genes received from her dam (maternal granddam of the individual)
    B. Permanent environmental factors affecting the dam's milking ability (example: loss of a quarter to mastitis)
    C. Age of dam
IV. Other environmental factors
    A. Contemporary group environment (example: creep fed vs noncreep fed
    B. Age of calf
    C. Other factors which are usually unknown (season, disease, temperature, humidity, rainfall, etc.)

Factors such as age of dam and age of calf have been researched and quantified, thus, they are routinely adjusted out of weaning weight records in most performance testing programs. Environmental factors, other than permanent environment affecting the dam's milking ability, are usually dealt with through contemporary grouping. That is individuals are compared within a contemporary group which contains animals for the same sex, similar age and born in the same season, each given equal opportunity to perform. The importance of proper contemporary group identification cannot be over-emphasized particularly as it relates to using weaning weight as an indicator of the dam's ability to produce milk and subsequently the genetics she possesses for milking ability.

National Cattle Evaluation programs use mixed model BLUP procedures and the reduced animal model to compute EPDs for both weaning growth and milking ability, each measured as pounds of weaned calf. Actually the procedure provides real values (ie. pounds) for most of the factors in the above outline. The values for those factors in the above outline referring to genes are called breeding values. Breeding values are computed in units of original measurement such as pounds. For example, a breeding value for milking ability is computed as pounds of weaned calf resulting from milk produced by the dam of the calf. Remember EPDs are equal to breeding values divided by two.

It is important to realize that milking ability EPDs indicate the individual's ability to transmit genes for milk production and may not reflect exactly the current producing ability of a cow. This is because environment has a marked effect on a cow's milk production (eg. climatic conditions, disease, etc.). That is a cow may be genetically superior of milk production but environment (eg. disease) may never let her express that ability in the record of her calf.

A cow's EPD for milking ability expressed as pounds of weaned calf is given by computing her breeding value for milking ability according to the following equation and then dividing by two:

$$\text{Milking ability Breeding Value} = \text{Weighting factor} \times \left| \text{Cow Calves' weaning records} - \text{Contemporary group effect} - \text{Calves growth breeding value} - \text{Permanent environmental effect of the cow} \right|$$

<summed over all the cow's calves>

$$+ \text{Weighting} \times \left| \text{Sum of the milk breeding values for relatives} \right| \text{factor of the individual}$$

$$- \text{Weighting} \times 1/2 \left| \text{Sum of the milk breeding values for mates of} \right| \text{factor the individual}$$

$$+ \left| \text{Adjustment for the relationship between growth and milking ability} \right|$$

For a cow, the first part of the above equation adjusts the records of her calves to reflect her milk production. First, the contemporary group effect is adjusted out of the record removing any environmental factors which may have influenced the record positively or negatively compared to all other calves' records in a particular contemporary group. Second, the calves' growth breeding values are subtracted from the records. This second subtraction removes the effect of the calves' innate genetic ability to grow leaving the portion of the record reflecting the cow's milking ability. This is the portion of the record the cow would influence through her milking ability regardless of the genetics possessed by her calves. Finally, to get the records to more adequately reflect the cow's genetics for milking ability, the permanent environmental effect is subtracted from the record. The weighting factor adjusts for the heritability of the trait and the relationship between this piece of information (records of her calves) and other possible sources of information (relatives of the cow).

The second part of the equation brings the pedigree of the individual (a cow in this case) into the computations. The procedure moves backwards and forward through he pedigree. It picks up information (breeding values) on the ancestors of the individual, particularly the sire and dam. However, if progeny are available it will gather the information (breeding values) on each progeny. The third part adjusts for mates of the individual removing any bias caused by non-random mating. The final entry in the equation adjusts for any genetic relationship between growth and milking ability.

An example from a recent breed analysis conducted at the University of Georgia will show the contribution of each piece of information to the computation of a milk EPD for a cow with one calf.

Available Information							
Record of the calf (lb)	Contemp-orary group effect (lb)	Calf's breed-ing value (lb)	Cow's permanent environ-mental effect (lb)	Sire of cow milk breeding value (lb)	Dam of cow milk breeding value (lb)	Progeny of cow breeding value (lb)	Sire of calf milk breeding value
505	486.8	56.2	-7.2	6.2	16.4	7.6	7.8

The contribution of the cow's own record for milk (weaning weight record of her calf) is given by .074 (505 - 486.8 - 56.2 + 7.2) = -2.3 lb. Remember, here the weaning weight of the cow's calf is taken as a measurement of the cow's ability to milk. The contribution of the cow's sire and dam is .37(6.2 + 16.4) = 8.4 lb. The progeny contribution is .37(7.6) = 2.8 lb and the adjustment for the sire of the calf is (-.37) (.5) (7.8) = -1.4 lb. Summing the contributions provides the cow's breeding value for milking ability (-2.3 + 8.4 + 2.8 - 1.4) = 7.5 lb. The cow's EPD for milking ability expressed as pounds weaned calf is 7.5 - 2 = 3.75 lb. Note here that the largest contribution is from the pedigree (sire and dam) which will not always be the case particularly if the pedigree information is only average.

Sire EPDs for milking ability are computed in a similar manner; however, because milking ability is a sex limited characteristic the first part of the equation is never used for sire computations. Sire EPDs for milk are based primarily on their pedigree and any female progeny which are in production.

An accuracy value is computed for each EPD which provides an indication of the reliability of the EPD. Accuracy values range from zero to one with values closer to one indicating greater accuracy or reliability of prediction. Unfortunately, accuracy values are only approximations and may sometimes underestimate or overestimate the true accuracy of the EPD. Basically, the accuracy values indicate the amount of information available for the EPD computation. For example, one individual may have pedigree information and another may not; this would be reflected in the accuracies of EPDs for those two individuals. For individuals with progeny, both number and distribution will affect the accuracy of the EPD. An individual producing 50 progeny in 10 herds will have a larger accuracy than an individual producing 50 progeny in 2 herds. In the case of sires, accuracy is affected by the number of direct comparisons made in contemporary groups with other sires. Thus, a young sire can attain reasonable accuracy if he is used in several herds against several sires already published in the breed's national sire summary. Non-parent EPD (eg. young bulls not producing progeny yet) accuracies are affected by the accuracy of their parents' EPDs because the pedigree plays an important part in the computation of non-parent EPDs.

The theory of mixed linear models (BLUP) is finding widespread application in the beef cattle industry. The procedures provide a most accurate method for making selection decisions. Today's cattlemen, both purebred and commercial, who learn to use the genetic information available in a creative breeding program will achieve greater profitability over time. This is because genetic stability will allow for sound management decisions including those decisions with respect to marketing and merchandising.