EMBRACING CHALLENGES AND OPPORTUNITIES WITH DATA FROM SENSOR DEVICES

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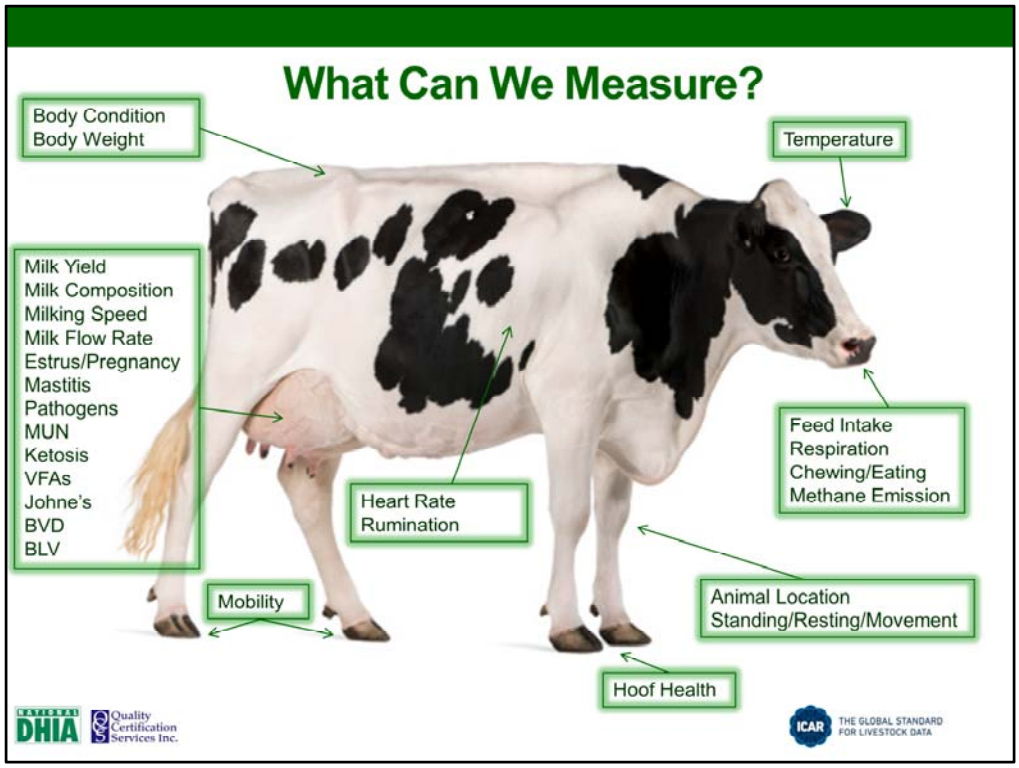
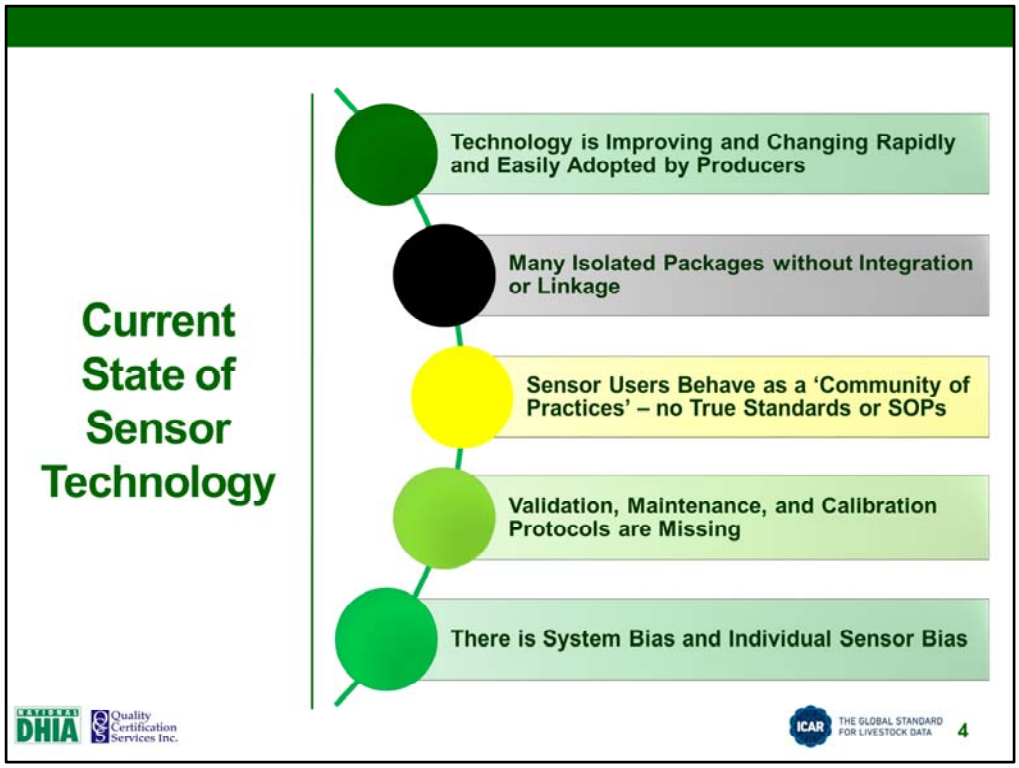
Steven Sievert
Manager, Quality Certification Services Inc.
Technical Director, National DHIA
Chair, ICAR Subcommittee for Recording and Sampling Devices

It is an exciting time to be in the herd recording business as new technology meets biology with respect to measurement and capture of both old and new metrics in livestock production. One of the foundations in herd recording is the use of practical standards and guidelines for different traits to deliver meaningful data for herd management and improvement. As the Technical Director for National DHIA as well as the Chair of the International Committee for Animal Recording (ICAR) Recording & Sampling Devices Subcommittee and the ICAR Sensor Devices Task Force, it is my pleasure to share the work being conducted at both the international level and in the US in embracing the challenges and opportunities with new streams of data from sensor devices with respect to herd recording programs.

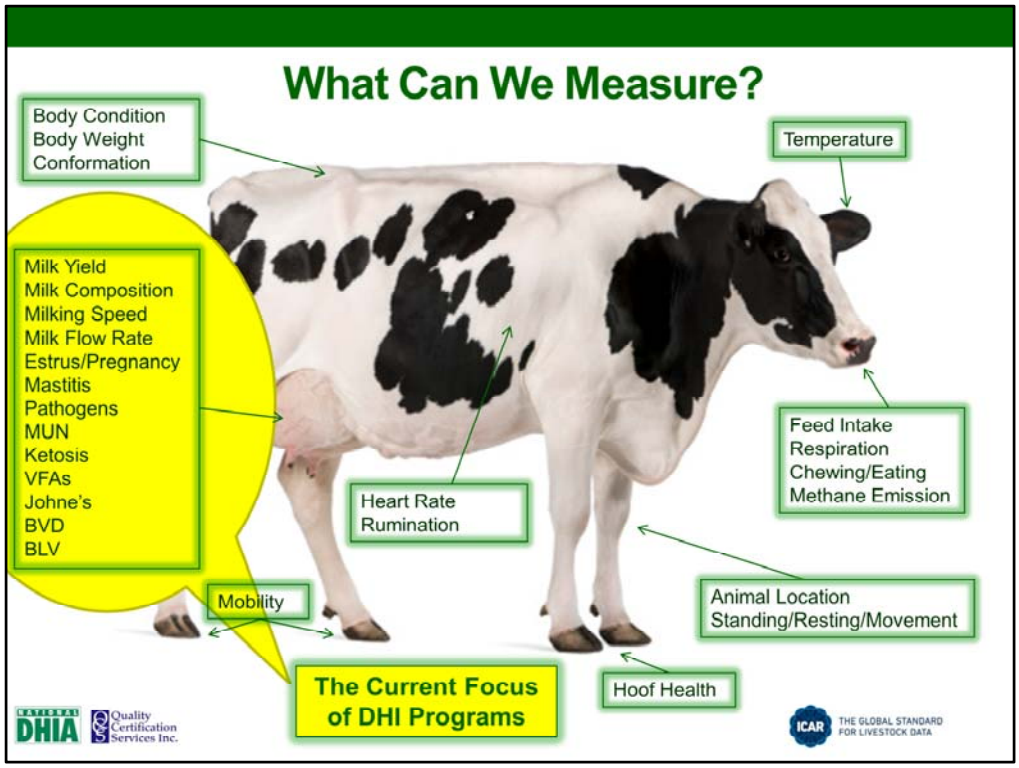
One of the great things working with livestock and dairy in particular is that cattle are ideal candidates for providing all types of data over their lifetime. But the challenge is integrating and understanding everything our cows can tell us. With all the data being provided on the farm related to producer investment in new sensor devices and tools, National DHIA (and other service organizations and agricultural businesses) are faced with two questions. The producer asks us 'can you use my data?' and individual organizations ask 'what are we going to do?'



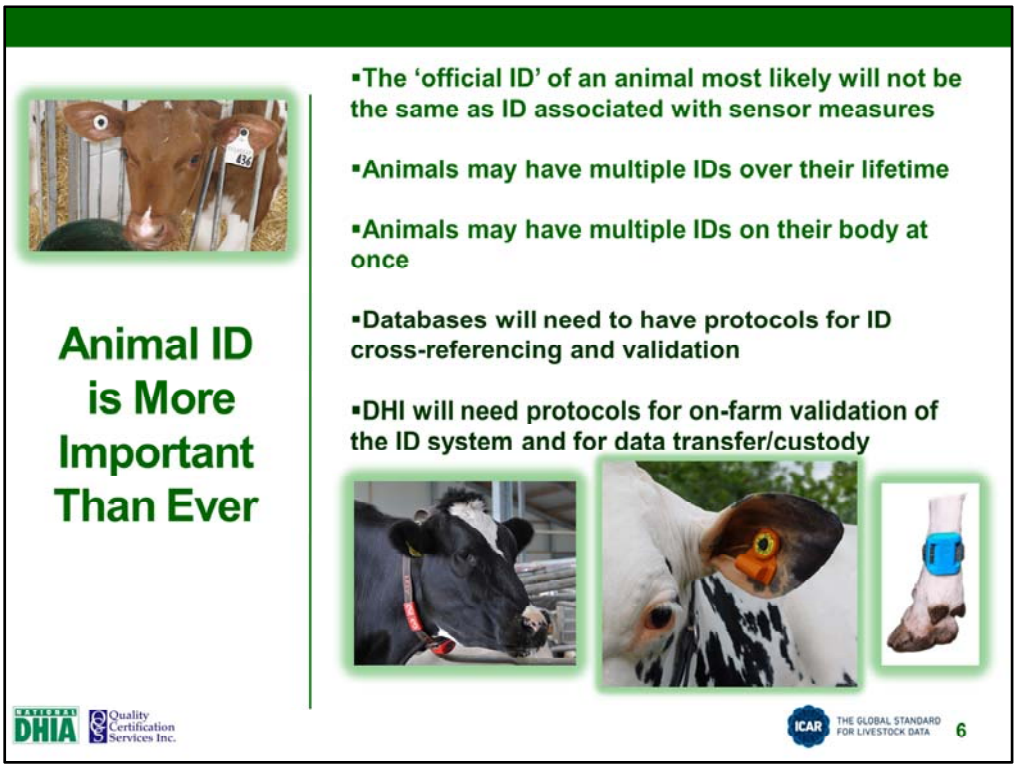
Whether it is a cow as pictured or a sow, ewe or doe, most have seen a picture like this. There is an infinite amount of data our animals can provide related to production, health, performance and in the end, potential profitability. Some of the measures like milk yield and composition are mainstays of the DHI business and other measures open the door to new traits and approaches to livestock management and genetic improvement. This list of measures will change as technology in the sensor space continues to improve and new or novel approaches.



A quick look at the current state of sensor technology shows much promise but also real limitations to be addressed at the farm level and the DHI/herd recording level. While technology is constantly improving (2nd and 3rd generation devices are already in the marketplace), there are no national or international standards, standard operating procedures, or guidelines for measurement of many traits. As a result, many sensors users end up behaving as a 'community of practices' where users of each manufacturer's devices do 'their own things.' With isolated behavior and systems, it is hard to integrate or link devices and data from different systems and harder to use data in the traditional databases.



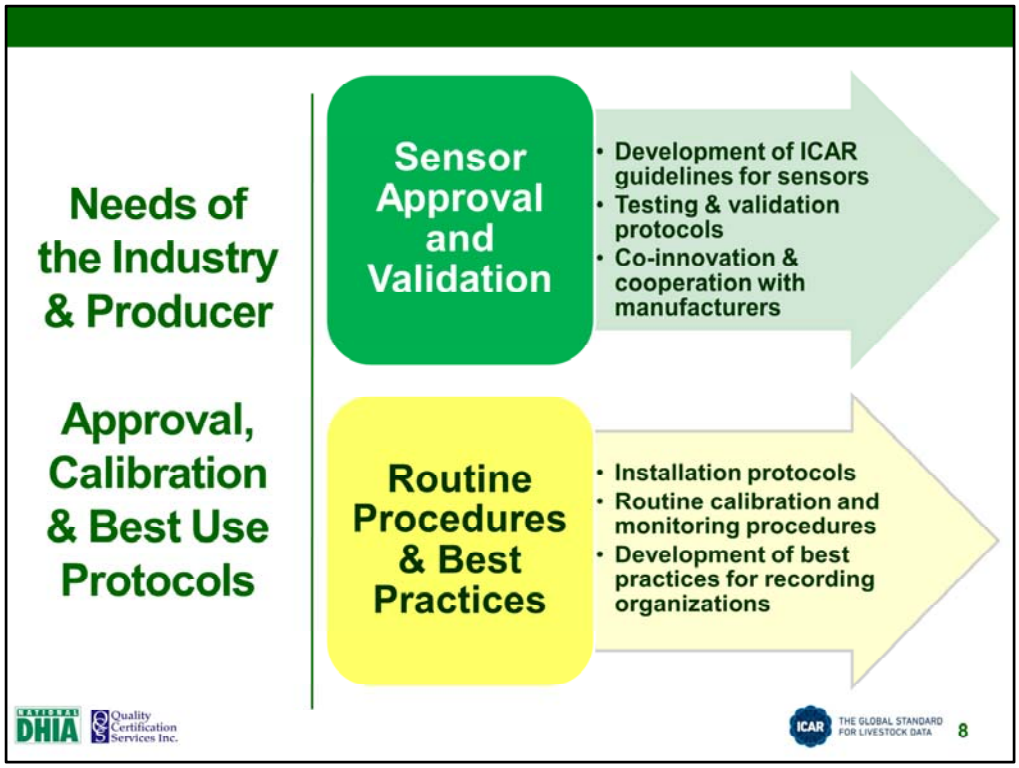
The current focus of DHI programs is finding more value in the DHI milk sample – everything from traditional milk components like fat, protein, MUN and SCC to new screening or diagnostic tests for animal health and reproductive status. But that is a small portion of the data our cows can provide. While the traditional milk sampling devices provide and accurate and representative sample for laboratory analysis, many sensor devices analyzing milk rely on a snapshot or portion of the milk letdown to estimate some parameters. While some devices succeed for some parameters, challenges exist for other milk components. Cows are individuals with variations in milk flow rate, milk yield, milk components, and milking time. Bringing these variables together into one measure is a challenge that must be discussed.



Before we get ahead of ourselves, it cannot be stated enough that animal ID will be more important than ever in automated data recording/sensor systems. It is important to remember that the ID in the sensor may not be the same as the animal's 'official ID' in DHI or the herdbook. In fact, animals may have more than one ID (sensor, tag, pedometers, transponder, etc.) on their body at one time.

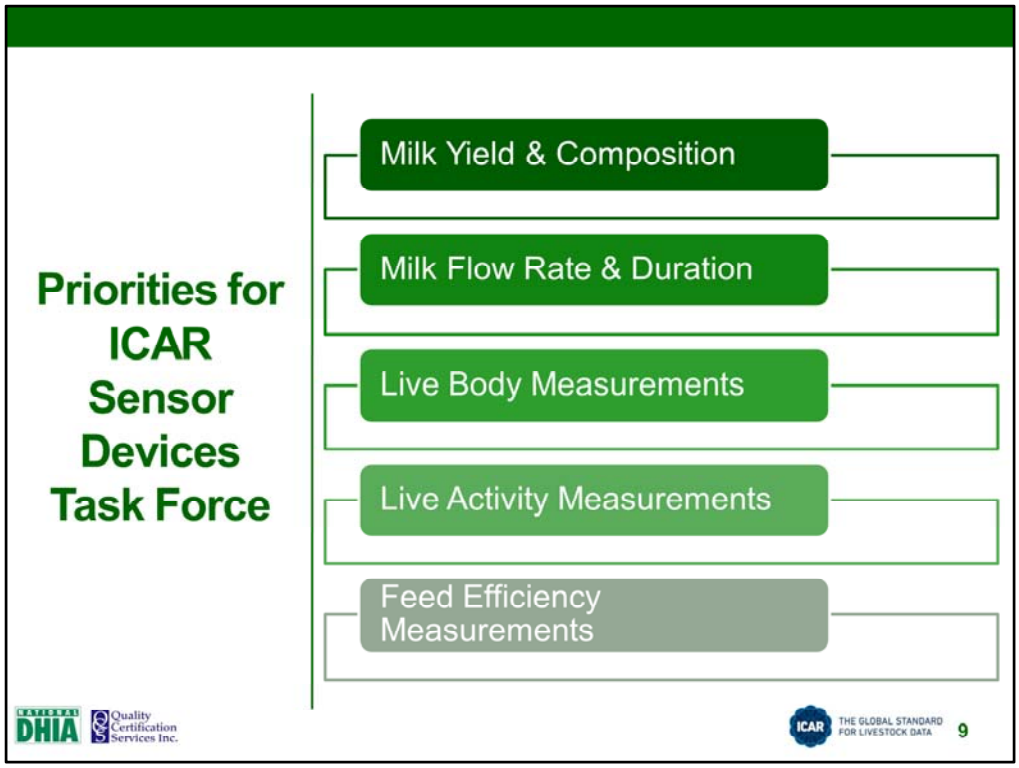
Managing and linking these IDs in on-farm software and in national databases or herdbooks will be a priority. For without a valid ID, the data recorded is just random numbers in a computer file.

To address the challenges and opportunities with data from sensor devices, ICAR has established a Sensor Devices Task Force. With leadership and expertise in many areas such as milk analysis, herd recording, database management and statistical modeling, this team is working to establish guidelines, standards and best practices for sensor devices.



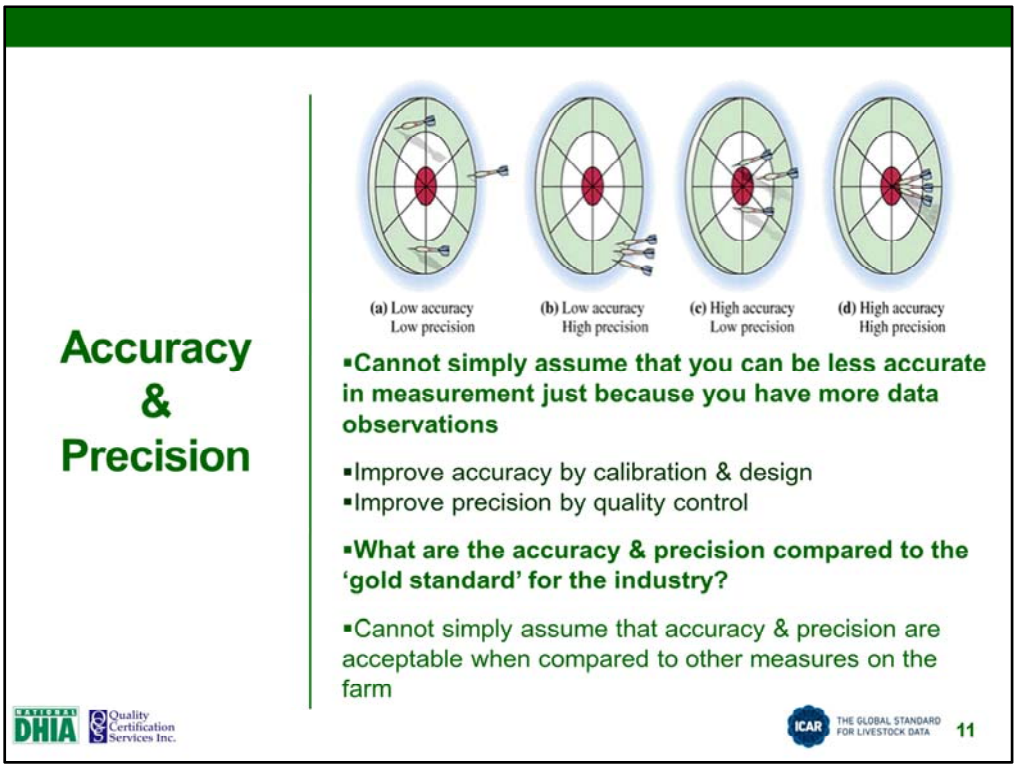
When looking at both the producer and the industry, the needs with sensor devices fall into two areas – sensor device approval/validation and best or routine practices for working with sensor devices/data.

Progress in each of these areas will require research, new approaches to testing and data flow and most importantly, co-innovation and cooperation with manufacturers and industry partners like DHI, genetic organizations and breed associations as well as other agribusiness sectors.



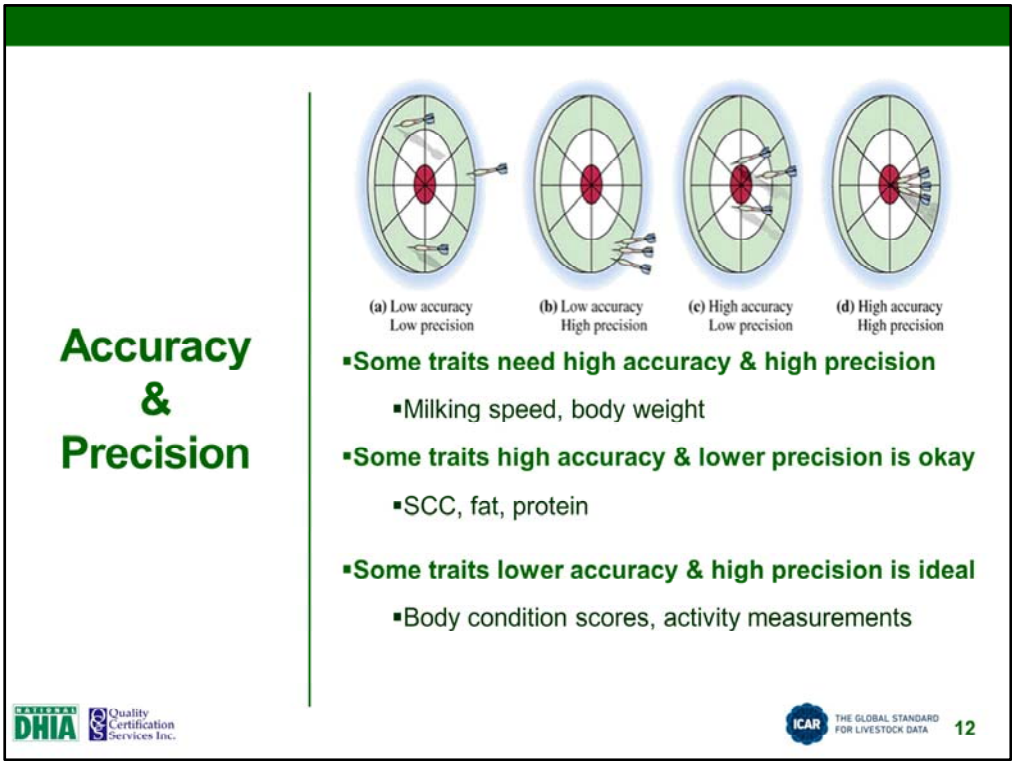
In 2017, the ICAR Sensor Devices Task Force conducted an international survey of recording organizations, herd consultants/experts and device manufacturers. While numerous traits or measures were defined, in the end the priorities for development sorted themselves into five focus areas or priorities. Some categories are self-explanatory and others like 'live body measurements' which will include body condition score, conformation estimates, body weights to name a few are new ground for the many people. Delivery of usable guidelines in each of these focus areas will require involvement from many industry sectors and will involve a broad range of technical expertise.

One of the challenges in reviewing existing and new streams of data is trying to classify the data into workable categories or silos. The most common approach is to look at data usage – management, welfare, health or genetic improvement. But it is also important to look at the data/traits as to type of data. Data linked to farm payments (i.e. milk check) compared to alarm data (health change) or even trend data over the course of a lactation will have different needs and ultimately different standards for accuracy and precision.

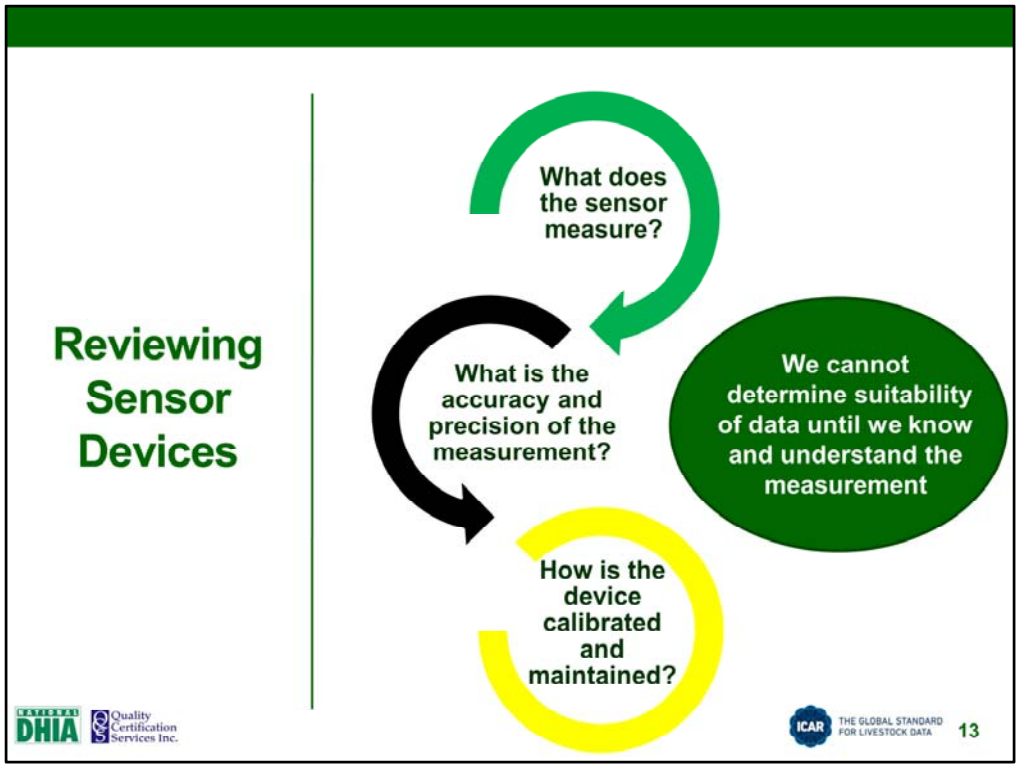


Looking at the dartboard and dart groupings is one of the best ways to help understand what accuracy and precision mean. And the question we need to ask for each trait or measurement is what is the level of each that is needed for that trait. Once we understand our needs, we can improve accuracy with a focus on design and calibration of devices. Likewise, precision itself can be improved by having quality control practices in place.

One of the common misperceptions is what is the accuracy or precision of a device compared to the 'gold standard' however many misinterpret what that standard should be. For example, the fat, protein, or SCC on the milk settlement check is not a gold standard, rather the analysis of milk by reference procedures is the standard. Using the milk check in this example is a way building confidence in the device by comparing to what the producer perceives as value.



Some of the traits we measure like milking speed or weight require both high accuracy and precision. Others like milk components require high accuracy and moderate precision due to the repeated measures across the lactation for a cow. And for others, repeatability and reproducibility are more important than absolute accuracy. For example, let's take a look at body condition score. The real goal of BCS measurement is the change across a period of time or lactation. It does not matter if the cow is a 3.0 or 3.25 as long as the all cows with the same condition receive the same score from the sensor device. This way we have confidence that we can accurately estimate condition changes in individual cows and/or groups of cows.

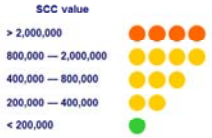


To bring the three previous slides together with respect to reviewing sensor devices, there has to be a three-step process for each device and measurement. Then, and only then, we can determine the suitability of the device and its respective data in recording programs. Some devices will have merits and other devices, while interesting, may not have a place in data recording outside of the individual farm.

What are We Measuring?

Multiple Indicators of Mastitis or Milk Quality

- Automated CMT/WMT
- Electrical conductivity
- L-lactate dehydrogenase
- N-acetyl-beta-D-glucosaminidase
- ATP luminescence
- Thermal imaging
- Visible, NIR, MIR spectroscopy



Milk quality measures are affected by sampling time, temperature, milk viscosity, calibration

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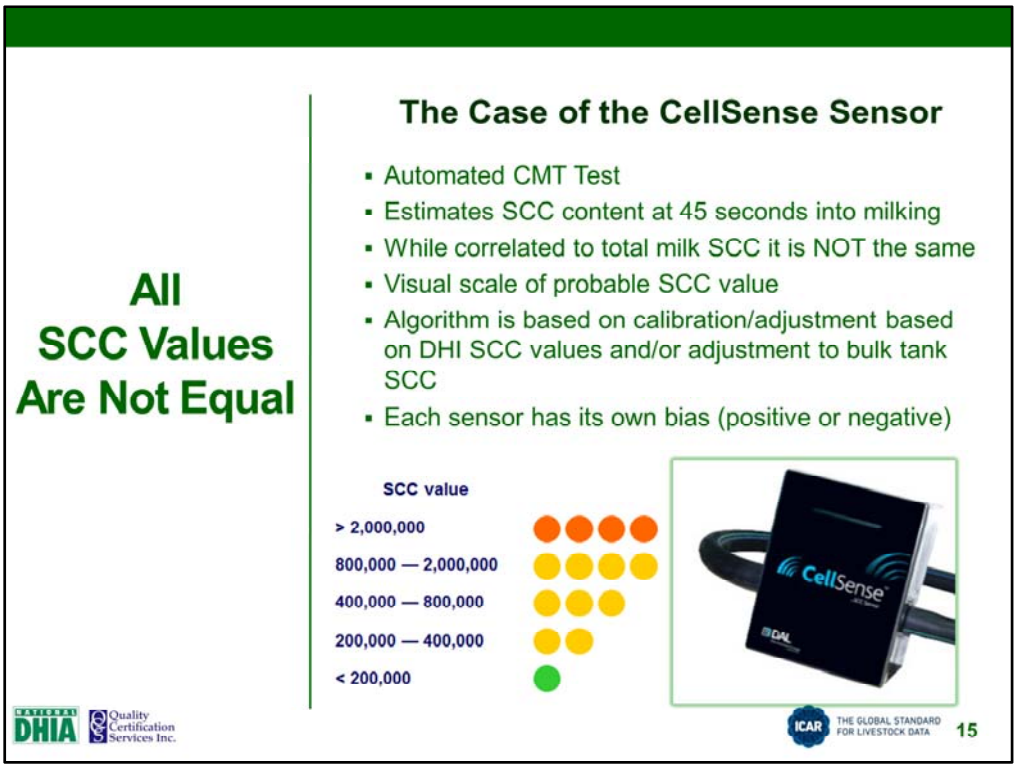
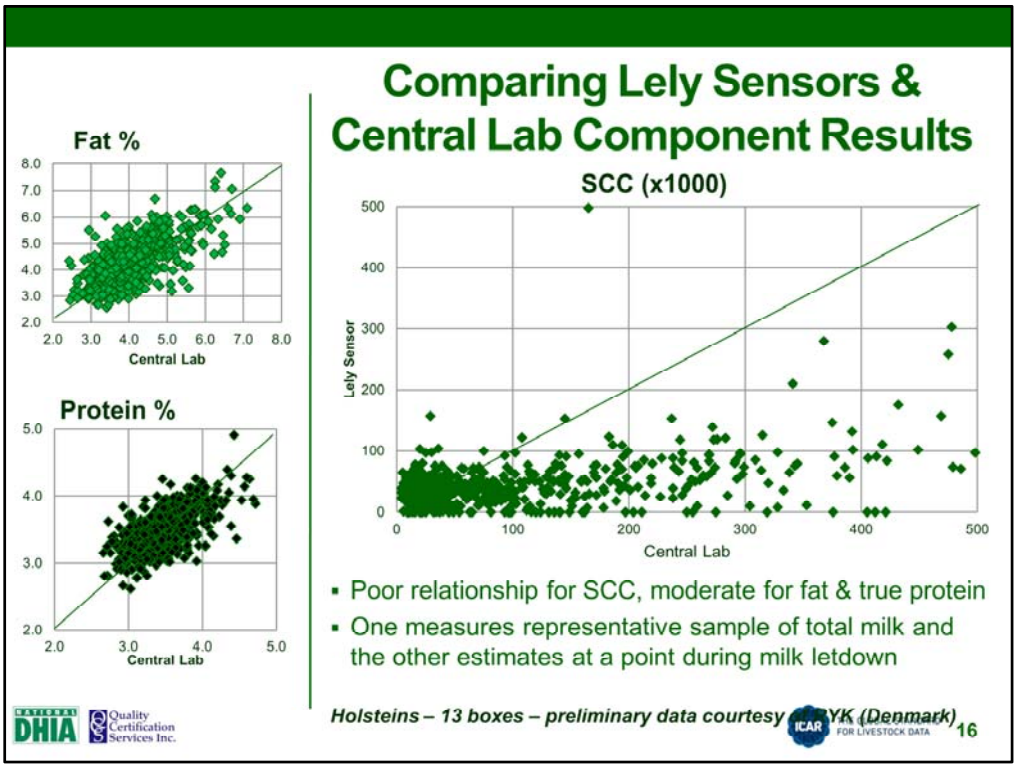
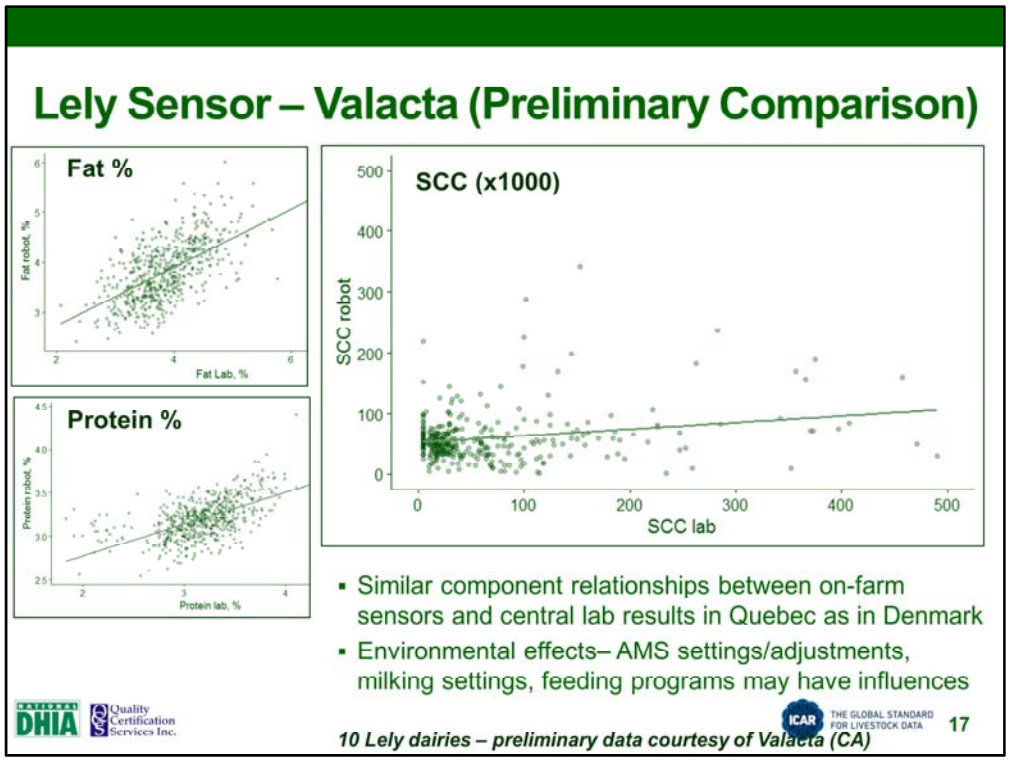
To help understand this challenge, a look at milk quality or mastitis is a good exercise. There are somewhere between ten and thirteen unique ways to estimate milk quality. In addition to traditional DHI collection and analysis of representative milk samples, indicators such as conductivity, thermal resonance and enzyme activity are among the ways to provide data. With programming and algorithms, all can be equated to a SCC value for the cow however they are not the same. Some will have high correlations, others may not.



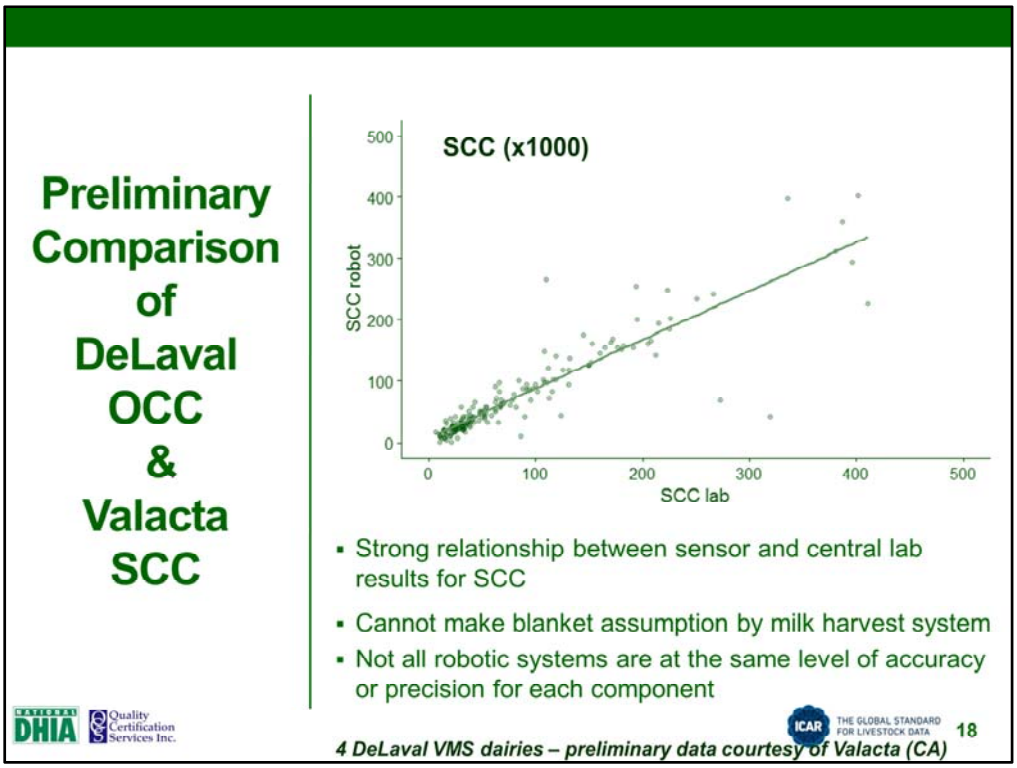
For example, the CellSense Sensor is an example of one of these devices. This device is actually an automated California Mastitis Test (CMT). A sample of milk is 'sensed' around 45 seconds into the milk flow. This timing, to deliver an alarm signal on potential milk quality or infection values by the end of the milkout is not the same as SCC value for the cow measured in traditional DHI programs. The milk letdown is not homogeneous for components like fat and protein or extracellular components like SCC and MUN. In other words, the SCC concentration varies across the letdown with the highest SCC values traditionally found in the last portion of milk flow (same for milk fat levels). Only a representative sample of the entire milk produced is the most accurate measure at the current time.



To help illustrate this concept, a comparison of fat, protein and SCC levels in milk are plotted in these charts. This data from Denmark was presented at the 2017 National DHIA Annual Meeting. The horizontal (x-axis) has the DHI results from analysis at central laboratories with instruments calibrated to the 'gold standard' for each component. The vertical (y-axis) has the sensor values for this system. If the values were equal, the points in the chart would line up on the identity line drawn in the graph. In this case, SCC from the is poorly correlated to DHI lab results. Fat and protein are moderately correlated but without guidelines for data recording, there can be no assumption of accuracy or the usability of data in recording programs.



A similar set of charts based on preliminary data from Canada show similar trends. This data, presented at the 2018 ICAR meeting, confirms the challenges with a blanket assumption of the accuracy of data for fat, protein, and SCC as estimated by some sensor devices. As with the Danish data, SCC sensor estimates are poorly correlated with traditional DHI results.



Another challenge is that not all sensor devices for a component show the same results. Looking at results from a different robotic system that offers SCC results, a higher correlation for SCC is apparent. With different methodology or device sensitivity, some SCC sensor data may have a place in recording programs. But the real caution here it that making blanket assumption by categories or traits should be avoided. Rather, knowing the data source and device is the protocol that should be preferred.

Using SCC Sensors

SCC sensors are intended for mastitis management – not animal evaluations

- Detect and monitor subclinical mastitis
- Manage bulk tank SCC
- Develop action list for cows to culture
- Identify cows for selective dry cow therapy
- Identify cows to cull

Our current data flow system cannot distinguish sources of SCC data – the need exists to capture source of data as well as reported value

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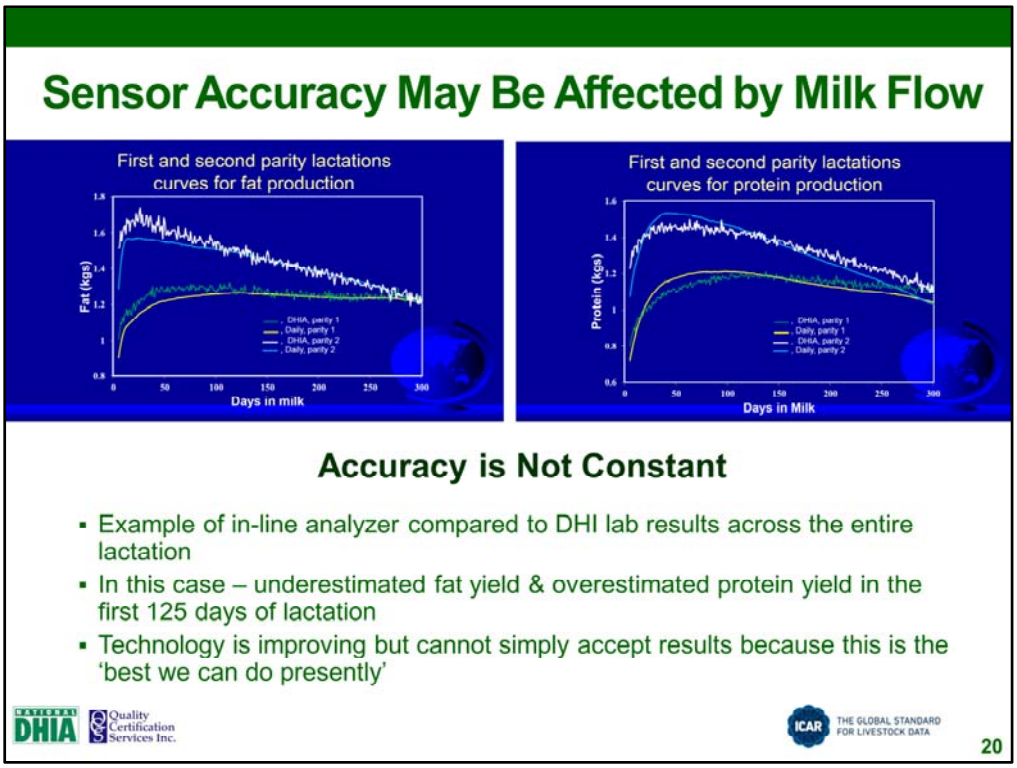
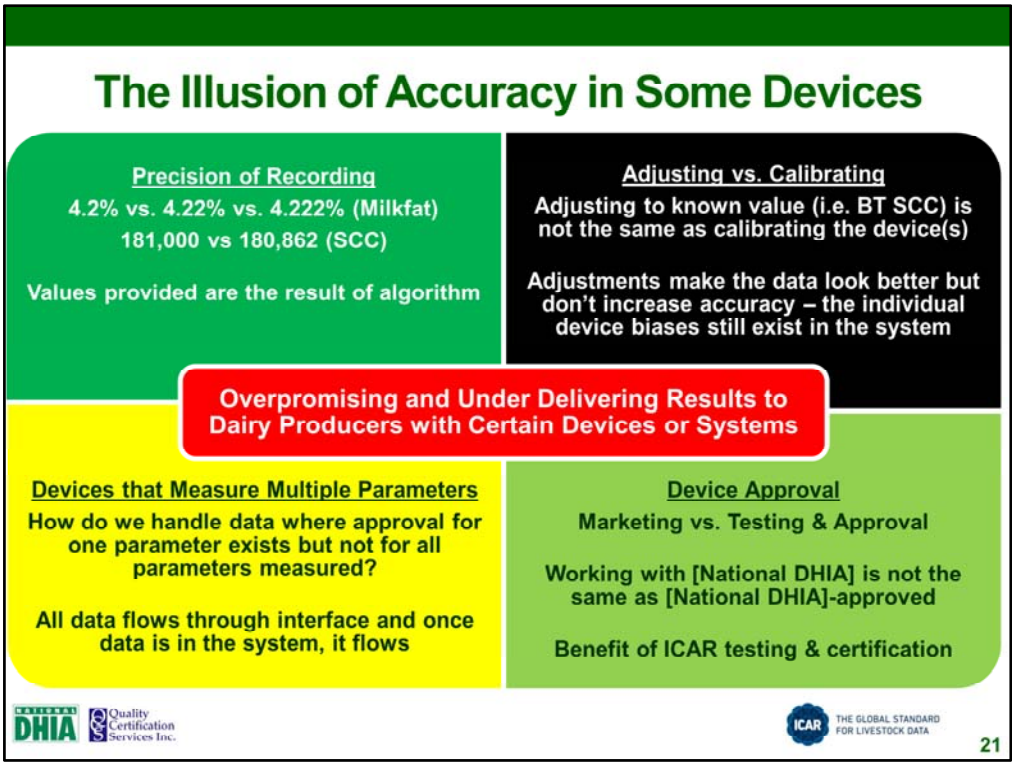
Where does that leave us today with respect to SCC sensors? At the present time, they are tools for alarm or signal data that could be incorporated into a herd or udder health program, but caution related to using data in herd recording database should be exercised.



Another factor the accuracy of sensor devices for milk composition is the influence of milk flow. In this case, the white lines are DHI data and the blue lines are daily sensor estimates for fat and protein in multiparous cows. What we see in this sensor is that fat is overestimated and protein underestimated in the first 100-125 days of lactation. In later lactation, the opposite is seen. The challenge here is that milk flow and volume have an effect on the sensor measurement. Even compounding the challenge is that many herd management decisions related to culling, breeding and/or treatment are made in the first third of the lactation.



One of the common concerns expressed in the industry is related to the illusion of accuracy that some devices portray. For example, showing an extra place after the decimal point such as 4.222% fat instead of 4.22% fat does not mean the device is more accurate. Rather, it means that the software programmer allowed for the additional place from the results of the algorithm.

Another common concern is trying to make the data 'look better' by adjusting to the bulk tank value. Adjustment of data/results is not the same as calibration of the devices. One of the key concepts faced by the industry is the balance of deliverable results vs. results advertised.

What Do We Need to Capture?

Define the parameter and recording period – for example…

- 7 consecutive days - BCS
- 30 consecutive milkings - SCC

What else do we need to capture?

- animal ID
- date/time stamp
- parlour/stall location where applicable
- sensor device name/type
- define other linked data or traits

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When looking at data from sensor devices, care must be taken to capture all the relevant data points necessary. Traditional DHI programs have data collection standards to aid in this space. However some sensor devices may have different definitions of what constitutes a measure such as average 24-hour milk yield or average condition score. And in addition to the estimate from the sensor, capture of animal ID, date and time, stall location, and device name are important in recording programs. The latter is critical not only to identify data quality but also for research and management benchmarking.

Is the Data Real?

Handling of missing data points
- How are missing points estimated?
- Mean of actual data only?

Outlier handling, exclusion, smoothing

System bias or system adjustment?

Range of accurate measurement

Evaluation of algorithm
- Test data set to send through system algorithm to validate output?
- Protecting IP must be a consideration

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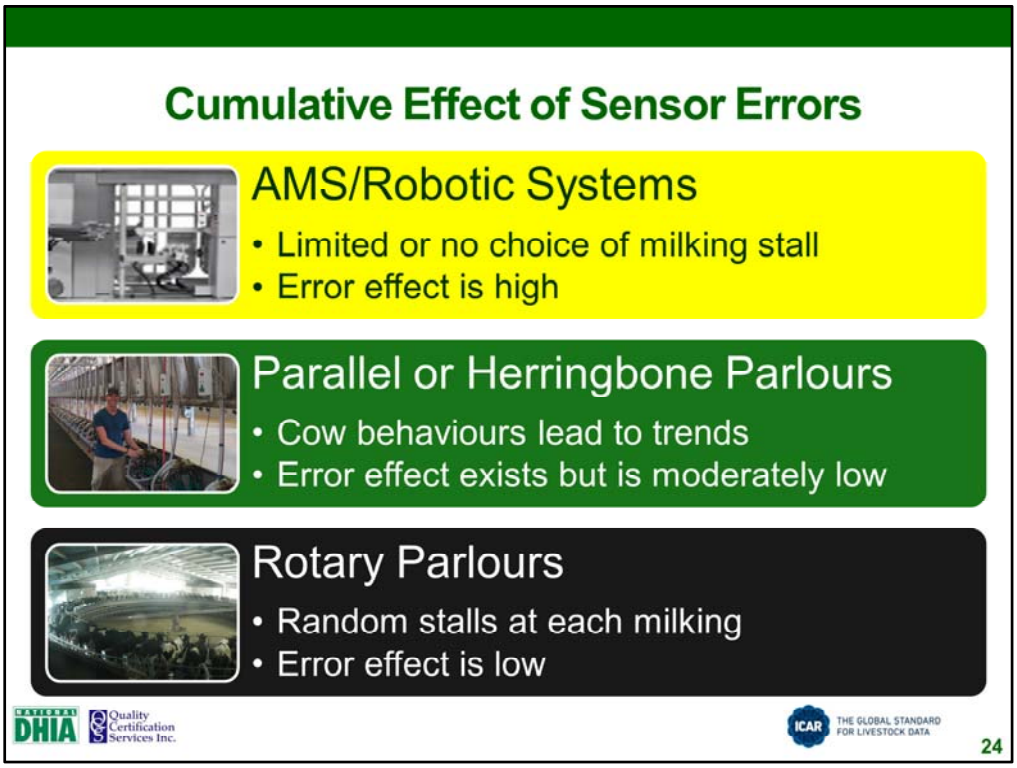
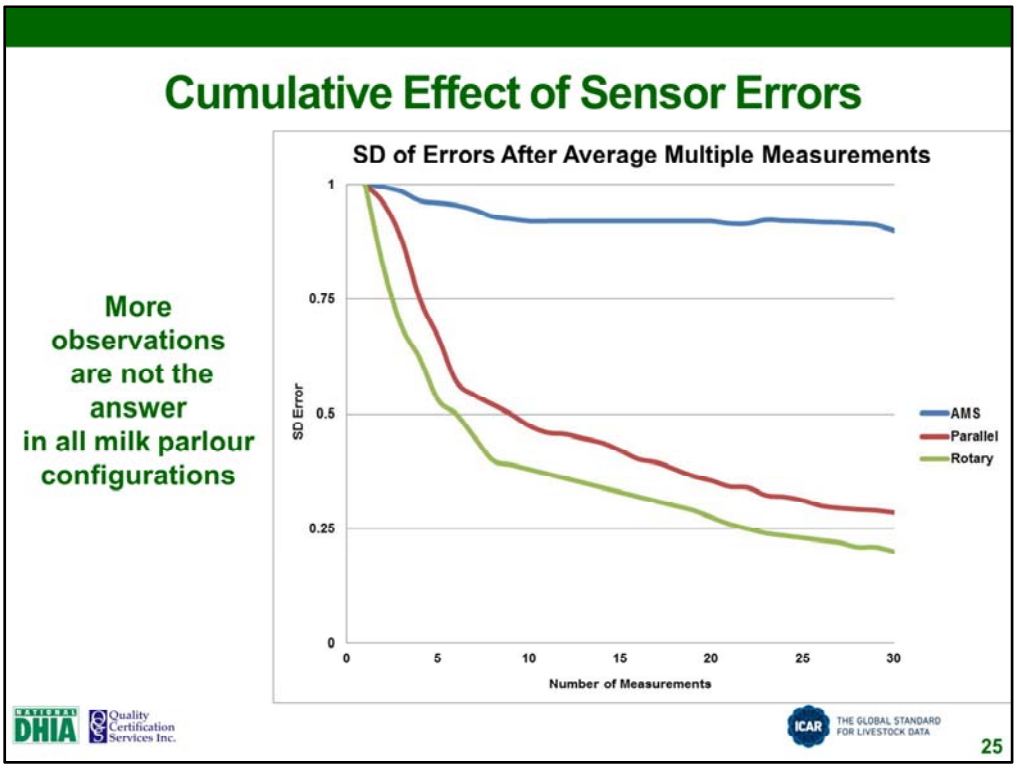
Another challenge faced in assessing the usability of data from automated sensor device recording is understanding what is real and what is estimated data. Having data values in the biological range of the animal as well as handling of missing data or outliers is important.

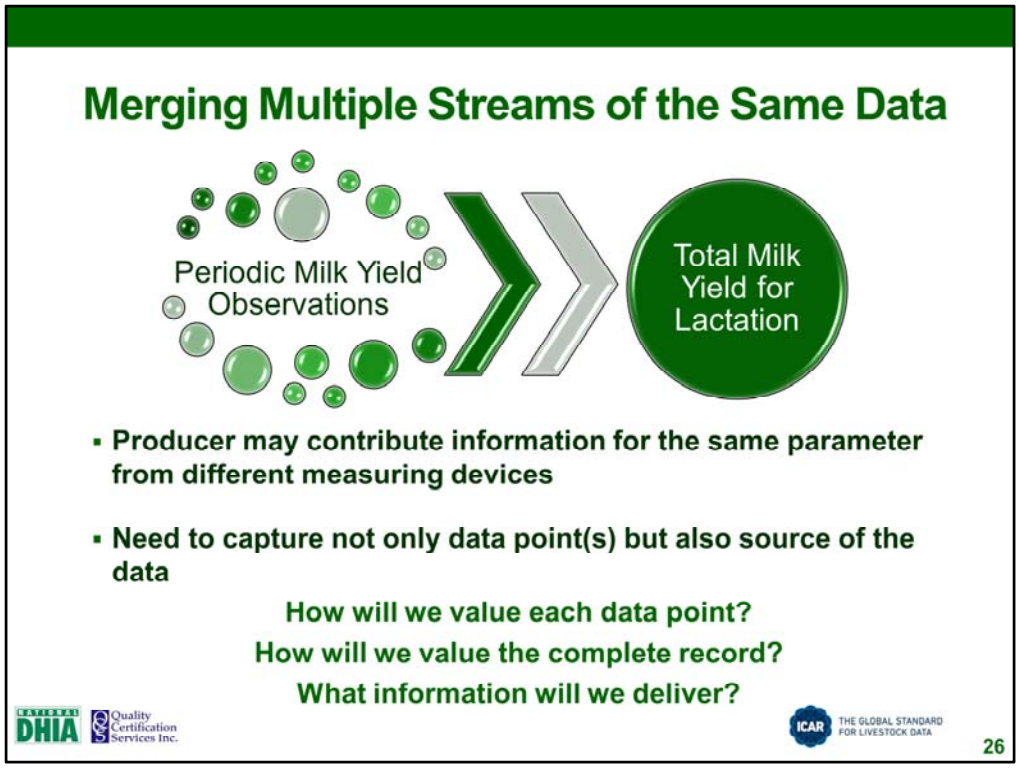
A common approach to data presentation is to have 'smooth' or 'clean' charts and graphs. Yet the individual nature of cows is nothing but smooth with daily, weekly, and seasonal variation to say the least. In addition to evaluating the device, evaluating the software that provides the data will be necessary through a cooperative effort with manufacturers that protects their intellectual property while assuring accuracy to the industry.



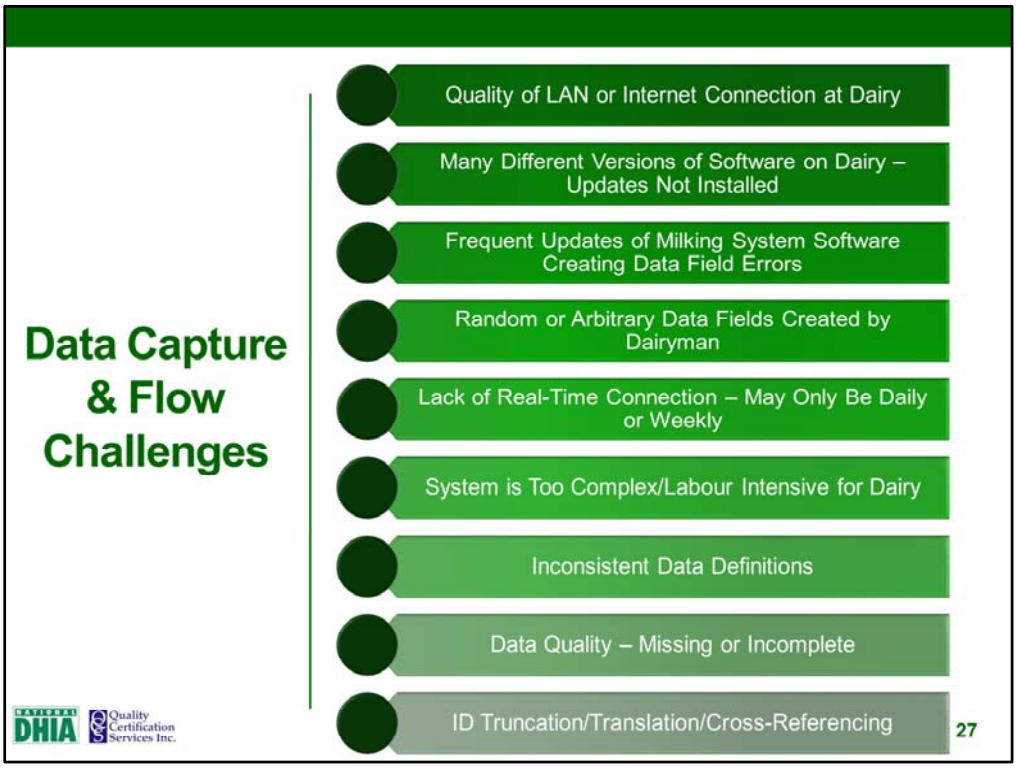
Even the type of parlor or milking setup will have an impact on accuracy of the data as a whole. A rotary system has the most random effect, with the cow not really having a choice of which stall is available when her turn to enter is there. On the other end, AMS or robotic systems have higher error effects. The cows in AMS systems may have only one or two choices for milking. If a bias exists, then all cows could be affected to varying degrees based on their production and milk composition.



One of the most common statements heard regarding sensor data is 'you do not have to be as accurate when you record more data points or observations.' As illustrated the cumulative effect of sensor errors from the three parlor configurations is characterized. In AMS or robotic herds, there is not the expected reduction in errors by collecting daily data for a month compared to rotary or herringbone milking systems. Knowing and capturing the parlor configuration will be an important part of using sensor data in recording systems.

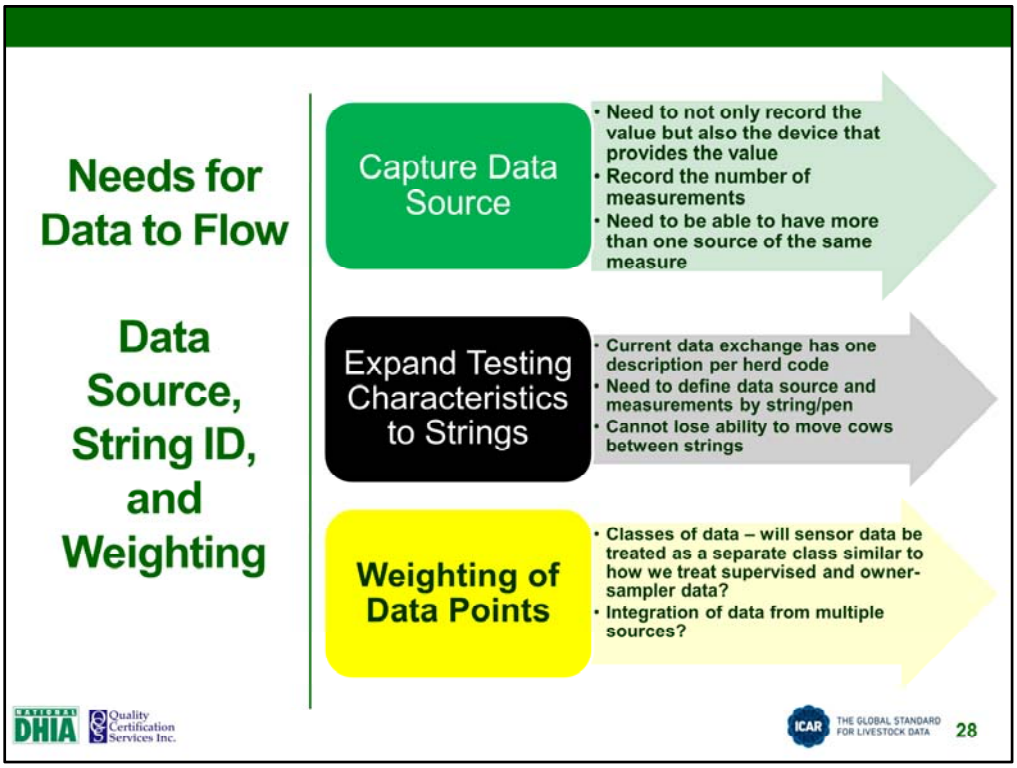


Another challenge that herd recording programs and databases will face is combining data for the same trait from different devices into 'one' value for the lactation. For example, we may have DHI milk yields and sensor milk yields in the same cow file. While sound methodology in weighting these differing data observations will the be needed, the opportunity to improve the overall estimate for the lactation in the case of milk yield holds promise.

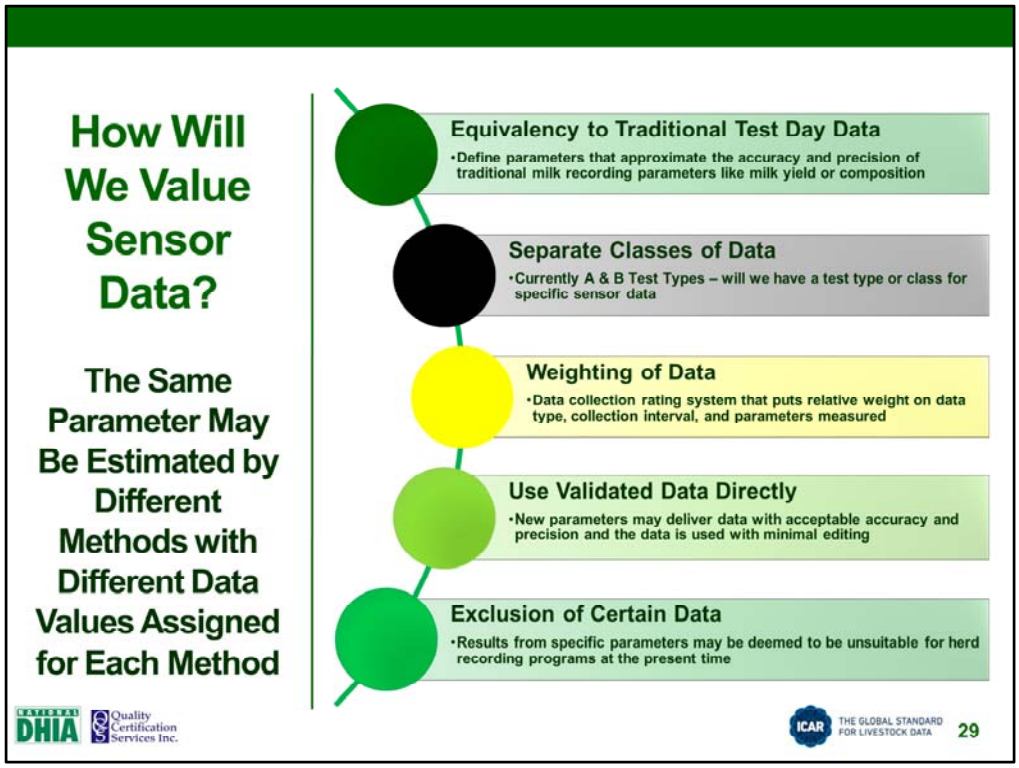


While I have focused on the actual sensor device and its measurement capabilities, I think it is important to highlight some external challenges with data capture and flow. Connectivity, internet or Bluetooth capabilities, software upgrades/updates are a just a few items that can affect the data package.

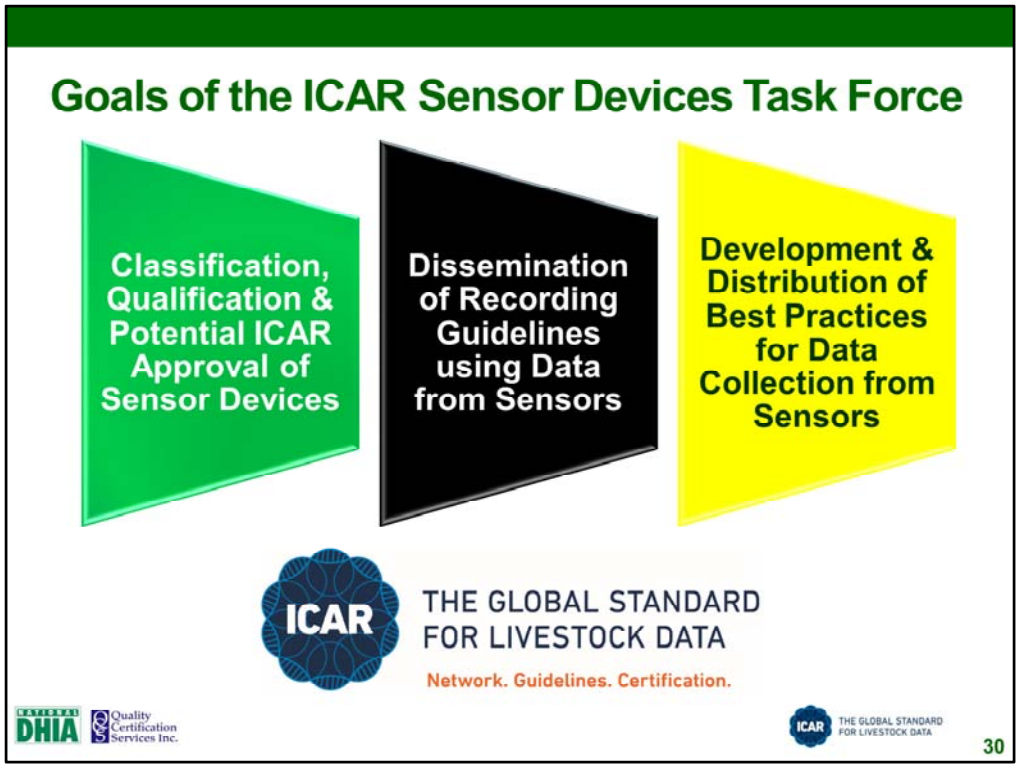
Another concern is that producers create new or arbitrary data fields creating confounded data flow. Even more problematic is the continued commitment to the system as whole. Be it the workload on the farm or the complexity of the system, incomplete data over a single lactation or lifetime of the animal will result in lower accuracy or possibly data exclusion in recording programs.



For sensor data to flow into herd recording systems or databases, the industry needs to focus on three areas as I have touched on earlier. We need to not only capture the measurement itself but also the source of the measure and the unique characteristics for the group of cows/animals measured by the device(s). From there, we can determine suitability and usage of data based on type and accuracy and/or precision.

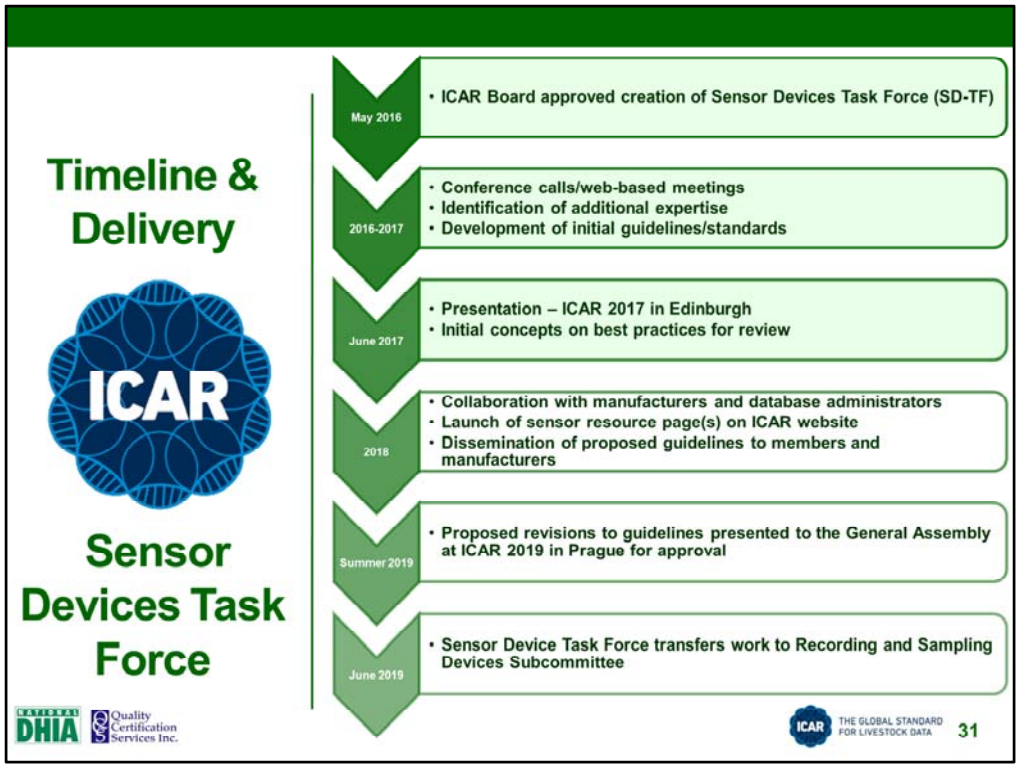


One of the remaining questions is how will DHI/recording programs (or other industry partners such as genetic organizations) value sensor data. Some data like body condition score is in need of standard definitions and device validation, with data suitable for use. Other data may require validation and weighting. Another option may be to classify data into a separate classes. While there are options to explore, it will be imperative to capture data source and have a robust quality certification program in place.



As discussed, the challenges with data from sensor devices are many but the opportunities for using this data in the DHI system are exciting. Helping chart this course, the ICAR Sensor Device Task Force has three goals for the recording industry to guide National DHIA and other organizations worldwide.

These goals of classification and ICAR approval of devices, dissemination of guidelines, and distribution of best practices are key to moving sensor data into DHI programs.



The timeline for delivery of the first set of guidelines by the ICAR Sensor Devices Task Force is expected in June 2019 however development for different traits will most likely proceed along different timelines. One key will be cooperation with manufacturers in every step.

DHIs Will Have a Key Role with Sensor Herds

- **Traditional roles will still exist – Sample Takers**
  - Frequency of sampling will change
  - Types of lab analysis will change
  - May not sample all the cows on every visit to the dairy
- **Need to redefine DHI employee roles/responsibilities**
  - Data Handlers
  - Information/Technology Specialists
- **System set-up/communication and ID validation will be important role for DHI organizations**
- **All industry partners (DHI, GE, AI and Breeds) will have a revised & an enhanced role in data/solution delivery – communication and cooperation is vital**

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As DHI and other industry organizations recording data are evaluating their respective roles in the future, I think it worth noting that DHI will have a key role with sensor data herds. Some the job titles and responsibilities may change but the core processes of herd recording will remain. ID system validation, milk sample collection for both old and new analyses, and data handling will be key.

But it is also important to note that all industry partners will have a role to play in data flow and delivery of solutions. Communication and cooperation will be key to develop producer-focused tools and programs that recognize the producers investment in both sensor devices and industry programs.

Final Thoughts and Discussion Points

- Opportunities and challenges exist to capture new data observations from sensor devices.
- Industry needs to evaluate the opportunity of integrating sensor data with appropriate evaluation based on research data as each sensor is unique in deliverable data both in accuracy and precision.
- Investment and programming by all industry segments will be needed to capture not only data, but source and quality to assure appropriate use.
- Data delivery for management and health decisions will be the primary driver as opposed to data for genetic evaluations and research
- Will need a balance of cooperation and competition – COOPETITION

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I would like to thank you for taking time to learn about some of the challenges and opportunities related to sensor data and future inclusion in herd recording programs. As noted previously, all industry partners need an integrated approach to meet producer needs in addition to providing core services in each industry segment. While DHI programs may have its roots in genetic evaluations with work continuing this space; data delivery for herd management, individual management and health or welfare decisions will be the primary driver in herd recording programs in the future.