Where I Come From
Kentucky Dairy Industry

80,000 dairy cows across 740 dairy farms

The Future

NEXT EXIT
May You Live in Interesting Times

Technological Marvels

• Tremendous technological progress in dairy farming (i.e. genetics, nutrition, reproduction, disease control, cow comfort)

• Modern dairy farms have been described as “technological marvels” (Philpot, 2003)

• The next “technological marvel” in the dairy industry may be in Precision Dairy Farming
1. Changing Dairy Landscape

- Fewer, larger dairy operations
- Narrow profit margins
- Increased feed and labor costs
- Cows are managed by fewer skilled workers

2. Consumer Focus

- Continuous quality assurance
- “Natural” or “organic” foods
- Greenhouse gas reductions
- Zoonotic disease transmission
- Reducing the use of medical treatments
- Increased emphasis on animal well-being
3. Information Era

- Unlimited on-farm data storage
- Faster computers allow for more sophisticated on-farm data mining
- Technologies adopted in larger industries have applications in smaller industries

4. Cow Challenges

1. Finding cows in heat
2. Finding and treating lame cows
3. Finding and treating cows with mastitis
4. Catching sick cows in early lactation
5. Understanding nutritional status of cows
   a. Feed intake
   b. Body condition (fat or thin)
   c. Rumen health (pH/rumination time)
Precision Dairy Management

The use of automated, mechanized technologies toward refinement of dairy management processes, procedures, or information collection.

Automated Milking Systems
Automated Calf Feeding

Precision Feeding
Data Management Solutions

Precision Dairy Monitoring

• Using technologies to measure physiological, behavioral, and production indicators

• Focus on preventive health and performance at the cow level

• Make more timely and informed decisions
Precision Dairy Farming Benefits

- Improved animal health and well-being
- Increased efficiency
- Reduced costs
- Improved product quality
- Minimized adverse environmental impacts
- Risk analysis and risk management
- More objective (less observer bias and influence)
The Book of David: Cow People Benefit Most

Sheldon’s Friendship Flowchart (as Modified by Wolowitz)
Ideal Technology

• Explains an underlying biological process
• Can be translated to a meaningful action
• Cost-effective
• Flexible, robust, reliable
• Information readily available to farmer
• Commercial demonstrations
• Continuous improvement and feedback loops
Data Handling

- Industry needs to establish guidelines for farmers to follow
- What questions should they be asking?
- What to do with information provided?

What Technologies are Out There?
Electrical Conductivity

- Ion concentration of milk changes, increasing electrical conductivity
- Inexpensive and simple equipment
- Wide range of sensitivity and specificity reported
- Results improve with quarter level sensors
- Improved results with recent algorithms
- Most useful when combined with other metrics

Brandt et al., 2010; Hogeveen et al., 2011

Milk Color

- Color variation (red, blue, and green) sensors in some automatic milking systems
- Reddish color indicates blood (Ordolff, 2003)
- Clinical mastitis may change color patterns for three colors (red, green and blue)
- Specificity may be limited

www.lely.com
• Not all cases of mastitis result in a temperature response
• Best location to collect temperature?
• Noise from other physiological impacts
Thermography

• May be limited because not all cases of mastitis result in a temperature response
• Difficulties in collecting images

Hovinen et al., 2008; Schutz, 2009

Agricam

DVM TempTrack

1331 had Strep uberis isolated from her LF and RF quarters on 11/29/11

Amanda Sterrett et al.
DVM Systems Temperature and Milkline
Individual Quarter Conductivity

Amanda Sterrett et al., Unpublished Data

Reticulorumen Temperature:
Water Intake

Melissa Cornett et al.
Time to Return to Baseline

\[ \text{Time to Return to Baseline} = 2.63 + (23.59 \times \text{Water Quantity}) + (0.03 \times \text{Water Temperature °F}) - (0.23 \times (\text{Water Quantity} \times \text{Water Temperature})) \]

Water Temperature (°C)

<table>
<thead>
<tr>
<th>Water Quantity (Liters)</th>
<th>5.7</th>
<th>11.4</th>
<th>22.7</th>
</tr>
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<tbody>
<tr>
<td>Time to Return to SD Baseline, Minutes</td>
<td>100</td>
<td>80</td>
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Temperature Drop

\[ \text{Temperature Drop} = 7.59 + (2.85 \times \text{Water Quantity}) - (0.08 \times \text{Water Temperature °F}) - (0.02 \times (\text{Water Quantity} \times \text{Water Temperature})) \]

Water Temperature (°C)

<table>
<thead>
<tr>
<th>Water Quantity (Liters)</th>
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<tr>
<td>Maximum Drop in Temperature (°C)</td>
<td>10</td>
<td>8</td>
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Melissa Cornett et al.
### Water Intake Conversion Chart

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<th>Water Temperature (°F)</th>
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</tbody>
</table>

### Reticulorumen and Ambient Temperatures within Day

The nadir and zenith RT appeared 10:00 and 23:30, respectively.
Ambient and Reticulorumen Temperatures

Breed Temperatures

Di Liang et al.
Milk yield and Temperature

Automated CMT or WMT

- CellSense (New Zealand)
- Correlation with Fossomatic SCC 0.76 (Kamphuis et al., 2008)
- Using fuzzy logic, success rates (22 to 32%) and false alerts (1.2 to 2.1 per 1000 milkings), when combined with EC were reasonable (Kamphuis et al., 2008)
**Mastiline**

- Uses ATP luminescence as an indicator of the number of somatic cells
- Consists of 2 components
- In-line sampling and detection system, designed for easy connection to the milk hose below the milking claw
- Cassette containing the reagents for measuring cell counts

---

**Spectroscopy**

- Visible, near-infrared, mid-infrared, or radio frequency
- Indirect identification through changes in milk composition
- AfILab uses near infrared
  - Fat, protein, lactose, SCC, and MUN
- May be more useful for detecting high SCC cows than quantifying actual SCC
Biosensors and Chemical Sensors

- Biological components (enzymes, antibodies, or microorganism)
- Enzyme, L-Lactate dehydrogenase (LDH), is released because of the immune response and changes in cellular membrane chemistry
- Chemical sensors: changes in chloride, potassium, and sodium ions, volatile metabolites resulting from mastitis, haptoglobin, and hemoglobin (Hogeveen, 2011)

Brandt et al., 2010; Hogeveen et al., 2011

Milk measurements

- Progesterone
  - Heat detection
  - Pregnancy detection
- LDH enzyme
  - Early mastitis detection
- BHBA
  - Indicator of subclinical ketosis
- Urea
  - Protein status
Cows' lady parts text farmers when it's time for a booty call

A female cow's privates aren't so private anymore with Anemon, a system that senses when she is in heat and texts an alert to the farmer.

Wireless intravaginal temperature sensor

[Diagram showing the Anemon system and its components]
4Sight-Fionn Technologies

- Northern Ireland
- Photosensitive optic beams across barns
- Software recognizes cows
- ID’s when cows cross beams

Estrus Detection

- Efforts in the US have increased dramatically in the last 2 years
- Producer experiences are positive
- Changing the way we breed cows
- Only catches cows in heat
- Real economic impact
HR Activity and Rumination/DVM Bolus Temperature for Estrus Detection

Bred on 7/22/11

Comparison of Timed AI and Activity Based Heat Detection

- Compare reproductive performance between both systems
- Days to first service, interval between services, cumulative pregnancy rate at 150 days postpartum, percent successful breedings for first, second, and third services
- Conducted on three commercial Kentucky dairies
- Economic analysis of both methods

Karmella Dolecheck et al.
SCR HR Tag

- Measures rumination time
- Time between cud boluses
- Monitor metabolic status

SCR Rumination Time

Amanda Sterrett et al.
Lying Behavior Monitors

• On-farm evaluation of lying time:
  • Identification of cows requiring attention (lameness, illness, estrus)
  • Assessment of facility functionality/cow comfort
  • Potential metric to assess animal well-being
Rumen pH

- Illness
- Feeding/drinking behavior
- Acidosis

Vel’Phone Calving Detection

1. Thermometer is placed in the animal
2. Thermometer registers temperature rise
3. Typical variation in the animal’s temperature
4. Thermometer expelled by water bag
5. Calving begins

*Once the thermometer is activated the animal’s temperature is sent by SMS once or twice a day at the selected times.*

Medria ELEVAGE Monitoring solutions
CowManager Sensor

- Temperature
- Activity
- Rumination
- Feeding Time


Amanda Sterrett et al.
Alanya Animal Health

- Behavioral changes
- Temperature
- Lying/Standing Time
- Grazing Time
- Lameness
- Estrus Detection (multiple metrics)
- Locomotion Scoring

RumiWatch

- Rumination, Drinking, Eating Behavior
- Lying, Standing, Steps
• Greenfeed measures methane (CH₄)
• Select for cows that are more environmentally friendly
• Monitor impacts of farm changes (rations) on greenhouse gas emissions
StepMetrix

- Lameness detection
- BouMatic

Belgian Lameness System

- Pressure-mat data
  - Find touch and release of hoof
- Video data
  - Find matching camera image
  - Automatic measure of touch and release angle

Reference:

J. Dairy Sci. 95:1736-1748
http://dx.doi.org/10.3168/jds.2011-4547

Automatic measurement of touch and release angles of the fetlock joint for lameness detection in dairy cattle using vision techniques

A. Plokh, C. Bulic, A. Pourzabeli, W. Maertens, A. van Nuffel, and D. Berckmans

Department of Veterinary Science and Management (VET), KU Leuven, Herestraat 49, B-3000 Leuven, Belgium

Belgische Kweekbedrijfsgroepen, Oeverbeek 61, B-3000 Leuven, Belgium
Real Time Location Systems

• Using Real Time Location System (RTLS) to track location of cows (similar to GPS)
• Better understand distribution of animals within barns
• Information used to design better barns and modify existing barns
• Behavior monitoring-implications for estrus detection, time at feedbunk, social interactions

Randi Black et al.
GEA CowView

- Feeding time
- Waiting time
- Resting time
- Mounting
- Distance Covered

SmartBow
Kentucky Precision Monitoring

- Quantify physiological and behavioral changes associated with events
  - Estrus
  - Mastitis
  - Metritis
  - Lameness
  - Respiratory diseases
  - Metabolic diseases
- Using multiple Precision Dairy Farming technologies

- HR Tag (SCR Engineers)
- IceQube (IceRobotics)
- AMATS (Netquest Services)
- Surface Temperature Monitor
- Rumen Temperature Monitor
- Leg Accelerometer: Lying Time
- DVM Bolus (DVM Systems)

Sterrett et al.
### Summer 2013 UK Coldstream Dairy Monitoring Capabilities

<table>
<thead>
<tr>
<th>Technology</th>
<th>Parameter(s) Measured</th>
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<tbody>
<tr>
<td>SmartBow</td>
<td>Position, Movement</td>
</tr>
<tr>
<td>VePhone</td>
<td>Calving Time, Vaginal Temperature</td>
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<tr>
<td>Alanya</td>
<td>Temperature, Lying Time, Activity, Locomotion, Behavior</td>
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<tr>
<td>AfliLab</td>
<td>Fat, Protein, Lactose</td>
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<td>Pedometer Plus</td>
<td>Lying Time, Steps</td>
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<tr>
<td>HR Tag</td>
<td>Rumination Time, Neck Activity</td>
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<tr>
<td>Track-a-Cow</td>
<td>Lying Time, Time at Feedbunk</td>
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<tr>
<td>Mastiline</td>
<td>Somatic Cell Count</td>
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<td>CowManager Sensoor</td>
<td>Rumination Time, Feeding Time, Ear Skin Temperature, Activity</td>
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<td>IceQube</td>
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<td>Anemon</td>
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<td>Reticulum Temperature</td>
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<td>AccuBreed</td>
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<td>CowScout</td>
<td>Leg Activity</td>
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Thank You to All our Consortium Sponsors!

### Changes Around Mastitis

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean difference</th>
<th>Standard Error</th>
<th>P-value</th>
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<td>-109.10</td>
<td>13.03</td>
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<td>Neck activity</td>
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<td>-81.18</td>
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<td>Milk yield (kg)</td>
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<td>-5.10</td>
<td>0.72</td>
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<td>Reticulum temperature (° C)</td>
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<td>0.07</td>
<td>&lt; 0.01</td>
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</table>

Amanda Sterrett et al.
Automated Body Condition Scoring

- Reduced labor requirements
- Less stressful on animal
- More objective, consistent measure
- Increased observation frequency
- Early identification of sick animals
- Tracking BCS trends of individual animals and management cohorts

Body Condition Scoring

- 100% of predicted BCS were within 0.50 points of actual BCS.
- 93% were within 0.25 points of actual BCS.

Bewley et al., 2008
Body Condition Scoring

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<td>Hook Angle</td>
<td>153.5°</td>
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</table>

Bewley et al., 2008

Now, Automation

Lau, Shelley, Sterrett, and Bewley, 2013
Feed Intake: 3D Imaging

Lau, Shelley, Sterrett, and Bewley, 2013
Early Test Results

Lau, Shelley, Sterrett, and Bewley, 2013

Cow Sleep Monitoring

- Sleep Quality = Improved Immunity?
- New Way to Measure Cow Comfort?

Donohue, Lihamon, O'Hara, Klefot, and Bewley, 2013
What automatic monitoring technologies do you currently have on your dairy?

<table>
<thead>
<tr>
<th>Most Used Parameters</th>
<th>Respondent Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily milk yield</td>
<td>52.3%</td>
</tr>
<tr>
<td>Cow activity</td>
<td>41.3%</td>
</tr>
<tr>
<td>Not applicable¹</td>
<td>31.2%</td>
</tr>
<tr>
<td>Mastitis</td>
<td>25.7%</td>
</tr>
<tr>
<td>Milk components (e.g. fat, protein, and SCC)</td>
<td>24.8%</td>
</tr>
<tr>
<td>Standing heat</td>
<td>21.1%</td>
</tr>
<tr>
<td>Feeding behavior</td>
<td>12.8%</td>
</tr>
<tr>
<td>Temperature</td>
<td>12.8%</td>
</tr>
<tr>
<td>Body weight</td>
<td>11.0%</td>
</tr>
<tr>
<td>Rumination</td>
<td>10.1%</td>
</tr>
<tr>
<td>Rumen activity</td>
<td>9.2%</td>
</tr>
</tbody>
</table>

¹Respondents replying "Not applicable," were those not currently utilizing precision technologies on their farms.

Rate the importance of the following criteria for evaluating technology purchases

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit: cost ratio</td>
<td>4.57 ± 0.66</td>
</tr>
<tr>
<td>Total investment cost</td>
<td>4.28 ± 0.83</td>
</tr>
<tr>
<td>Simplicity and ease of use</td>
<td>4.26 ± 0.75</td>
</tr>
<tr>
<td>Proven performance through independent research</td>
<td>4.24 ± 0.75</td>
</tr>
<tr>
<td>Availability of local support</td>
<td>4.12 ± 0.95</td>
</tr>
<tr>
<td>Compatibility with existing dairy practices and systems</td>
<td>4.12 ± 0.86</td>
</tr>
<tr>
<td>Time involved using the technology</td>
<td>4.07 ± 0.88</td>
</tr>
</tbody>
</table>

¹Results calculated by assigning the following values to response categories: Not important: 1, Of little importance: 2, Moderately important: 3, Important: 4, Very important: 5.
## Rate the potential usefulness of the following measures

### Most Useful Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastitis</td>
<td>4.77 ± 0.47</td>
</tr>
<tr>
<td>Standing heat</td>
<td>4.75 ± 0.55</td>
</tr>
<tr>
<td>Daily milk yield</td>
<td>4.72 ± 0.62</td>
</tr>
<tr>
<td>Cow activity</td>
<td>4.60 ± 0.83</td>
</tr>
<tr>
<td>Temperature</td>
<td>4.31 ± 1.04</td>
</tr>
<tr>
<td>Feeding behavior</td>
<td>4.30 ± 0.80</td>
</tr>
<tr>
<td>Milk components (e.g. fat, protein, and SCC)</td>
<td>4.28 ± 0.93</td>
</tr>
<tr>
<td>Lameness</td>
<td>4.25 ± 0.90</td>
</tr>
<tr>
<td>Rumination</td>
<td>4.08 ± 1.07</td>
</tr>
<tr>
<td>Hoof health</td>
<td>4.06 ± 0.89</td>
</tr>
</tbody>
</table>

1Results calculated by assigning the following values to response categories: Not useful: 1, Of little usefulness: 2, Moderately useful: 3, Useful: 4, Very useful: 5.

---

### Least Useful Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rumen activity</td>
<td>3.94 ± 1.10</td>
</tr>
<tr>
<td>Lying and standing behavior</td>
<td>3.79 ± 1.05</td>
</tr>
<tr>
<td>Rumen pH</td>
<td>3.62 ± 1.16</td>
</tr>
<tr>
<td>Jaw movement and chewing activity</td>
<td>3.61 ± 1.15</td>
</tr>
<tr>
<td>Respiration rate</td>
<td>3.40 ± 1.15</td>
</tr>
<tr>
<td>Body weight</td>
<td>3.26 ± 1.20</td>
</tr>
<tr>
<td>Body condition score</td>
<td>3.26 ± 1.15</td>
</tr>
<tr>
<td>Heart rate</td>
<td>3.07 ± 1.15</td>
</tr>
<tr>
<td>Animal position and location</td>
<td>2.75 ± 1.26</td>
</tr>
<tr>
<td>Methane emissions</td>
<td>2.20 ± 1.16</td>
</tr>
</tbody>
</table>

1Results calculated by assigning the following values to response categories: Not useful: 1, Of little usefulness: 2, Moderately useful: 3, Useful: 4, Very useful: 5.
Comparisons Between Countries for Parameters Currently Measured

<table>
<thead>
<tr>
<th>Parameter Measured</th>
<th>United States</th>
<th>Other Countries</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rumination</td>
<td></td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>Rumen activity</td>
<td></td>
<td></td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Milk components</td>
<td></td>
<td></td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Mastitis</td>
<td></td>
<td></td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Lying and standing behavior</td>
<td></td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Feeding behavior</td>
<td></td>
<td></td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Daily milk yield</td>
<td></td>
<td></td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Cow activity</td>
<td></td>
<td></td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Body weight</td>
<td></td>
<td></td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

What Are the Limitations of Precision Dairy Farming?
PDF Reality Check

- Maybe not be #1 priority for commercial dairy producers (yet)
- Many technologies are in infancy stage
- Not all technologies are good investments
- Economics must be examined
- People factors must be considered

Murphy’s Law
Economic Considerations

• Need to do investment analysis
• Not one size fits all
• Economic benefits observed quickest for heat detection/reproduction
• If you don’t do anything with the information, it was useless
• Systems that measure multiple parameters make most sense
• Systems with low fixed costs work best for small farms

Purdue/Kentucky Investment Model

• Investment decisions for PDF technologies
• Flexible, partial-budget, farm-specific
• Simulates dairy for 10 years
• Includes hundreds of random values
• Measures benefits from improvements in productivity, animal health, and reproduction
• Models both biology and economics
NPV establishes what the value of future earnings from a project is in today's money.

Investment Analysis of Heat Detection Technologies

Heat detection is a major concern on many dairies today. Many technologies used to monitor activity and other cow parameters have been developed to more accurately manage heat detection.

This net present value tool can be used to compare up to 3 different heat detection technologies in order to determine which might work best economically on a specific dairy.

To use, change herd and technology information in the input tabs and then review the outcome in the "Results" and "Before vs. After" tabs.

Developed by Karmella Dolecheck and Jeffrey Bewley
Animal & Food Sciences Department
University of Kentucky College of Agriculture

www2.ca.uky.edu/afsdairy/HeatDetectionTechnologies Karmella Dolecheck et al.
Hover buttons explain inputs and results

Inputs adjustable in multiple ways

Compare up to 3 different technologies
### Example Analysis

**Investment-Unit Price-EDR**

<table>
<thead>
<tr>
<th>Technology Example</th>
<th>Net Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-50-90</td>
<td>$104,906</td>
</tr>
<tr>
<td>High-50-90</td>
<td>$99,906</td>
</tr>
<tr>
<td>Low-100-90</td>
<td>$94,300</td>
</tr>
<tr>
<td>High-100-90</td>
<td>$89,300</td>
</tr>
<tr>
<td>Low-50-70</td>
<td>$69,188</td>
</tr>
<tr>
<td>High-50-70</td>
<td>$64,188</td>
</tr>
<tr>
<td>Low-100-70</td>
<td>$63,582</td>
</tr>
<tr>
<td>High-100-70</td>
<td>$58,582</td>
</tr>
</tbody>
</table>

- **Low**: $5,000 initial investment
- **High**: $10,000 initial investment
- **50**: $50 unit price
- **100**: $100 unit price
- **70**: 70% estrus detection rate
- **90**: 90% estrus detection rate

Karmella Dolecheck et al.
Technology Pitfalls

• “Plug and play,” “Plug and pray,” or “Plug and pay”

• Technologies go to market too quickly

• Not fully-developed

• Software not user-friendly

• Developed independently without consideration of integration with other technologies and farmer work patterns

Technology Pitfalls

• Too many single measurement systems

• Lack of large-scale commercial field trials and demonstrations

• Technology marketed without adequate interpretation of biological significance of data

• Information provided with no clear action plan
• Be prepared for little things to go wrong
• Be careful with early stage technologies
• Need a few months to learn how to use data
• Data integration is challenging
• Read the manual

Sometimes When You’re Sitting on the Cutting Edge, It Hurts your Butt

Dr. Mike Schutz
From Purdue to Poor Due

Did I get the wrong PhD?

Sociological Factors

- Labor savings and potential quality of life improvements affect investment decisions (Cantin, 2008)
- Insufficient market research
- Farmers overwhelmed by too many options (Banhazi and Black, 2009)
  - Which technology should I adopt?
  - End up adopting those that are interesting or where they have an expertise
  - Not necessarily the most profitable ones
Why Have Adoption Rates Been Slow?

Reason #1. Not familiar with technologies that are available (N = 101, 55%)
Reason #2. Undesirable cost to benefit ratio
(N = 77, 42%)

Reason #3. Too much information provided without knowing what to do with it
(N = 66, 36%)
Reason #4. Not enough time to spend on technology (N = 56, 30%)

Reason #5. Lack of perceived economic value (N = 55, 30%)
Reason #6. Too Difficult or Complex to Use (N = 53, 29%)
Reason #8. Better alternatives/easier to accomplish manually 
(N =43, 23%)

Reason #9. Failure in fitting with farmer patterns of work 
(N =40, 22%)
Reason #10. Fear of technology/computer illiteracy (N = 39, 21%)

Reason #11. Not reliable or flexible enough (N = 33, 18%)
Reason #99. Wrong College Degree
(N = 289, 100%)

Customer Service is Key

- More important than the gadget
- Computer literacy
- Not engineers
- Time limits
- Failure of hardware and software
Cautious Optimism

- Critics say it is too technical or challenging
- We are just beginning
- Precision Dairy won’t change cows or people
- Will change how they work together
- Improve farmer and cow well-being

Path to Success

- Continue this rapid innovation
- Maintain realistic expectations
- Respond to farmer questions and feedback
- Never lose sight of the cow
- Educate, communicate, and collaborate
Future Vision

- New era in dairy management
- Exciting technologies
- Improved quality of life
- New ways of monitoring and improving animal health, well-being, and reproduction
- Analytics as competitive advantage
- Economics and human factors are key