Robotic milking represents the latest step in the steady increase in the automation of dairy farm tasks since the beginning of recorded dairy history. Some of the more momentous innovations include the use of animal power to repose human power, applications of mechanical power from steam engines to tractors for field and feed handling tasks, supply of electrical energy to dairy farms closely followed by the introduction of mechanical milking, automated feeding systems, milking parlor technology including automatic milking unit detachment and finally fully automated milking technology. Each of these steps has increased the ratio of cows milked to labor hours on the farm. A review of 100 years of milking: from Buckets to Robots can be viewed at this web site: https://youtu.be/sjmflKg-v2o

Douglas J. Reinemann is professor of Biological Systems Engineering at the University of Wisconsin-Madison where he has been on the faculty since 1990. Doug has been working at the interface between energy and agricultural systems for the past 20+years. His studies have included energy use and energy production in agricultural systems. He is a member of the sustainability group of the UW Great Lakes Bioenergy Research Center examining environmental impacts of biofuels production systems. He also leads the UW ‘green cheese’ team who are investigating synergies between dairy and biofuels production systems in Wisconsin. Doug has been actively involved with the Midwest Rural Energy Council – an organization of power suppliers addressing issues related to energy supply to agricultural production and processing operations as well as integrating renewable energy resources into the energy distribution grid. Dr. Reinemann has directed the activities of the UW Milking Research and Instruction lab since 1990. He is the US representative and Chair of the International Dairy Federation’s working group on machine milking and is the US representative to the International Standards Organization committees on milking machine performance and installation and Automatic Milking Installations. He has chaired the machine milking committees of the ASABE and the NMC. Doug received the National Food and Energy Award from the ASAE in 2001, the Pound Extension Award from the UW College of Agriculture and Life Sciences in 1998, the Young Engineer Award from the Wisconsin Section of the ASAE in 1998, and was nominated as a UW Distinguished Professor in 1997.

Labor Needs on Highly Automated Dairy Farms
Brian Houin, Homestead Dairy

Automated Dairy Barns for Cow Comfort
Nigel Cook, UW-Madison
Robotic Milking - Practical Adoption
Mat Haan, The Pennsylvania State University

The adoption of robotic milking systems is continuing to grow in the US and around the world. Labor considerations on the dairy, through a decreased labor need or greater labor flexibility on the farm, is a major factor driving this adoption. Research has shown that robotic milking on dairy farms can decrease labor, however, these studies show a wide range in labor per cow and per CWT of milk shipped from robotic milking dairy farms. Factors such as feed management, facility design, and use of data from the system will play important roles in labor needs and ultimately the successful and practical adoption of robotic milking systems on US dairy farms.

Feed management and nutrition are not only important to ensure health and productivity of the herd, but in a robotic milking dairy are also important in encourage voluntary cow visits to the robot. Voluntary visits can be limited if the partial mixed ration and robot feed are not properly balanced or if there are sudden changes in feed quality at the robot or at the fed bunk. If cows are not sufficiently motivated to enter the robot, milk production and labor requirements may be impacted.

One of the first factors to decide in the design of a robotic milking facility is free flow verses guided flow. The cow flow system will influence the number of fetch cows and other factors that can impact labor on the farm. Whichever cow flow system is used on a farm, the facility should be designed in a way that minimizes the amount of labor needed for performing routine tasks. Position of foot baths and cattle handling areas, manure management system, location of smart gaits, space around the robot, and inclusion of man passes within the barn are important design considerations to decrease labor needs on the farm.

One of the biggest advantages, and possible one of its biggest challenges, with robotic milking systems is the amount of data these systems can provide to the dairy producer. Milk production, milking interval, milking speed, body weight, and rumination patterns are just some of the information available to the dairy producer on a daily basis. Data from the robotic milker can be used to monitor cows as well as operation of the robot itself. As they gain experience with the robotic milking system and its management, producers need to learn what information they need to monitor and how frequently it needs to be monitored so they do not become overwhelmed.

Many examples of well-designed and managed robotic milking dairy farms exist, both small and large farms. There are lessons to be learned from these farms, as well as from farms that are not as efficient as they could be. A better understanding of how feed management, barn design, data management, and other factors influence the practical implementation of robotic milking systems on dairy farms are important to helping to advance adoption of this technology.

__Mat Haan__ is an Extension Dairy Educator with Penn State University. Mat has a B.S. in Animal Science and M.S. in Animal Nutrition and Sustainable Agriculture, both from Iowa State University. Mat has been in his current position for over 7 years having previously held research and outreach positions at Michigan State University and Iowa State University. Mat works with a wide range of dairy farms in south east Pennsylvania, with his main focus on precision dairy technology, pasture management,
organic dairy production and dairy business management. Mat has over 10 years’ experience working with farms that have adopted or are considering adoption of robotic milking technology.

**Robotic Milking Economics**
Jim Salfer, University of Minnesota

**Automated Calf Feeders – Practical Aspects of Feeding Calves**
Bob James, GPS Dairy Consulting

**Need for Automation in Feeding Lactating Dairy Cows**
Trevor DeVries, University of Guelph

Automation can be defined as technology that allows for a process to be performed automatically, with minimal human input. In the dairy industry the use of automation in feeding of lactating dairy cows is expected to grow, being necessitated to improve the accuracy and precision of diets fed to dairy cows in effort to improve health, production, and efficiency, as well as to minimize the requirements for human labor input. Human labor for dairy operations may not only be increasingly hard to come by and expensive, but may also be more prone to error and inconsistency in comparison to automated technologies.

Improved consistency, or precision, of diets provided to dairy cows may have significant impacts on herd-level performance. In a field study of commercial dairy farms feeding TMR we demonstrated that across days, high variability in ration nutrient and physical characteristics was observed; that variation was associated with herd-level performance. As example, greater DMI, milk yield, and efficiency of production were all associated with less day-to-day variability in ration energy content. Thus, measures to reduce ration variability, such as implementation of automation in diet preparation, may lead to improvements in herd performance and profitability.

Automation may also be important for delivery of diets, as well as in maintaining continual access to feed. It has been demonstrated that feed intake in dairy cows is greatly influenced by the timing and frequency of TMR delivery. Specifically, greater frequency of TMR delivery can promote more consistency in feed activity across the day, both in time and composition of feed consumed (through less feed sorting). This consistency in feed consumption, associated with greater TMR delivery frequency, has been associated in several studies with more consistent rumen fermentation patterns, resulting improved milk fat production. Field studies have also demonstrated benefits of delivering TMR more often on intake and production. Implementation of greater TMR delivery frequency on dairies is often constrained by time and cost associated with TMR preparation and its delivery. Thus, implementation of feeding automation, not only for diet preparation, but also for frequent delivery to cows across the day may have significant benefits.

Once feed is delivered, regular feed push-up helps minimize variation in feed consumed because it mixes up the feed that is no longer in reach with that currently available in the bunk. Thus, frequent pushing up of TMR in the bunk is necessary, particularly in the first few hours after feed delivery, when the bulk of the feeding activity has occurred. Field studies have demonstrated that frequent feed push-up, particularly through use of automation, may be associated with greater
herd-level production. Manual feed push-up, performed by farm staff, may be more prone to inconsistency, in time and frequency; thus, this again provides supports for the use of automation.

In addition to herd-level feeding precision achieved through automation, there is also opportunity to use automation to achieve that precision at a cow level. The rapid adoption of automated milking technology has also increased our ability to feed cows according to their individual requirements. While there are still many challenges associated with the successful implementation of such precision feeding strategies, on-going research would suggest that these opportunities will continue to grow, allowing for greater nutrient capture, less nutrient waste, and greater health and production.

Trevor DeVries is a Professor and Canada Research Chair in the Department of Animal Biosciences at the University of Guelph, Ontario, Canada. Trevor received his B.Sc. in Agriculture from The University of British Columbia (UBC) in 2001. Immediately following he began graduate studies at UBC, where he received his Ph.D. in 2006. Following that, he spent one year as a post-doctoral fellow with Agriculture and Agri-Food Canada. In 2007 he was appointed as faculty with the University of Guelph in the Department of Animal Biosciences. In that position Trevor leads a highly productive research program and has published over 150 peer-reviewed papers focused on dairy cattle nutrition, management, behavior, and welfare. He is also committed to extending that work to the field, as evidenced by over 250 invited research presentations. Trevor also contributes to teaching at the university, including instructing undergraduate and graduate courses in the areas of dairy cattle management, behavior, and welfare, coaching the university Dairy Challenge team, as well as mentoring of graduate and undergraduate students. Trevor also works diligently in public service, serving on several university committees, as well as various local, national and international professional committees.

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Lessons to be Learned from Automation of Other Sectors
Raj Bhasin, Robotic Systems Integration

What Other Opportunities are There for Dairy Automation?
Henk Hogeveen, Wageningen University