ARS National Program 101 Food Animal Production
Panel Report
Revised April 1, 2016

1) *Did we do what we said we would do?*
   - The NP101 portfolio includes a tremendous amount of work and accomplishments in developing genomic tools (e.g., genome sequence assemblies, genetic markers, bioinformatics, etc.), developing phenotypes & resource populations. These resources have allowed other scientists to be successful with these tools. Implementation of genomics tools in the beef and dairy industry has been done very well. In swine and poultry (due to consolidation within these industries), ARS seems to be working more to try to preserve genetic diversity.
   - In Component 2 and 2B (identify functional genomic pathways & their interactions), ARS scientists have not generated as much novel information. However, this area is more difficult than most scientists originally thought.
   - Work in Component 3A (product quality) and translating this technology to the end-user provided tangible outcomes that benefit the industry.
   - The work by ARS scientists on developing alternatives to antibiotics appears to be in addition to what was included in the original NP101 Action Plan.

   Some areas of the NP101 portfolio did not seem to include as many accomplishments as was planned. This could be due to a lack of ARS scientists, budget issues, or the timing of some CRIS projects ending in 2012 and new CRIS projects starting in 2013.
   - The metagenomics capacity is not mature yet.
   - Work on butyrate and effects on metabolism, or nutrient utilization were not apparent.
   - There appeared to be minimal effort to improve techniques for genetic modification and genetic engineering of food animals in the NP101 portfolio compared to efforts by ARS scientists in the past.
   - In Component 3B, studies on the healthfulness and nutritional value of meat products were absent. There were no results presented on studies to understand the biochemical and physical nature of meat quality.

2) *How well did we do it?*

Overall, ARS scientists have done an excellent job in addressing the major goals of the NP101 portfolio. Specific examples are listed under specific question #1 below.

Minor concerns:

- Some ARS teams may be doing research that complements other work by ARS scientists; however, they may not be aware of this complementary work.
- It was not clear if all of the projects aligned with the mission statements of the units (e.g., no examples of forage utilization from the US Dairy Forage Research Center in Madison, WI).

3) *What was the impact?*
   - The impacts of ARS research on academia and industry are impressive. ARS plays an important role in assisting nongovernment research by the resources that ARS provides and the tools that ARS develops.
   - ARS scientists have made important contributions in basic and applied research.
   - ARS also has major impacts in training students (undergraduate and graduate) and developing scientists (postdoctoral fellows, visiting scientists, etc.). The internships provided to undergraduates provide an important opportunity to have intensive research experiences.
   - The research conducted by ARS scientists in food security has been felt in international research communities. A number of international scientists come to ARS labs for training, then return to their home country to conduct research and will often collaborate with ARS scientists.
   - Research conducted by ARS scientists has had a tremendous, positive impact on the global dairy industry.
   - ARS accomplishments in the meat industry are greater than any one institution because USDA has a national presence.
   - ARS scientists are encouraged to communicate their research accomplishments to a broader audience, including scientists and the public. ARS scientists have done an excellent job of responding to consumer demand and stakeholder input. This is especially true for the portfolio of research on animal well-being. It is likely that other scientists and the public are not aware of ARS accomplishments in the area of animal well-being.

4) *Were customers' needs met?*

In general, the NP101 portfolio includes many excellent examples of how ARS research met the needs of consumers. ARS scientists do a nice job of thinking ahead and planning for what producers will need, especially in the areas of animal well-being and genomics. Some examples include:

- The OPP test was developed for sheep in response to requests from producers.
- Funding from the National Pork Board indicates that ARS scientists are working on issues that are important to swine producers.
- Studies on hatchability, cryopreservation of turkey sperm, and semen extenders in turkeys are relevant to the poultry industry.
- The ARS bank of cryopreserved semen for many species will be an important resource, if there is a need to repopulate animal populations in the future.

5) *Did we solve problems and/or make significant progress towards challenges in animal production?*

Overall, ARS scientists have solved some major problems (e.g., the infrared beak trimming procedure for poultry and the use of perches in hen cages). ARS scientists are also making progress toward significant challenges, including:

- How the gut microbiome affects feed efficiency. Future studies will need to move beyond characterizing the microbes that are present and move toward identifying how microbes cause changes in nutrient utilization, feed efficiency, gas emission, etc. ARS scientists should also be encouraged to lead the development of standards for collecting samples (rumen, hindgut, other) for microbiome analysis.
- Dairy cow wellness is coupled nicely with genomic solutions.
- Research on how nutrition affects reproductive traits (that are lowly heritable). This is a multidisciplinary approach that utilizes the strengths of various ARS scientists.
- The use of genomics as a tool to investigate various reproductive processes has also allowed progress on the challenges associated with infertility.
- Development of a new sheep composite breed that does not require shearing and has increased lamb numbers is a very practical step forward for the sheep industry.
- Research on beef grazing fescue and given estrogen implants and feed soybean hulls to mitigate effects of fescue toxicosis could have a major impact on beef production in the Southeastern US.
- Research to understand Marek's disease and how the animal responds is important to understand disease susceptibility/resistance.

Specifically:

1) *Was NP101's research relevant to the needs of the industry and food animal production?*
   There are many excellent examples of how research conducted by ARS scientists in the NP101 program is relevant to the needs of the industry, including:
   - Research in the animal well-being portfolio, including housing, beak trimming, and transport all address critical needs of the industry. The work on infrared beak trimming in chicks solved an important problem in the poultry industry. Rubber mats in front of feedbunks for dairy cattle led to decreased lameness.
   - ARS has the ability to conduct important studies on longevity/stayability of individual animals in the herd due to their long-term investments in swine and beef herds. These are valuable resources that are not available to academic scientists. It is not clear why ARS is not conducting similar studies with dairy cattle.
   - Research conducted by ARS scientists to develop new cryopreservation methods for turkey sperm and semen extenders for turkeys has led to significant improvements in fertility, which is a major contribution to the poultry industry.
   - Development of alternatives to antibiotics is important and timely. Specifically, feeding citrus pulp to swine and the resulting decrease in *E. coli* F18 is important. It also would be good to know if other pathogens were reduced in these studies.
   - ARS research programs have developed unique and comprehensive databases of phenotypes (e.g., US MARC) and developed resources and next generation methods for sequencing/resequencing animals.
   - ARS research stations are located across the US, which will allow ARS scientists to determine if genetic variants in one breed in one environment also work in other breeds or other environments. Communication/collaboration by ARS scientists across the NP101 portfolio will be necessary to address these issues.
   - ARS scientists conducted important studies to understand genetic resistance to Marek's disease. This is important because industry is usually very focused on health and it is hard to develop disease models in industry. However, it remains to be seen if this work will translate into commercially relevant lines of poultry.
   - Research to improve lamb survivability, reduce scours, and other cross-breeding efforts in sheep have met the needs of local producers.
   - The work by ARS scientists to develop instrument-based technologies to evaluate product-based quality is very important. This technology allows ARS scientists to make measurements that could not be measured previously. It is important for ARS to continue this work as well as other studies to understand how the underlying structural components of meat relate to taste.
   - ARS scientists can integrate genomics with phenotypes for meat quality traits. This research cannot be done by the swine industry.
   - It is not clear how the research on feeding yeast extracts to cattle will be translated to the industry. In many real-world situations, yeast extracts have not been effective. Yeast extracts may be beneficial to the broiler industry, but broilers are raised in a more controlled environment than cattle.

2) *Was NP101's research innovative?*

There are many examples of innovative research in the NP101 program:

- The new paradigms for sequencing to genotype and for genome assembly that result in 100x improvement in genome continuity with decreased costs and decreased time are innovative. These technologies were developed in goats and turkeys, which are usually considered minor species.
- ARS scientists have also developed innovative bioinformatics pipelines that have allowed more scientists to mine useful information from raw genome sequence data.
- Discovery of the dystrophin gene mutation in pigs and the potential of these pigs to be used as a biomedical model for human muscular dystrophy.
- Use of ovine microbes to reduce RDX in the environment.
- Spermatogonial stem cell transplants combined with CRISPR technology.
- Studies conducted by BARC scientists to develop a triple acting fusion protein (with 3 different enzymes) as gram-positive antimicrobials.
- Development of cryopreservation of turkey sperm with increased fertility after thawing.
- ARS research in the area of sow longevity is not especially innovative. There are many resources in pig breeding companies to do this work and sow longevity is relatively easy to measure. However, more basic research in the area of reproductive longevity is necessary and collaboration between ARS and industry is viewed as advantageous.

3) *Did NP101's research advance the science?*

There are many examples of research conducted by ARS scientists that has advanced the science, including:

- Research conducted by ARS scientists in dairy genomic/genetic evaluation has significantly advanced science. Many genetic tools have been developed, information has been incorporated into genetic evaluations, and this process has been turned over to a service provider/implementer. This is an excellent model of how ARS should conduct research and deliver tools to have an impact.
- There are several examples of projects that have used genetic markers to find causal mutations and continue with functional genomics studies.
- Research by ARS scientists has developed a novel approach to engineer a new protein with a protein transduction domain that is incorporated into cells to reduce mastitis infections.
- The research on ergot alkaloids and fescue toxicosis has provided strategies to improve beef production on fescue pastures.
- The dystrophin gene mutation in pigs could advance our understanding of human muscular dystrophy.

4) *Was NP101 responsive to emerging issues associated with food animal production?*
There are several examples of how research in the NP101 program is addressing emerging issues associated with food animal production, including:
    - Alternatives to antibiotics for pigs and poultry, including natural products or essential oils.
    - Animal husbandry practices (e.g., beak trimming of chicks, use of perches to deal with osteoporosis in laying hens, rubber mats for dairy cattle, etc.).
    - The nutrient value of meat products and the healthiness of meat products is an important issue to the public, especially since the new dietary guidelines are rather controversial. Although this area of research was in the previous NP101 portfolio, there were no projects in this area during the last five-year cycle.
    - ARS is encouraged to conduct research in euthanasia (especially with birds) due to the recent and massive depopulations of chickens and turkeys due to infectious diseases.
    - ARS is encouraged to conduct research to understand and prevent woody breasts in poultry. This is a major issue in the EU and is now arriving in the US.

5) *Did research in NP101 impact other government, university, and/or industry programs?*
There are many examples of how research in the NP101 program had a positive impact on other government, university, and/or industry programs, including:
    - Development of a 60K SNP chip for turkeys.
    - A new process to pre-incubate turkey eggs prior to incubation to decrease embryonic mortality.
    - Genotyping by sequencing.
    - The infrared beak trimming process for chicks has been adopted by industry in the US and EU to decrease pain compared to hot blade trimming. It would be good to know how many birds were affected by this process.
    - Veterinarians have adopted ovarian follicle counts into pre-breeding exams in cattle and other scientists have used these methods to study longevity in cattle.
    - Pigs with the dystrophin mutation were distributed to biomedical researchers to study muscular dystrophy in humans.
    - The audit conducted to measure tenderness in pork loins in different packing plants has enticed many plants to change (improve) their processes.
    - Development of a new starch assay and distribution of the assay throughout the entire US provides a reliable and accurate way to measure starch in feedstuffs.
    - Methods to improve radiant heater performance in poultry houses have saved the industry millions of dollars.
    - The willingness of ARS scientists (including the genetic resources gene bank and the animal GRIN database) to make databases open to other scientists is important.
    - The numbers of students (undergraduate internships and graduate student collaborations), postdoctoral fellows, and visiting scientists are important.

6) *Were new or improved scientific methods and approaches developed and transferred or published?*

There are several examples of new or improved scientific methods or approaches in the NP101 portfolio, including:

- New semen extender for turkeys that allows semen to be stored for 24 hours with increased fertility to 85% (from 40% with previous extenders).
- Semen cryopreservation for turkeys that increases fertility and hatchability.
- Infrared beak trimming in chicks has been rapidly adopted by the industry in the US and in the EU.
- An LED camera for grading and tenderness has been adopted by more than half of the beef plants in the US.
- In the animal well-being portfolio, ARS scientists developed noninvasive measurements of stress in pigs; an RFID for feeding behavior in feedlot cattle to find cattle that are off feed easier and may lead to an earlier diagnosis of disease; and indwelling catheters to take vaginal temperatures in cattle.
- A new starch assay has been developed and widely adopted by the industry.
- Development and implementation of a genomic evaluation system for dairy cattle and creation of a large genotype database has resulted in faster genetic progress and a shorter generation interval in dairy cattle around the world.
- Development of genomic selection methods (allele specific expression) beyond GBLUP for Marek's disease will have application beyond the poultry industry.
- Development and release of a new genetic marker associated with OPP susceptibility.
- Strategic feeding of replacement heifers developed on native range and providing less supplement to pregnant cows grazing native dormant forages in winter may lead to increased reproductive efficiencies (and cost savings) compared to conventional approaches. It will be important to continue these studies for longer time frames and repeat the studies with other breeds and in other environments.

7) *What was the quality of NP101's published work?*
This was the most difficult question for the panel to answer because not enough information was provided to evaluate the quality of publications. For example:

- If the number of publications is used as the metric, ARS scientists have about 8.5 publications/scientist/5 years (or about 1.63 publications/scientist/year). However, it is not clear if these numbers include co-authorships. If co-authorships are included, the overall number of publications/scientist seems low.
- Some publications might have the best readership (e.g., sheep & goat research) or the most impact for their audience, but the journals might have a low impact factor.
- Many publications were in a broad spectrum of high quality, high impact factor journals. However, it is more important to provide an estimate of the impact of publications rather than the impact of journals (journal impact factor can be manipulated by publishing many review articles that receive many citations).
- There were several examples in the annual reports of ARS scientists receiving the "most cited award in genetics & breeding" from the *Journal of Dairy Science*.
- In the future, it would be helpful to include the number of citations for each publication (or for the top cited publications), examples of the audience that is reached by publications in various journals, or other indicators of "quality" for publications.

8) *Did NP101 provide key tools, databases, and infrastructure for other animal production researchers?*

There are many examples of key tools, databases, and infrastructure provided by the NP101 program, including:

- The 60K SNP panel for turkeys.
- The Immunocrit assay to identify piglets that don't get colostrum.
- PigTurn, which is a stress-free simultaneous collection of behavior, biofluids, electrocardiac activity in pigs.
- The improved bovine reference genome assembly and annotation.
- Bioinformatics pipelines are a major contribution.
- Genomic prediction methods and the dairy genotype database have been transferred to the Council on Dairy Cattle Breeding and this information has been disseminated to the global dairy industry.
- The animal genetic resource gene banks and Animal GRIN are tremendous resources of semen and genotypes that are used throughout the world.
- The GPE program at the US MARC is the foundation of beef cattle breeding and has been a tremendous resource for many years.
- In general, the ARS animal resources and records/phenotypes are valuable tools for academic collaborators where large populations no longer exist. The willingness of ARS scientists to share these resources and collaborate with other scientists is remarkable.

9) *Did NP101 form effective partnerships with research cooperators and successfully leverage additional resources for its activities through those partnerships?*

There are many examples of effective partnerships and leveraging of resources, including:

- The GPE program at the US MARC trained 6 graduate students with partner universities since 2012.
- The partnership with Eureka Genomics/Affymetrix resulted in development of next generation sequencing to genotype specific targets by 8 countries (cattle, sheep, humans, maize, soy, barley, wheat).
- The collaboration with NHGRI, university and private researchers resulted in a new method to use only genome sequences obtained by the PacBio to develop reference genome assemblies.
- The dairy genomics group developed a new genomic evaluation system and created a new database with 1.2 million animals from 50 countries to make faster genetic progress and significantly decrease the generation interval in dairy cattle.
- ARS scientists created a CRADA to develop a new sheep breed that does not require shearing and produces 22% more lambs with 35-45% increased weaning rate and 10-15% increased survival rate.
- Overall, while a list of collaborations with international partners was provided, it was more difficult to determine how many academic or industry partners were working with ARS scientists. A list (or table) of specific partners for other ARS projects would have been helpful. Some, but not all, of the accomplishment stories mentioned their academic or industry partners. In addition, some ARS units have more collaborations with universities than others. The number of students that work with ARS scientists could be described as a major impact of the NP101 program. The internship research program for undergraduate students is an excellent program that should be replicated at more ARS units.
- In general, there were fewer CRADAs in the NP101 portfolio than were expected.